Summary of activities of CLIC Study Team for 2005

Ian Wilson

3rd March 2006

2005 - 20th anniversary of CLIC

1985 – Long Range Planning Committee under C. Rubbia created CLIC Advisory Panel chaired by K. Johnson

1985 – First CLIC Note (CN1) by J.D. Lawson

………….since then published > 650 others

Summary of activities of CLIC Study Team for 2005

Purpose of presentation – to give you brief overview (just a flavour) of all different subjects studied in 2005 without giving too much detail

This summary will be published as CLIC Note 653 in a more detailed form – note numbers quoted are 2005 year-end numbers

In particular I will :

- Review progress made CLIC Machine Studies (CMS)
- Give results obtained with test facilities – mostly CTF3
- Outline initiatives taken to expand CLIC collaboration to obtain additional resources – CLIC Accelerated R&D
- Mention CARE and EUROTeV activities within EU FP6

Given large amount of work accomplished by CLIC Team during this 12-month period – faced with 2 options for this presentation

- Either to choose some particular high-lights and give detailed results with plots and photos
- Or to provide an overall picture by trying to cover all activities with only a very brief statement of what we have achieved
- Chosen latter because I believe once a year - important to review and make public - full extent and quality of our achievements

Comment

- Since this is my own summary - if the experts see errors please let me know after meeting so I can correct CLIC Note before it goes out

Parameters (1)

- Basic parameters updated during course of year to take advantage of (i) new 30 GHz HDS design resulting from better understanding of surface-field, power and pulse-length limitations (ii) improvements in generation of low emittance beams in damping rings, and emittance preservation during beam transport through main linac and beam delivery system.

- New HDS design optimized to give highest peak luminosity in 1% energy bin per MW of mains input power - resulting structure has excellent long-range damping characteristics allowing bunches to be spaced at 8 rf cycles – the reduced aperture ($\langle a \rangle/\lambda = 0.178$) requires number of particles per bunch to be reduced from 4x10^9 to 2.56x10^9 to limit short-range wakefield effects

- Reduced spacing has enabled pulse length to be reduced from 130 ns to 68 ns whilst still maintaining same luminosity (in 1% energy bin) of 3.3x10^34 cm-2s-1 at 3 TeV.

- N.B. Single bunch luminosity could be further increased if horizontal spot size at IP could be reduced from present value of 60 nm to optimum value ~ 37 nm, but no lattice layout has yet been found to do this.

Parameters (2)

- New parameters provide total L of 6.5x10^34 cm-2s-1 at 3 TeV with 220 bunches at rep. rate of 150 Hz for total AC site power of 418 MW.
- New drive-beam-generation mode of operation - so-called 'double-pulse scheme' been adopted for new parameters with reduced rf pulse length that maintains both basic layout, and good compromise between transverse stability in decelerator and collective effects (wake-fields and CSR) in drive-beam-generation complex.
- Contrary to previous scheme which had a separate drive-beam generation complex for each linac, new scheme uses same one for both linacs and consists of (i) single 2.4 GeV drive-beam accelerator (ii) short delay loop (21 m for 70 ns) (iii) two long combiner rings (84 m and 334 m for 70 ns).
- New mode of operation is to inject and to combine 2 pulse trains at same time, then to extract a 2-pulse couple and separate it sending one to each linac. With this scheme number of decelerator sections per linac is 21.
- Main hardware changes - reduction of delay line length and need of kicker after extraction from 2nd CR, to switch every 2nd pulse from e- to e+ linac.

Damping ring

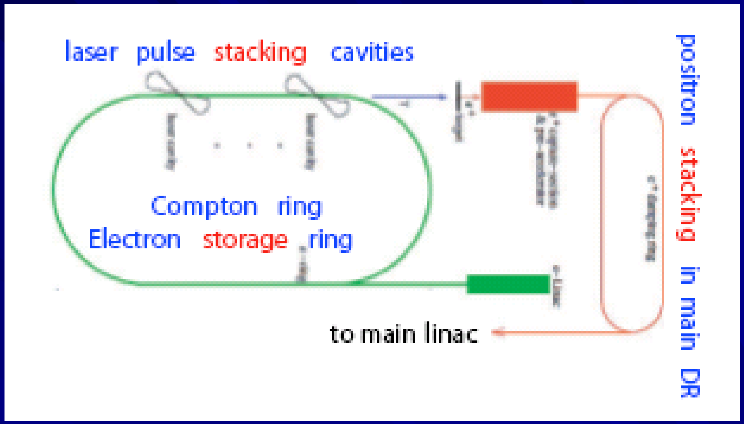
- Basic layout of DR remains essentially same for new parameters but mode of operation modified - 2 trains now extracted simultaneously and combined using a subsequent delay line and RF deflectors - advantage of this is bunch spacing in DR (16 RF cycles at 30 GHz) is twice that in linac (8 RF cycles) which alleviates impact of electron-cloud and fast-ion instabilities, and results in lower RF frequency of 1875 MHz in ring which itself leads to a longer bunch and reduced IBS.

- Due to reduced bunch population (2.6x10^9) which decreases collective effects - 2.42 GeV DR now gives transverse equilibrium emittances for perfectly aligned machine of $\gamma\varepsilon x$ = 550 nm and $\gamma\varepsilon y$ = 3.3 nm respectively (IBS, radiation damping, and quantum excitation – taken into account).

- Although wiggler period reduced from 20 cm to 10 cm - hope this can be reduced further resulting in even smaller emittances - novel wiggler design based on Nb3Sn technology developed in collaboration with BINP (Novosibirsk) achieves period of 45-mm with a 2.5 T peak field - with these parameters H/V normalized emittances at extraction would be reduced from 550 nm to 375 nm, and from 3.3 nm to 2.3 nm respectively.

- One of problems associated with use of wigglers in straight sections is large synchrotron radiation heat load produced which has to be absorbed - not yet resolved but solutions being studied.

Polarised positron source



- A possible layout and parameters for a polarized positron source been developed following experimental tests at ATF which have demonstrated production of 10^4 polarized e+ per bunch with about 77 % (+/- 10%) polarization.

- Scheme foresees collection of polarized positrons after conversion of polarized X-rays on a metal target – the polarized X-rays themselves created by Compton scattering of a 1.3-GeV electron beam off a YAG laser in a 42m circumference storage ring with possibly just one optical cavity.

- Positron yield per turn from Compton ring has been simulated with dedicated programme and was found to be close to ideal maximum value and compatible with CLIC requirements.

BDS studies

- Status of CLIC BDS studies reviewed at one-day mini-workshop at CERN in November 2005 - topics covered included (i) beam-beam effects (ii) time-dependent luminosity performance (iii) possible use of very fast intra-train beam feedback (iv) progress on a non-linear collimation system (v) aberrations and spot-size limitations (vi) tuning studies and integrated simulations (vii) halo studies (viii) crab cavity and extraction line design (ix) beam diagnostic issues.

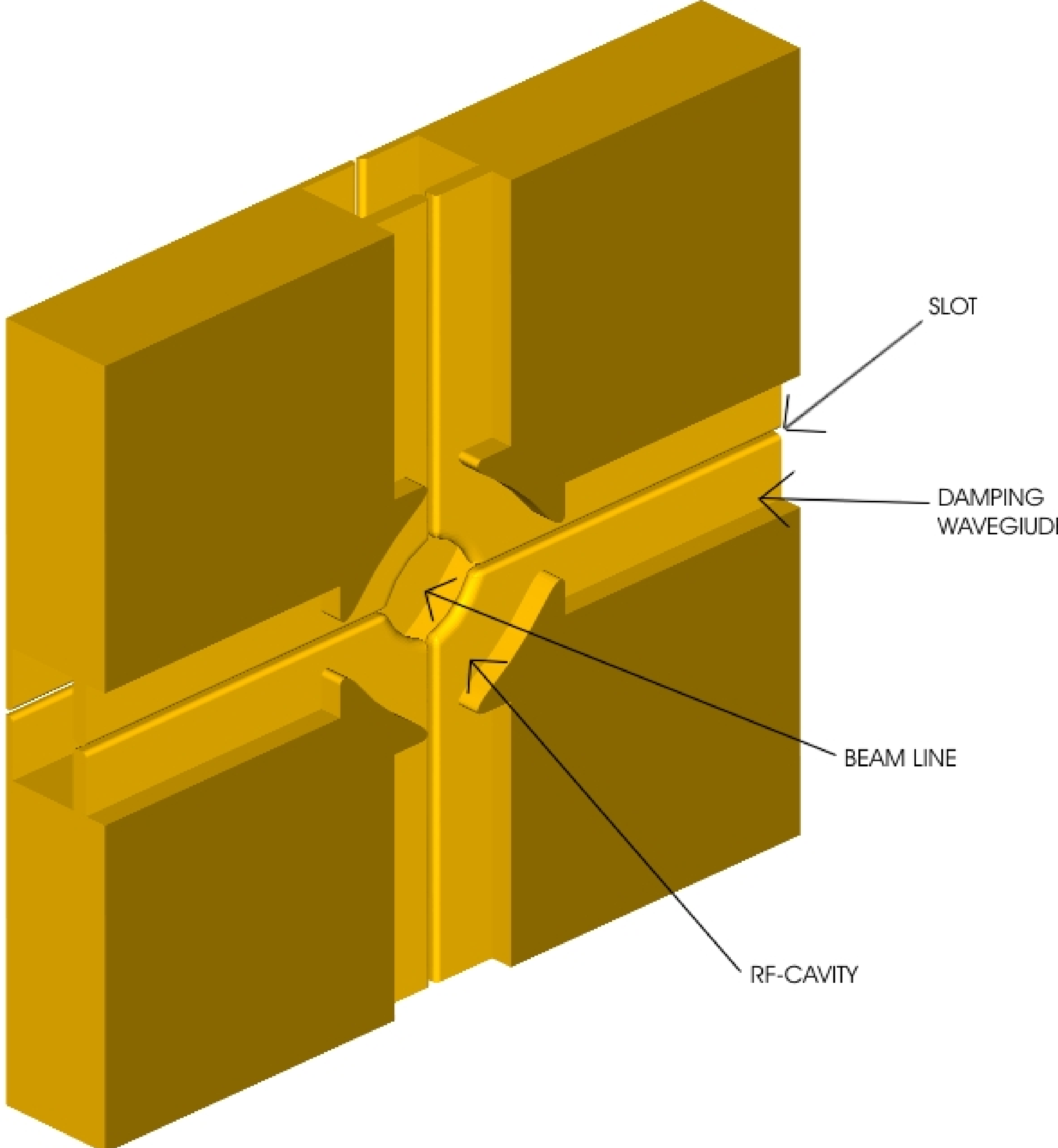
- During year several simulation codes, namely MAD-X, SAD, PLACET, and PTC bench-marked and used to characterize performance of present baseline linear BDS which has total length of 2.5 km and consists of particularly compact 0.5 km FF section (uses optics derived from NLC) plus 2 km collimation section for energy and betatron collimation.

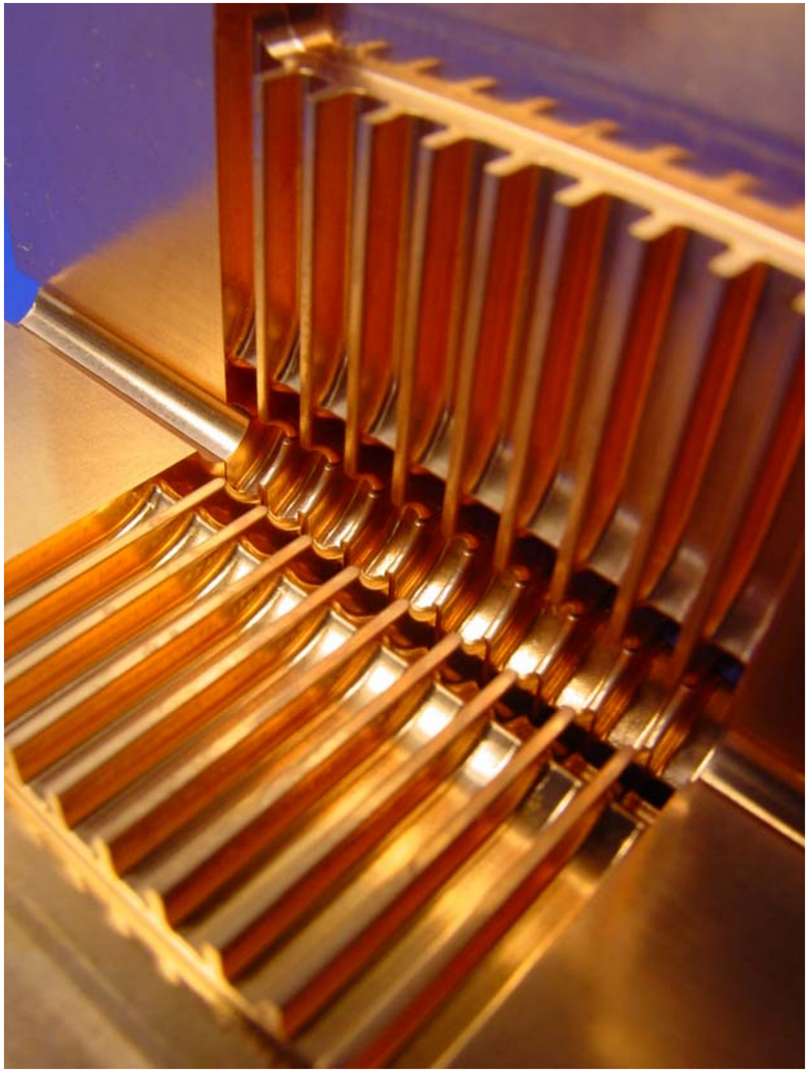
- Luminosity (without pinch effect) obtained by particle tracking is 3.6 x 10^34 cm-2s-1 which falls short of target value of 9.3 x 10^34 cm-2s-1 - largest loss in collimation section since with FF alone luminosity is 4.85 x 10^34 cm-2s-1.

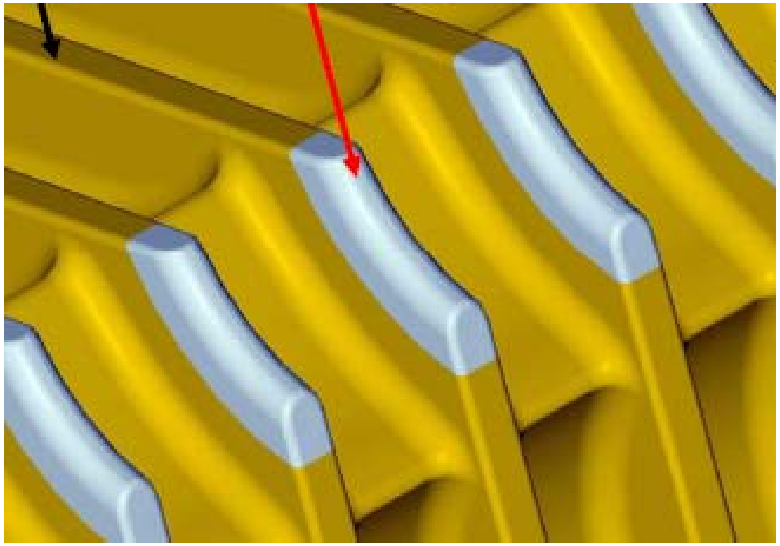
  More work required on collimation system

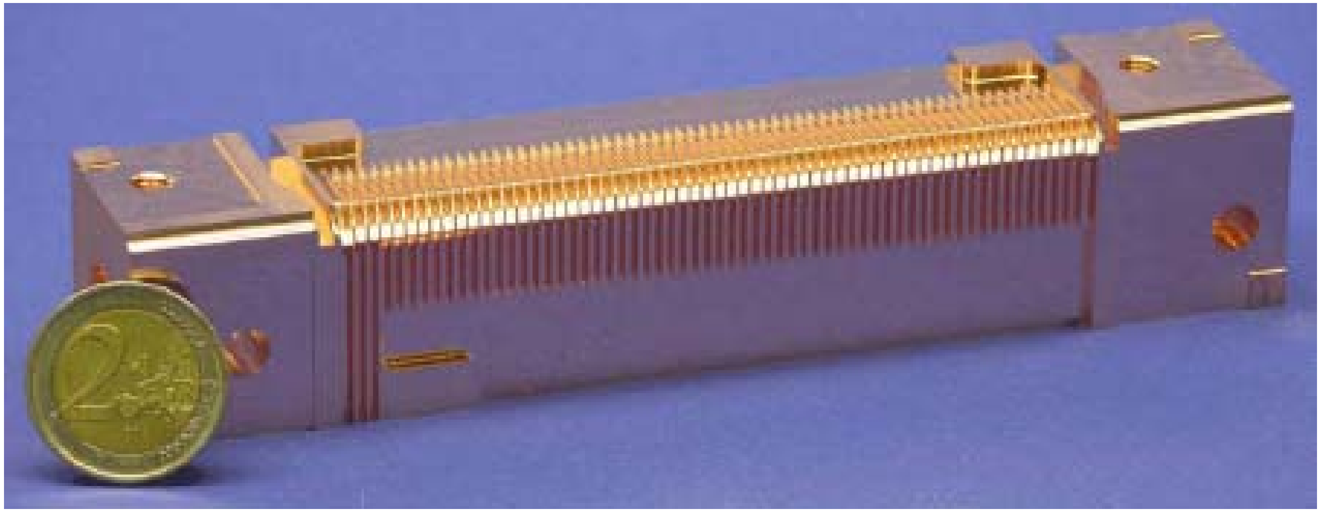
Accelerating structure design (1)

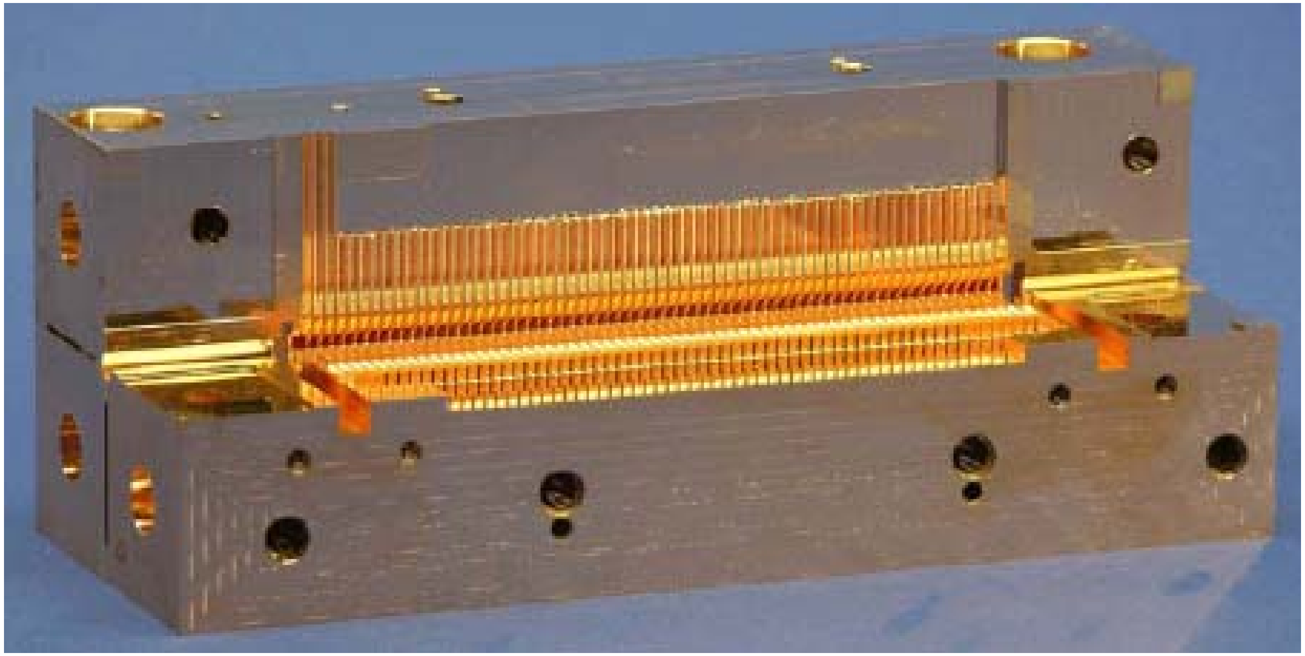
- New HDS design has new geometry which includes
  (i) fully-profiled rf surfaces optimized to minimize surface fields
  (ii) hybrid damping using both iris slots and radial waveguides.
- Slotted irises allow a simple structure fabrication in quadrants with no rf currents across joints.
- New structure constructed from two different metals, molybdenum used for tips of irises and copper zirconium used for cavity walls.
- New structure-optimization procedure used to simultaneously balance surface fields, power flow, short and long-range transverse wakefields, rf-to-beam efficiency and ratio of luminosity to input power.
- This procedure is based on interpolation of structure parameters and allows millions of structures to be analyzed taking into account full and complex interplay between rf and beam dynamics parameters.


SLOT
DAMPING
WAVEGIUDE
BEAM LINE
RF-CAVITY









Accelerating structure design (2)

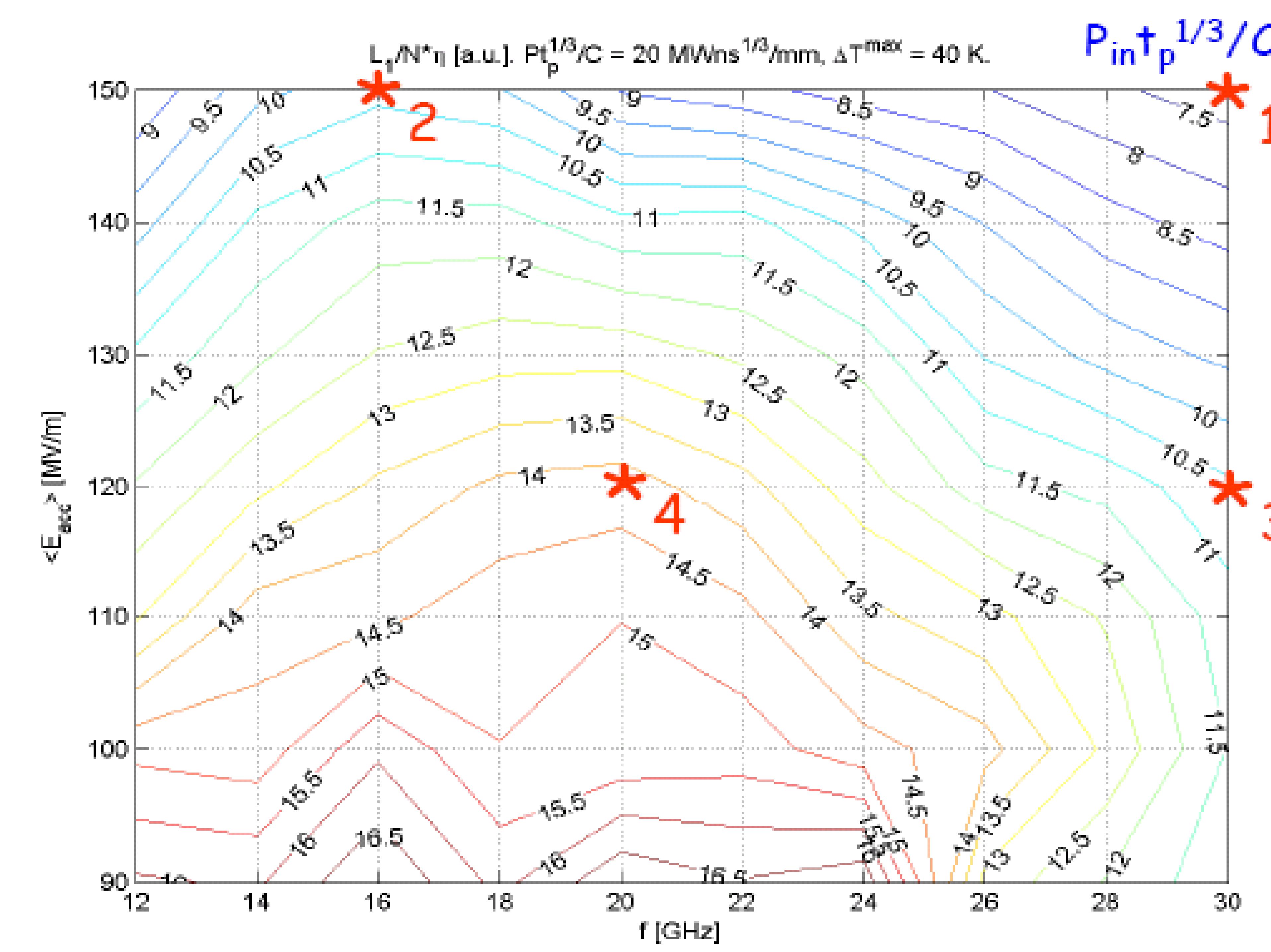
- Criteria used in this process continuously being updated to take into account latest experimental data and most probable interpretation of both new and old data - 3 criteria currently being used. 1. max surface electric field - for molybdenum 380 MV/m 2. pulsed rf surface heating limit which for lifetime of 10^10 pulses for copper-zirconium 56C° 3. power/pulse-length limitation.

- At beginning of year power/pulse length limit used in optimisation process was $P\sqrt{\tau} < 1200$ MW$\sqrt{\text{ns}}$ - based essentially on SLAC NLCTA data for X-band structures - led to optimised HDS structure with phase advance of 60° per cell, a bunch spacing of 8 rf cycles, pulse length of 68 ns, rf-to-beam efficiency of 31 %, and input power of 151 MW for nominal loaded gradient of 150 MV/m.

- Later in year - better fit for existing data found using $P\tau$^1/3/circum < 21 MW ns ^1/3 / mm instead of $P\sqrt{\tau}$ - if this new criterion is shown to be valid - means the newly-adopted structure for new parameters would most likely not work and would have to be re-optimised.

Accelerating structure design (3)

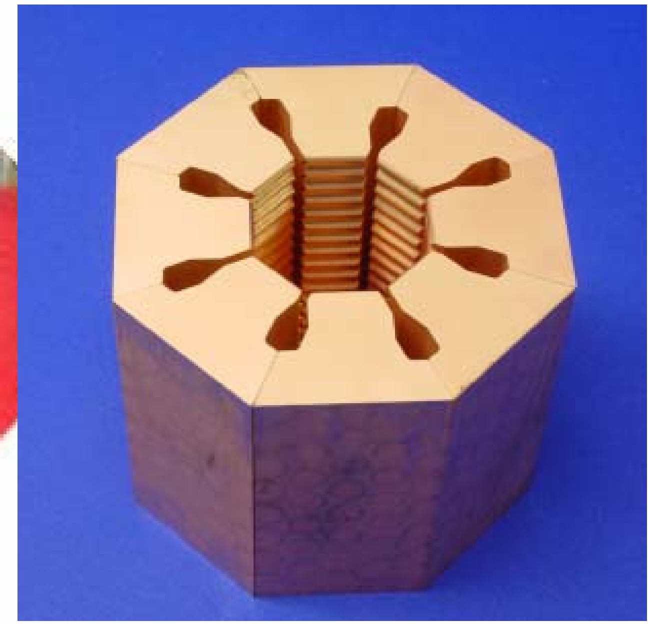
- If we use this criterion - figure of merit and pulse length of optimised HDS both roughly halved - means twice power to keep same luminosity - not yet clear if such short pulse lengths (~35 ns) are compatible with present CLIC layouts – needs more study.
- For all above-mentioned optimization work - assumed structures would operate at 30 GHz and 150 MV/m - since these 2 parameters may themselves not be optimised - decided to carry out optimization study in which gradient and frequency also free parameters.
- Using same figure of merit (luminosity per MW) and new power flow criterion $P\tau$^1/3/circum - found that (roughly) a 50% improvement could be made by either (i) maintaining frequency at 30 GHz and reducing gradient to ~ 120 MV/m, or (ii) maintaining gradient at 150 MV/m and reducing frequency to ~18 GHz.
- Other hand - 100% gain could be achieved by both changing frequency to ~ 18 GHz and reducing gradient to ~ 120 MV/m - for all these studies - pulse length of optimised structures was ~ 30 ns



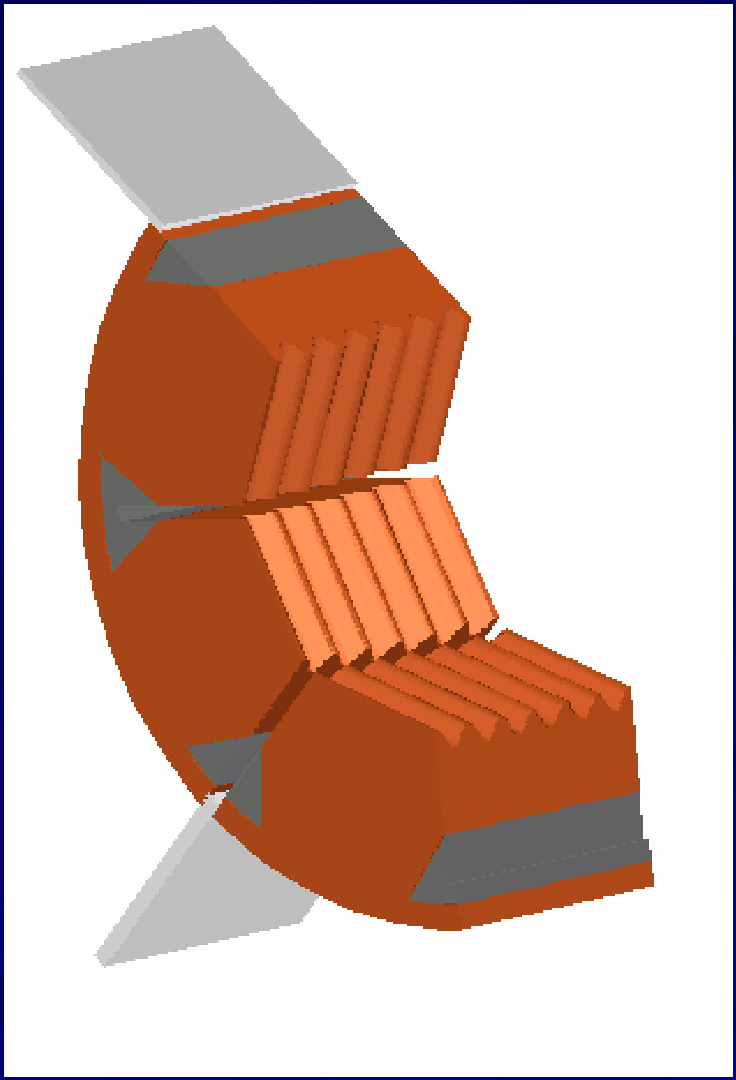
$P_{in}t_p^{1/3}/C$
L1/N*η [a.u.]. Ptp1/3/C = 20 MW/ns1/3/mm, ΔTmax = 40 K.
<E_acc> [MV/m]
f [GHz]
1
2
3
4

CLIC Power Extraction and Transfer Structures (PETS)

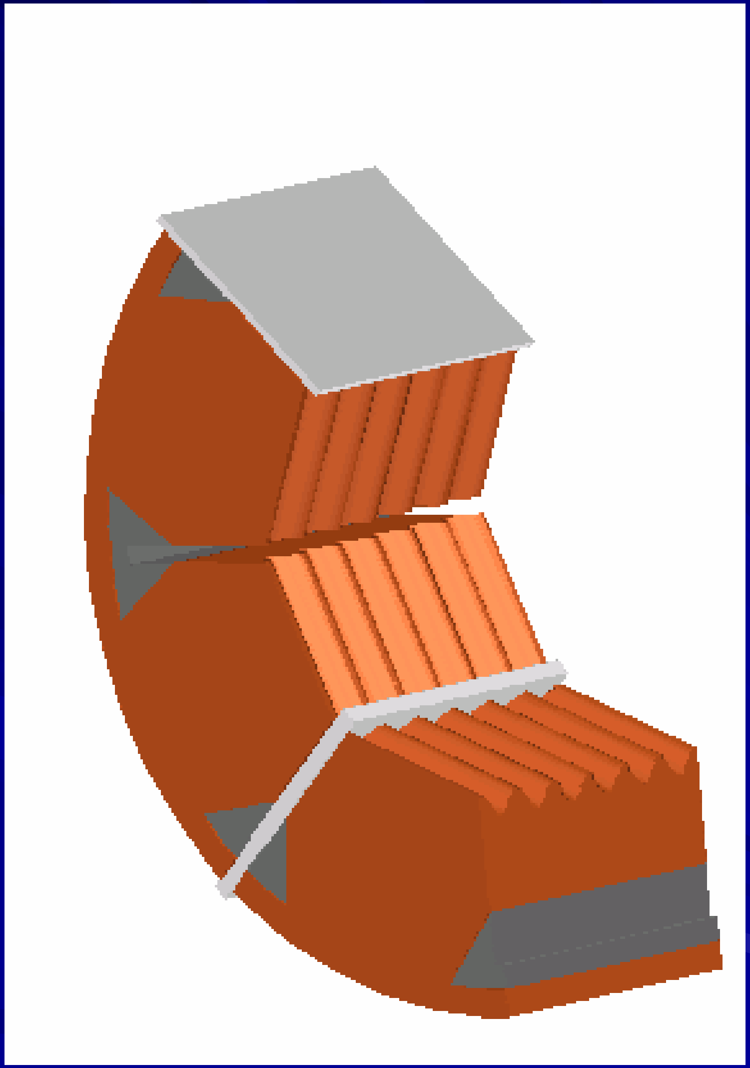
- Good progress made with design of CLIC PETS - designed to produce 642 MW from 181 A drive beam with an extraction efficiency of 94%.
- Eight radial 1.3 mm wide slots cutting PETS all the way along its length, channel out disruptive HOM energy to SiC loads.
- Main body has octagonal x-section (~22.5 mm diameter) composed of 8 identical racks with shallow (~1.3 mm deep) sinus-type corrugations with 140 degrees phase advance per period.
- At end of year - first 40 cm long prototype CLIC PETS with active length of 23 cm - rf tested at low power on bench - assembled using 8 racks machined by high speed milling to accuracy of +/-10 μm which is CLIC specification for the PETS.
- Foreseen to turn power OFF or attenuate it by inserting thin (~1.6mm) corrugated metal wedges into PETS through 4 of 8 damping slots - wedges detune synchronous mode frequency and prevent coherent build up of excited field - study of mechanism to do this started in TS Department.

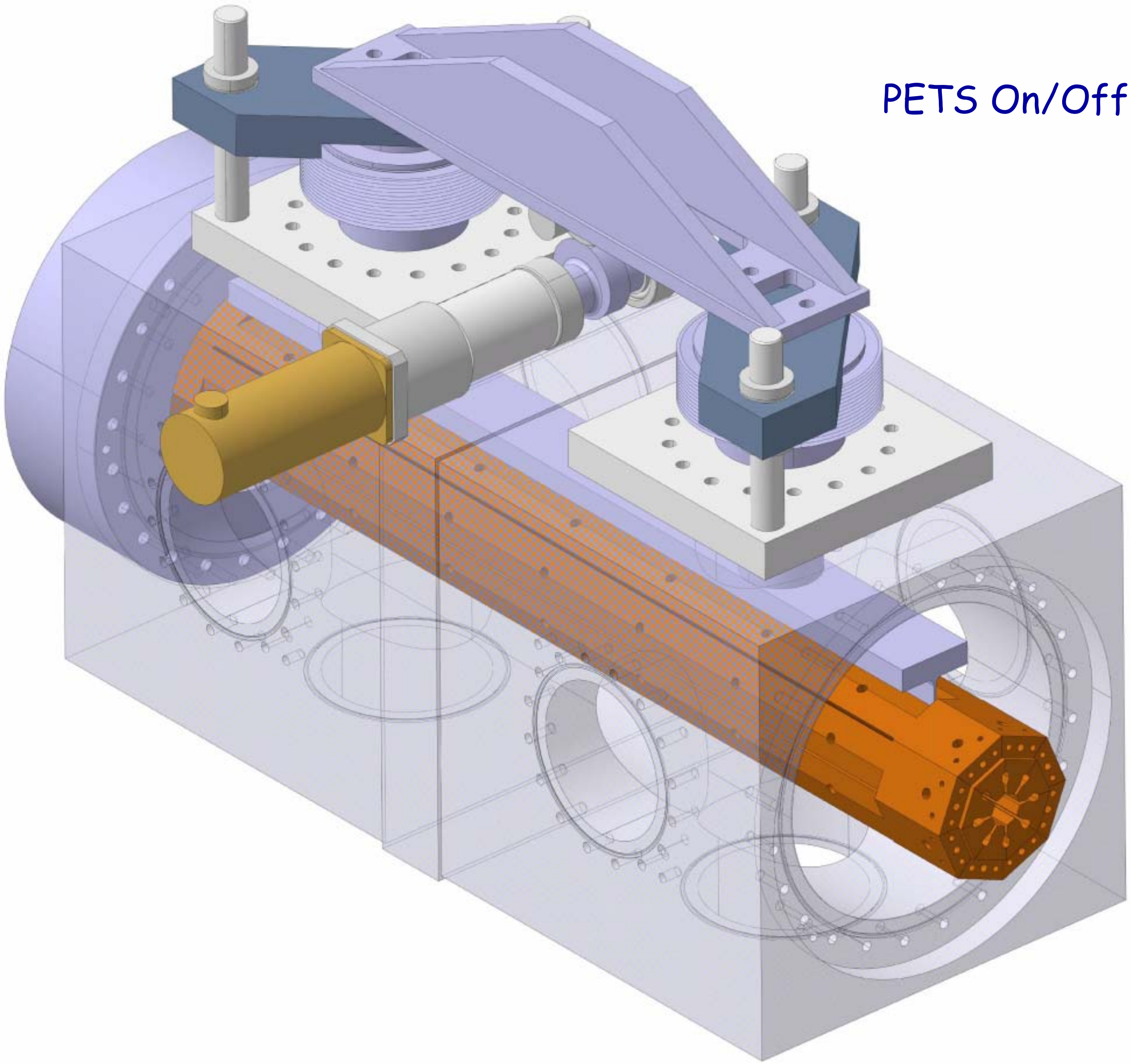
Power 'on'



Power 'off'

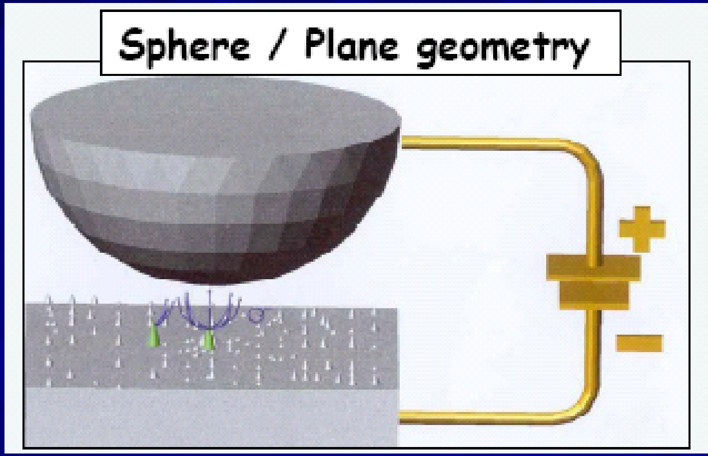


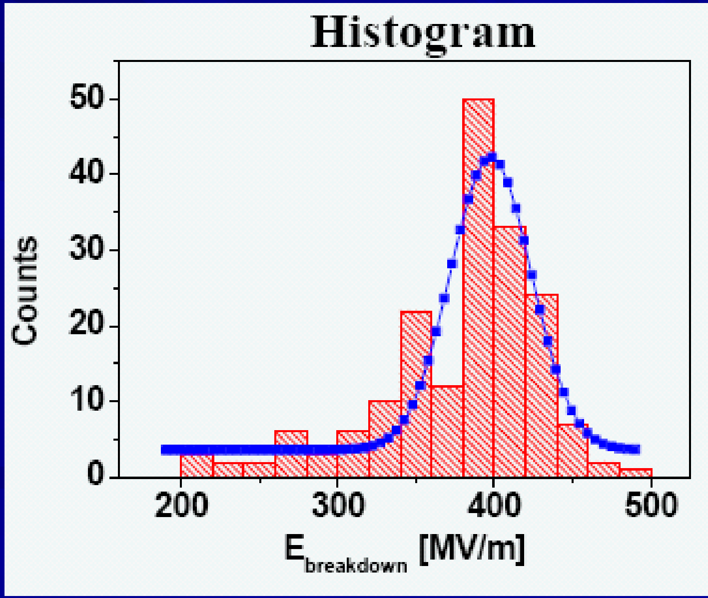
PETS On/Off mechanism



Material test facilities (1)

- The two new experimental facilities, “dc-spark test stand” and “laser pulsed-surface-heating test stand” - developed for CLIC by TS were fully-exploited in 2005. These facilities will speed-up technical development in areas such as materials studies and preparation techniques
- “dc-spark test stand” used for breakdown studies on Mo, W and Ti
- For Mo - found - thermal treatments accelerate conditioning process. Exposure to CO and dry air up to 10^-5 mbar range during conditioning can reduce breakdown field by as much as 50% - contrary to behaviour of Cu which shows no change in levels
- For Ti - produced even higher fields than Mo but with large scattering in values from one breakdown to next - and more importantly with substantial erosion of material





Material test facilities (2)

- For CLIC main-linac structures amplitude of thermal cycling due to rf surface heating is ~ 56° C and estimated lifetime of linac is ~ 7 10^10 pulses – the TS " laser-surface-heating test stand" simulates this thermo-mechanical fatigue behaviour - criterion used for fatigue damage is change in surface roughness.

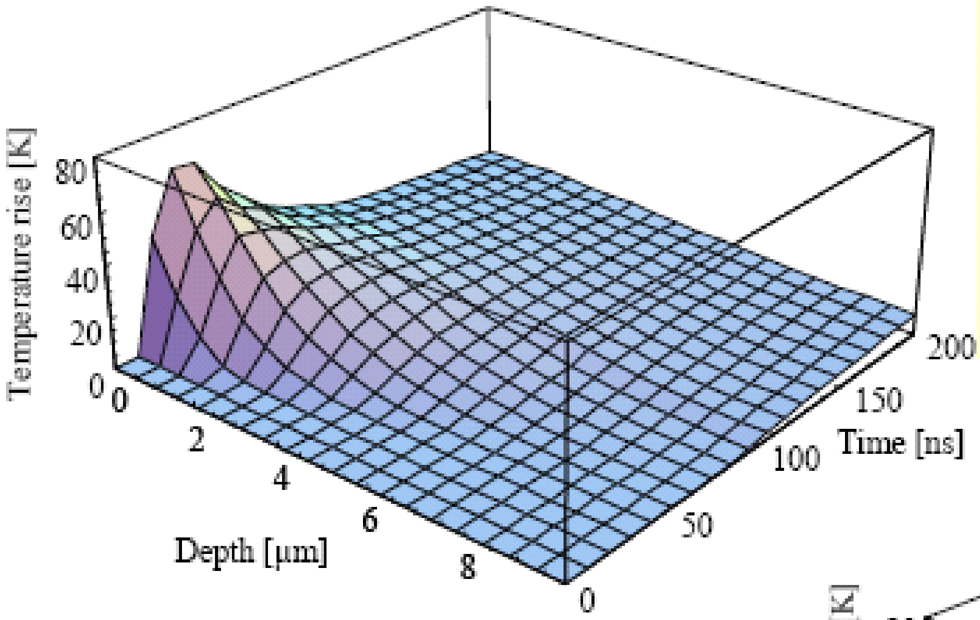
  Lot of time lost this year due to relocation of test stand to bldg 101.

- Fatigue data obtained for CuZr in different states and for Glidcop.

  Glidcop (aluminium oxide dispersed in Cu matrix) showed a better resistance to fatigue than published data for properly-aged CuZr - experiment needs to be repeated to confirm reproducibility.

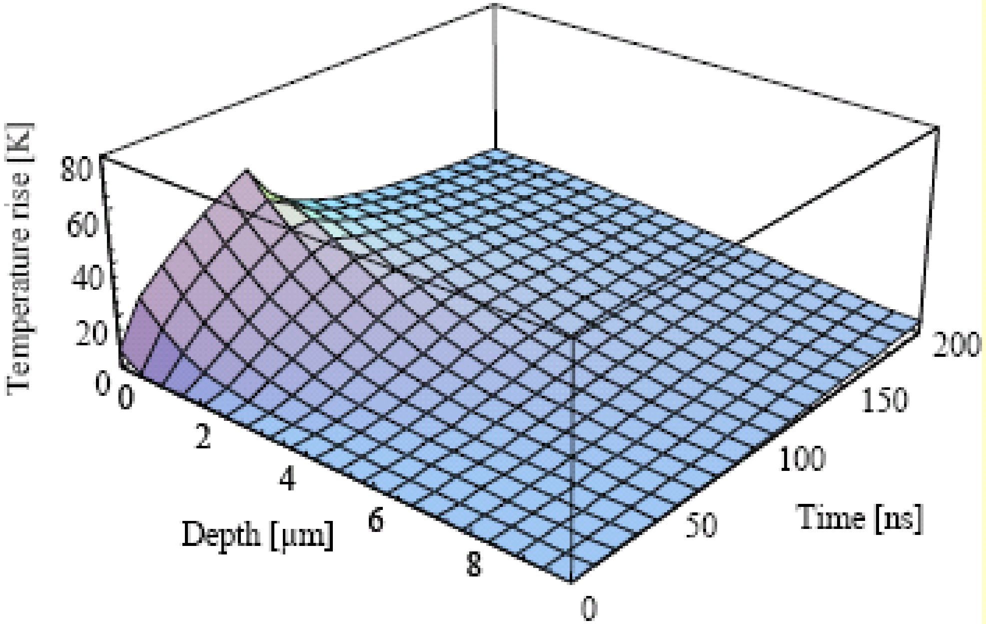
- At end of year a new laser enabling a higher repetition rate (200 Hz instead of 25 Hz) was installed - now ready for operation - should speed-up data acquisition process.

Comparison of heating profiles



← Laser pulse

RF pulse ↓



The pulse shapes correspond.
In particular the temperature profile at the peak is very similar, and results in similar stress level.

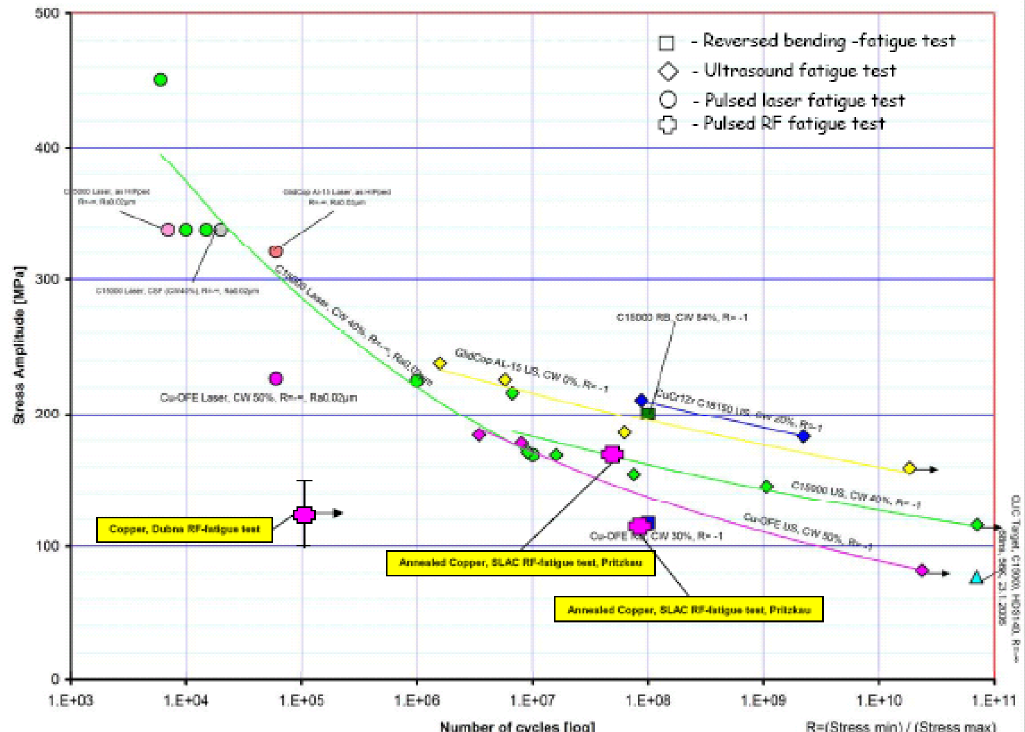
$$\sigma = \frac{\Delta T * E * \lambda}{(1-\nu)}$$

Material test facilities (3)

- New "ultrasonic fatigue test stand" became fully operational in 2005 and towards end of year was working 24/24 and 7/7. Since this device works at 24 kHz data is acquired very rapidly
- Major challenges in getting this set-up working was (i) design of mechanically-resonant sonotrodes (the test pieces) using ANSYS (ii) precise determination of material properties and
  (iii) development of an accurate LED strain calibration system.
- Fatigue data up to 7x10^10 cycles (estimated lifetime of CLIC) obtained for pure Cu and CuZr in different states of hardness.
- Collaboration with Japanese metal industry proving to be very fruitful. Hitachi Cables provided free of charge various CuZr alloys in different states to evaluate fatigue properties
- New technique to improve fatigue resistance of materials called 'Cavitation Shot-less Peening' being studied in collaboration with Tohoku University, Japan

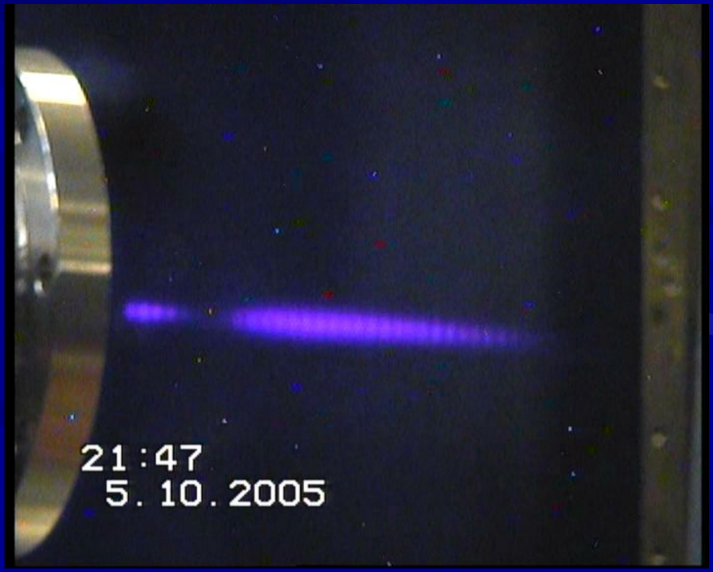

Ultrasound fatigue test samples


Fatigue crack


- Reversed bending -fatigue test
- Ultrasound fatigue test
- Pulsed laser fatigue test
- Pulsed RF fatigue test
Stress Amplitude [MPa]
500
400
300
200
100
0
Cu-OFE Laser, CW 50%, R=-∞, Ra0.02µm
GlidCop AL-15 US, CW 0%, R= -1
C15000 RB, CW 84%, R= -1
CuCr1Zr C18150 US, CW 20%, R=-1
C15000 US, CW 40%, R= -1
Cu-OFE US, CW 50%, R=-1
CW 30%, R= -1
Copper, Dubna RF-fatigue test
Annealed Copper, SLAC RF-fatigue test, Pritzkau
Annealed Copper, SLAC RF-fatigue test, Pritzkau
1.E+03
1.E+04
1.E+05
1.E+06
1.E+07
1.E+08
1.E+09
1.E+10
1.E+11
Number of cycles [log]
R=(Stress min) / (Stress max)

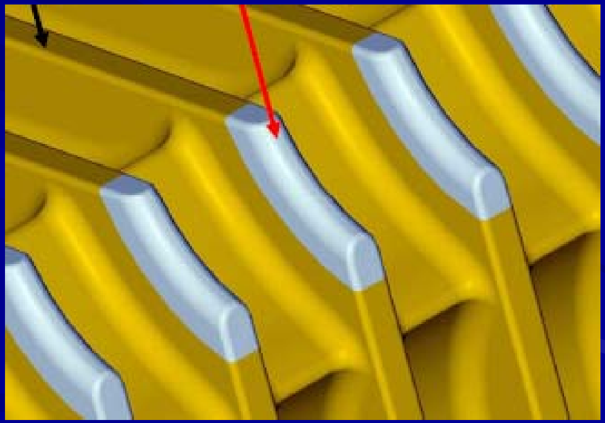
Material test facilities – JINR / Dubna

- JINR (Dubna) pulsed-surface-heating fatigue experiment again delayed this year by need to replace and improve many parts of JINR FEM - currently producing ~ 15-20 MW but breakdown problems at output window have again slowed progress.
- Running >4 years late - new schedule foresees results by mid-2006.
- Worth persevering with this experiment since it will provide essential data from an rf test set-up to cross-check validity of results from other high-repetition-rate fatigue set-ups.



Material and machining studies – TS Department

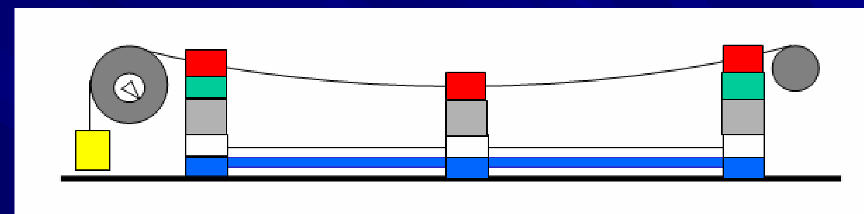
- Extensive studies on fabrication and machining of HDS and PETS structures are being made - bimetallic bars of CuZr with Mo core from METSO and Lutch Institute have been tested and some samples of explosively-bonded Mo-Cu have been investigated.
- Ten 40 cm long PETS racks were successfully machined by high speed milling to accuracy of +/-10 μm by Finnish firm IMTEC and used for first CLIC proto
- IMTEC also supplied prototype HDS60 (60 cells) copper quadrants and will deliver HDS11 quadrants out of Cu, Al, Ti, Mo and St. Steel
- Interfaces between CATIA and HFSS now exist for accurate exchange of dimensional data for rf analysis and subsequent CNC machining of complex 3D shapes.

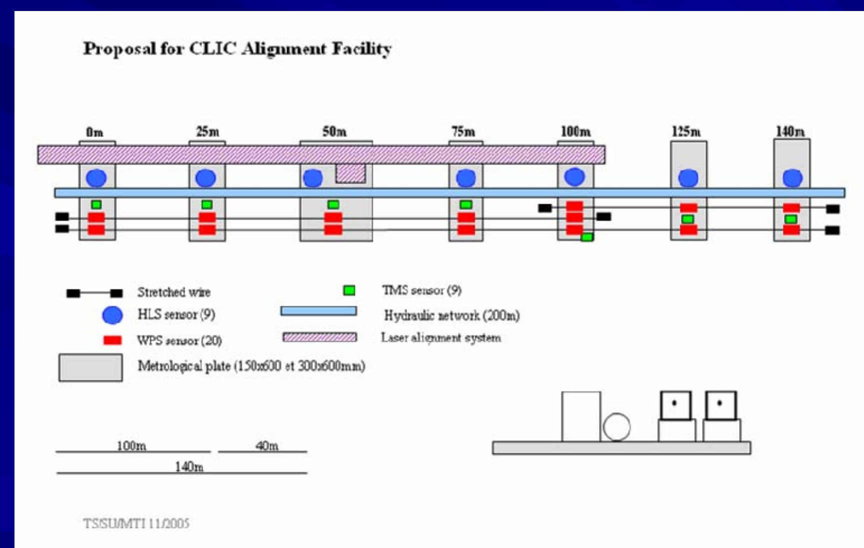


Alignment studies

- CERN Survey Group - now responsible for CLIC alignment studies - decided to follow two directions of studies concerning active pre-alignment system : first to validate already-proposed stretched-wire solution and to find solutions to remaining problems, and second to define together with NIKHEF Institute in Holland an alternative laser-alignment solution based on very successful RASNIK sensors.
- In order to evaluate relative performances of these two systems – SU propose to build new 100 m long pre-alignment test stand (RASCLIC) in underground transfer tunnel TT1 incorporating both solutions.
- This new facility will be used to make detailed studies of effects that could possibly perturb two alignment systems, and identify items needing further investigation
- For WPS - include (i) wire protection issues (ii) effects of wire length on modelization of catenary and quality of measurements (iii) other influences such as temperature or gravity perturbations.
- For optical system - include (i) diffraction due to air fluctuations (ii) optical alignment (iii) loss of coherence of laser (iv) choice of targets or patterns (v) reflection in tube (vi) laser instabilities (vii) thermal and other effects.
- New test facility expected to become operational during course of 2006.

Alignment studies





CLIC Test Facility (CTF3) Studies

- **Large fraction of CLIC resources devoted again in 2005 to CTF3.**
- **Appropriate at this moment to mention - this facility is being built and exploited in collaboration with**
  - Ankara University Group (Turkey)
  - BINP (Novosibirsk)
  - CAT (India)
  - CEA (Saclay)
  - CIEMAT (Spain)
  - HIP (Finland)
  - INFN (Frascati)
  - IN2P3 (LAL and LAPP)
  - JINR (Dubna)
  - North-Western University of Illinois
  - SLAC
  - University of Uppsala,
- **Following transparencies summarize various CTF3 activities in 2005.**

Installation - CTF3 linac

- During winter shut-down two more SICA structures installed in 1st part of linac before PETS 30 GHz power line and collimator added in PETS line – now total of 14 structures in linac and two in injector.
- After many problems with manufacturer of HV power supply for 1.5 GHz TW tubes for SH bunching system - one power unit finally installed and one cavity successfully operated at end of year.
- During shutdown - 3 GHz RF power distribution system rearranged to enable PETS line to be operated at repetition rate of 50 Hz.
- Some progress made with on-going problem of finding someone to repair Valvo klystrons – permission obtained to make klystron drawings available to eventual repairer for small nominal fee.
- New cooling water station and temperature stabilization system for RF pulse compressors installed during shut-down and successfully commissioned at start of 2nd run. In contrast to old system which required ~ 1 h to reach equilibrium after step increase of RF power - new system takes only few mins.
- Dramatic improvement of stability of CTF3 during 2nd run - almost entirely attributed to successful implementation of new water system


LINAC TUNNEL

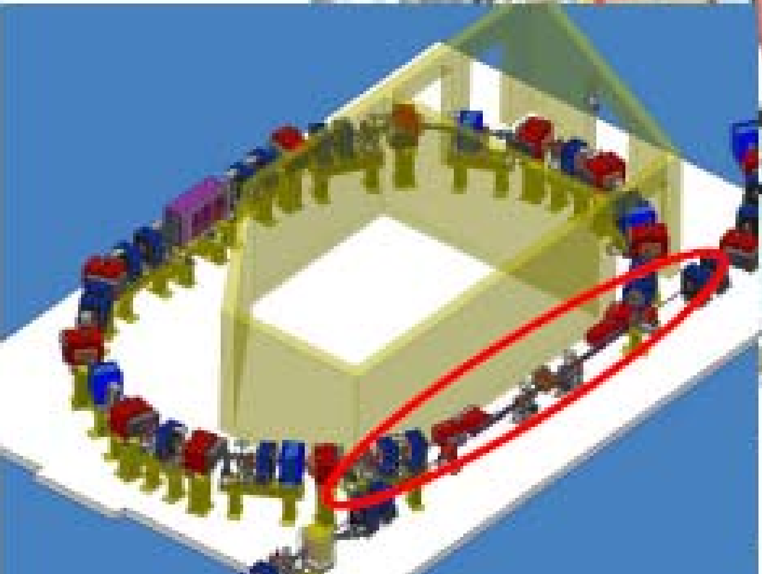

SICA STRUCTURES

30 GHz POWER PRODUCTION

Installation – CTF3 delay loop

- The installation of delay loop - fully under responsibility of INFN (Frascati) - successfully completed during year except for few BPIs - INFN provided sextupoles, wigglers, corrector magnets, vacuum system, 1.5 GHz RF deflector, waveguides and some beam diagnostics.
- CERN provided dipoles, quadrupoles, some correctors, power converters, septa, controls, 1.5 GHz RF power system, vacuum pumps, and all infrastructure (cabling, alignment, water, installation support).
- Very fitting after all effort by both Frascati and CERN teams to complete installation of all this equipment in very tight schedule - first test of beam combination was achieved at very end of last CTF3 run of year – bravo ! More on that later.

CLIC TEST FACILITY
(CTF3)
WIGGLER
DELAY LOOP
QUADRUPOLE AND SEXTUPOLE
SEPTUM CHAMBER
CHICANE
RF DEFLECTOR
TRANSFER LINES
INFN



Delay Loop installation

CTF3 beam diagnostic equipment (1)

- Development of beam diagnostic equipment for special requirements of CTF3 beams continued during 2005. New materials found to replace C and Al foils presently used as OTR screens. Basic problem – to produce homogeneous and flat reflective surfaces – Excellent results obtained with polished CVD SiC and polished aluminium-coated silicon wafers.

- In spectrometer lines 2 possible ways of improving problem of "intensity dependence on position" were studied and prototypes tested in lab.

  First idea – use diffusive screen – second – use parabolic screen to provide focusing effect exactly where OTR light is created.

  Best results with parabolic screen – will be tested in 1st run of 2006.

- Another problem – degrading performance of OTR system due to fact – above 80 MeV – SR yield emitted in visible range by electrons in 30° bend equivalent to OTR yield – this unwanted radiation successfully suppressed by introducing additional thin carbon foil in front of OTR foil.

- Developments to obtain time-resolved measurements of position/energy variations within bunch train progressed well – results now very encouraging. A new slit dump tested with beam currents ranging from 1-5 A and demonstrated very good S-to-N ratio and 50 MHz time resolution.

CTF3 beam diagnostic equipment (2)

- Encouraging results also obtained from 32-channel segmented photomultiplier (PMT) - showed better time resolution than slit dump with good signal-to-noise ratio - unfortunately PMTs sensitive to beam losses which degrade performance.
- Design work on sub-picosecond bunch-length monitor similar to Cesar monitor used in CTF2 started in collaboration with North-Western University - CTF2 monitor measured bunches as short as 0.7 ps - limited by maximum mixing frequency of 90 GHz - Intention to improve performance by (i) increasing maximum mixing frequency to 170 GHz to be able to measure bunch lengths of 0.3 ps, (ii) possibly using a diamond RF window and (iii) using large-bandwidth waveform digitizer to make online single shot FFT spectral analysis.
- Several beam diagnostic systems installed in collaboration with INFN in time for successful commissioning of DL at end of year - included (i) 6 beam position monitors (ii) one button pick-up for bunch length and phase measurements (iii) 5 MTVs and one optical line to streak camera lab. All systems worked well with no major problems.
- Work on machine protection system started this year using 4 WCMs to detect beam loss and to trigger the gun interlock – more needed.
- On CTF2 side, two faraday cups and set of 5 X-ray monitors installed in 30GHz accelerating structures test stand to monitor breakdown.

Delay Loop synchrotron radiation monitor

CD.MTV0241

CD.MTV0331

CD.MTV0361

Requires a lot of lead shielding blocks to protect sensitive equipment

CTF3 operation (1)

- Only two runs in 2005 – 1^{st} from 17 May–10 June 2^{nd} from 3 Oct–16 Dec. Total of only 13 weeks of beam operation with not only normal working days but also night and week-end working.

- Although only 4/5 specialists able to tune machine - many hours of extra high-gradient test work made possible by presence of non-machine-experts from both CERN and Ankara University during PETS running.

- Summer shut-down and 2 weeks in 2^{nd} run used for more installation work.

- Beginning of 1^{st} run used to consolidate m/c for 30 GHz power generation.

  Proved to be problematic due to (i) stability problems (slow drifts and beam jitter) (ii) reliability and availability problems due in main to inadequate cooling water temperature regulation and (iii) lack of time for beam measurements and re-matching.

- Reliability and availability was much better in 2^{nd} run - thanks to (i) newly-installed stabilized water cooling system (ii) reduction of power supply ripple on key units (iii) improved diagnostics and more time spent on setting-up beam.

CTF3 operation (2)

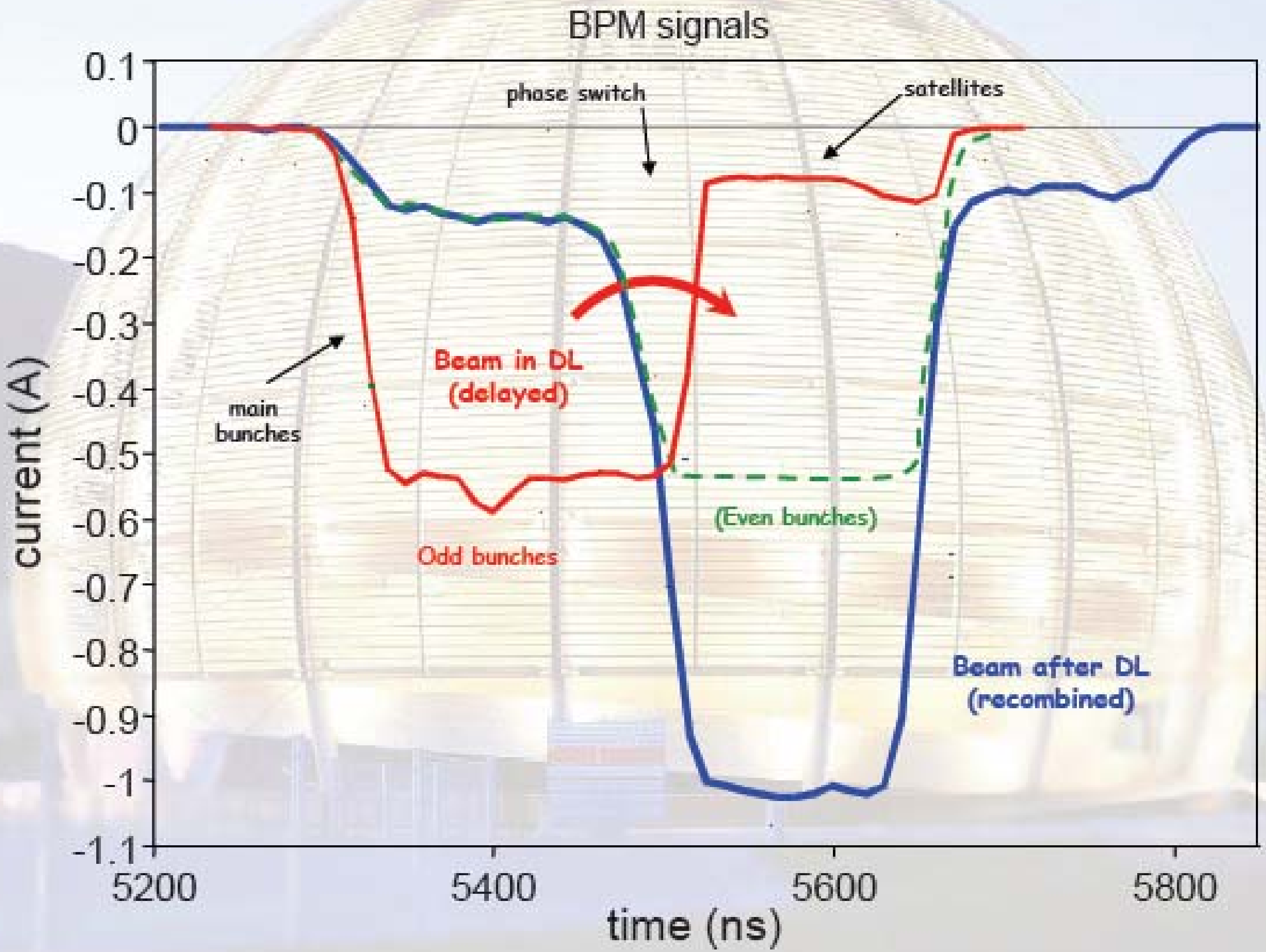
- The 2 runs dedicated to testing of molybdenum-iris accelerating structure and commissioning of DL - after 20 h running at 50 Hz with current of 3.5A - leak appeared in a flange in 30 GHz PETS power line at place of high beam loss and although leak was sealed by simply tightening flange - repetition rate reduced to 10 Hz as precaution for rest of run

- Last part of 30 GHz power generating activity dedicated to long-pulse running with view to using 30 GHz RF pulse compressor.

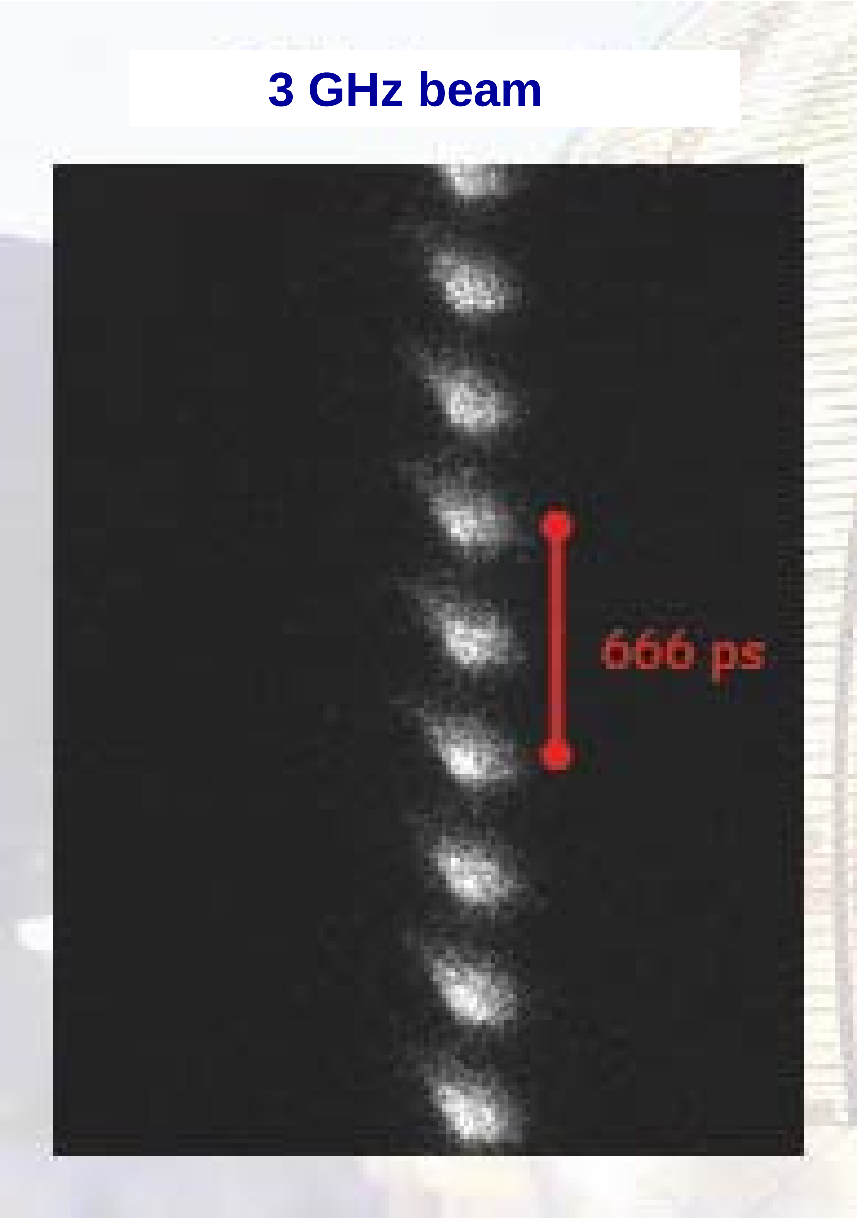
- Although very little time available for commissioning of DL - circulating beam of about 1 A (300 ns) obtained in very short time first of all using magnetic deflection into ring (3 GHz beam) - and at very end of run using an RF deflector and one unit of 1.5 GHz sub-harmonic bunching system combined with 180 degree phase flip to provide the bunch coding

Delay Loop - recombination

Nominal conditions, 1.5 GHz from SHB system (one cavity only), and phase switch



R. Corsini, 10 Feb 2006


3 GHz beam
666 ps

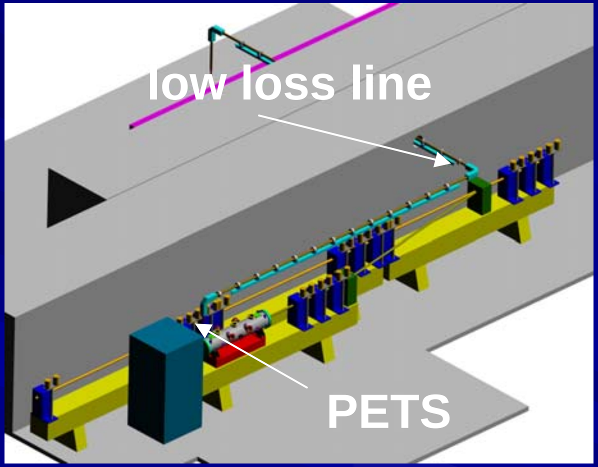

1.5 GHz beam

Operation

……… many thanks to the CTF3 collaboration !

30 GHz power generation

- CTF3 PETS line regrettably still only source of 30 GHz power for high-gradient development work – no money for stand-alone power source
- The 400-cell copper PETS which produces power - made from 3 segments with apertures of 6 and 9 mm which follow waist of drive beam.

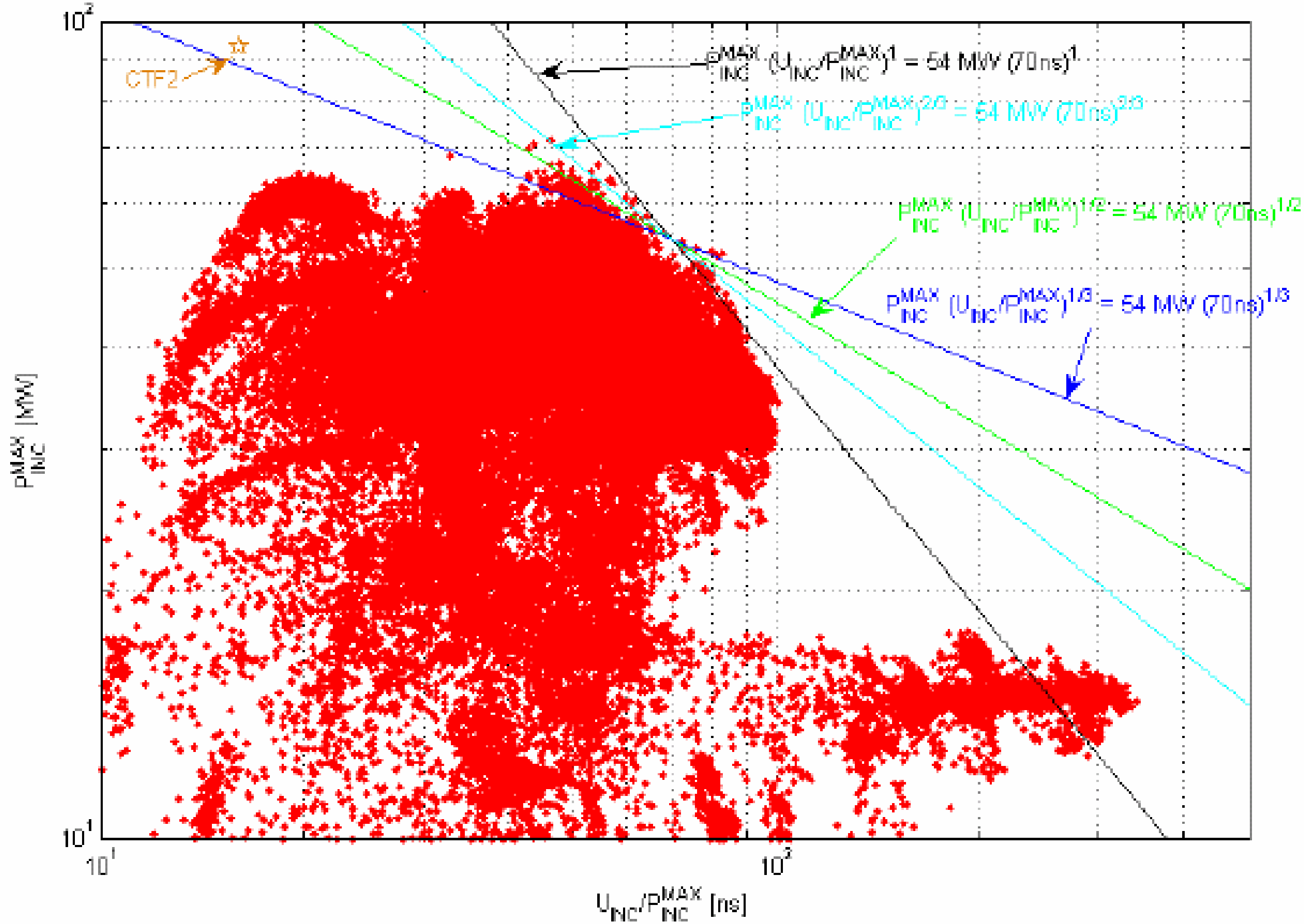


- PETS powers of 30 MW, 77 MW and 100 MW obtained using beam currents of 3.5 A, 4.5 A, and 5 A respectively - consistent with field form factor F=0.9 and transmission through PETS ~ 80-85%.
- Power transferred to CTF2 via low-loss (<5%) line.

30 GHz high-gradient testing

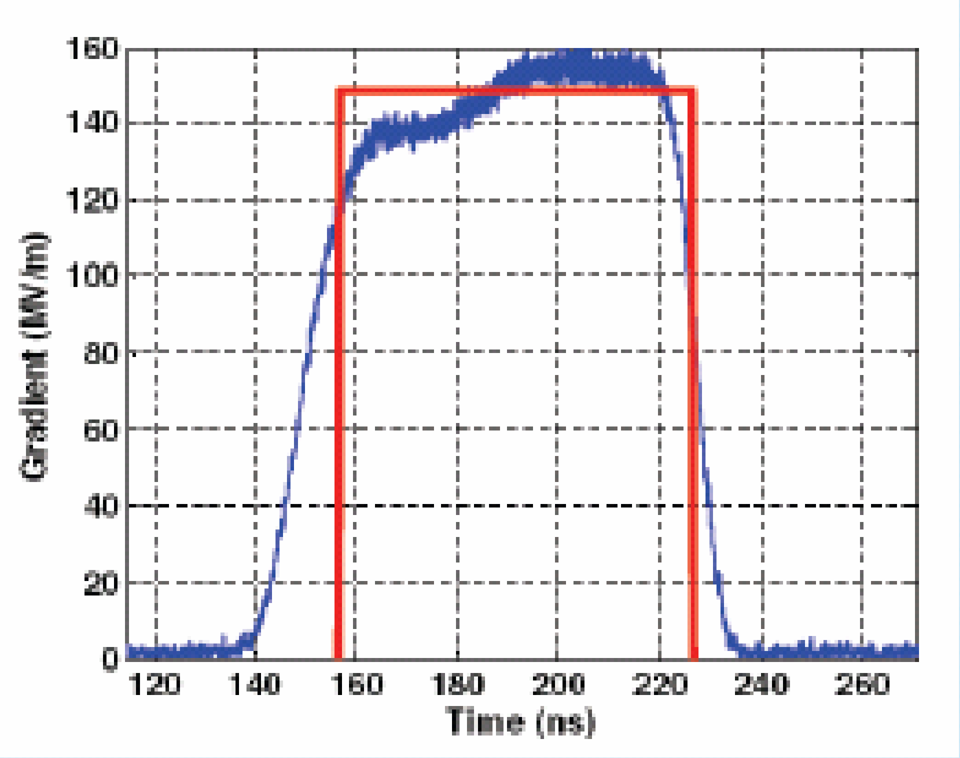
- During shut-down - clamping of molybdenum-iris structure increased to make sure contacts not limiting performance.
- Conditioning at first very slow - process was interlocked with Faraday-cup signal and stopped after every breakdown - later this restriction removed and rate of conditioning increased dramatically - obviously molybdenum reacts favourably to an aggressive approach.
- By end of run - CLIC nominal gradient (150 MV/m) and pulse length (70 ns) achieved albeit with very high breakdown rate and at limit of available power (55 MW).
- Some long-pulse running made in preparation for eventual use in CTF2 of SLEDII-like RF pulse compressor (installed and configured for 70 ns pulses but not yet connected) - about 15 MW achieved with 300 ns pulses - evidence that several components in system were limiting performance and needing to be conditioned - need ~30 MW for 400 ns.
- Calorimetric power measurement set-up completed and ready for use when right conditions available – this system requires reasonably high average powers to give accurate readings.

Conditioning: Peak power vs. Pulse length



Reached nominal CLIC values :

150 MV/m 70 ns



Preparation for the next CTF3 stages

- Good progress was made in parallel with the 2005 installation and test programme, to design, build and order equipment in preparation for next installation phases.
- Following transparencies summarize this preparatory work.

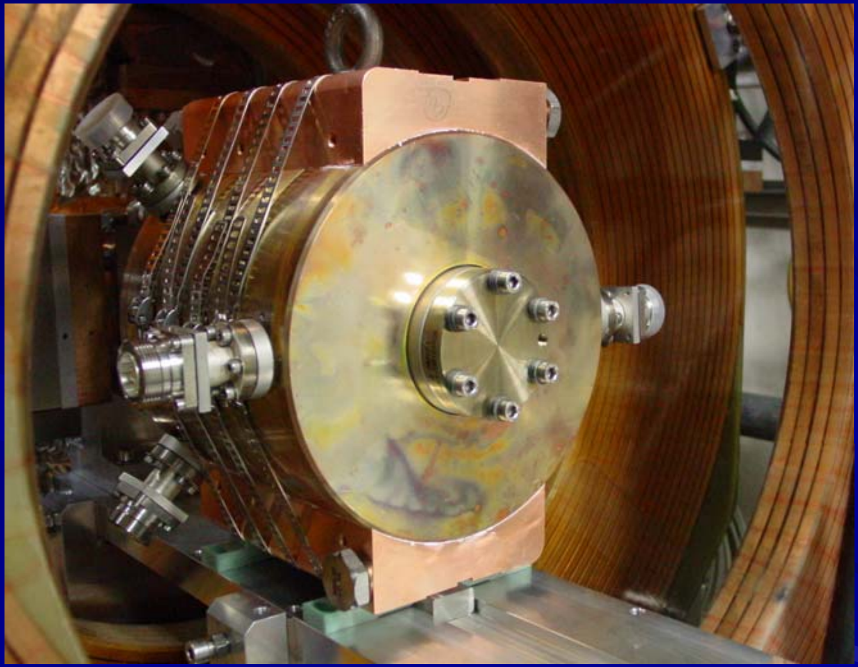
Preparation – miscellaneous magnets

- AT magnet group involved in one way or another with all magnets for future CTF3 phases - either as supplier, technical coordinator or collaborating partner - magnets concerned

- 8T/m Slim Quads for TL1/CR/TL2 manufacturer BINP (delivery early 2006)
- 33 H/V Corr Magnets for TL1/CR/TL2 manufacturer ANTEC (del early 2006)
- 32 Recuperated Quads (8T/m) from LURE for CR – first 16 end March 2006
- 26 Sextupoles (180 T/m2) for CR – BINP delivery foreseen beginning 2006
- 6 Bending Magnets (1.3T) for TL2 drawings in preparation – needed for 2007
- 16 Quads for TL2 (CELSIUS) – already delivered – installation in 2006
- 18 Quadrupoles and moving tables for TBL – CIEMAT – required for 2008
- 12-16 Quadrupoles for Two-Beam test stand – required for 2007
- 4 Wigglers for DL and CR - 2 units delivered to CERN by Sigmaphi/France

Preparation – sub harmonic bunching system

- 1.5 GHz sub-harmonic bunching system almost complete - three 6-cell large-aperture TW structures installed and 2 of 3 40 kW TW tubes and power supplies been delivered/installed.
- This wide-band (10%) bunching system will allow phase of bunching voltage to be changed very quickly (typically 10-20 ns) so that bunches of 140 ns-long bunch trains can be placed alternatively in even and odd RF buckets.



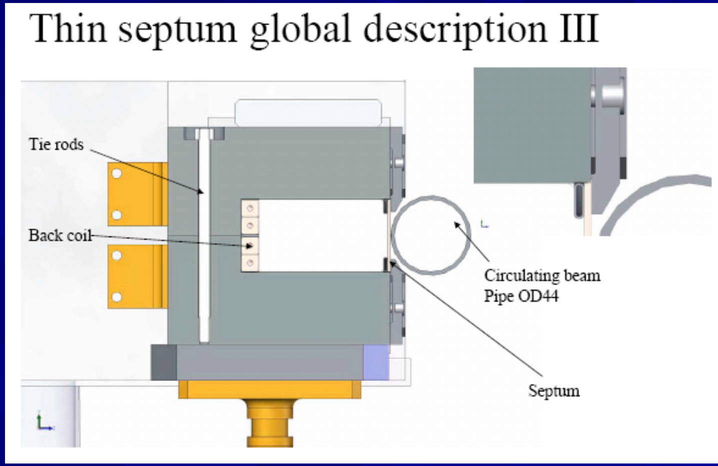
Preparation – septa

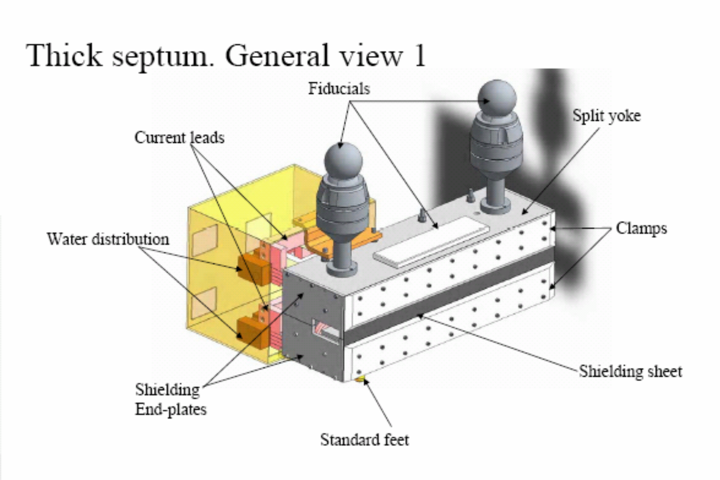
- **Conceptual design of 2 types of septa for injection and extraction in CR ring made by ELYTT Energy S.L. on behalf of CIEMAT - manufacturing drawings are being prepared.**

- **For thin septum - plate made out of 1.5mm thick Glidcop sheet with two cooling tubes brazed at top and bottom and insulated by 2 layers of 0.1 mm thick polyimide.**

- **Thick septum design based on 4-turn magnet divided into 2 coils - an horizontally-split yoke allows magnet to be insertion around v/c**

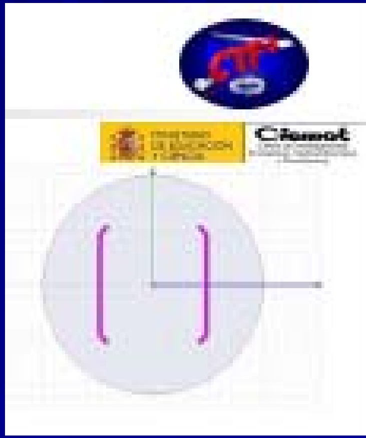
  The circulating beam shielded from stray field by 1 mm mu-metal sheet. Iron plates at ends shield stray field as well as controlling magnetic length



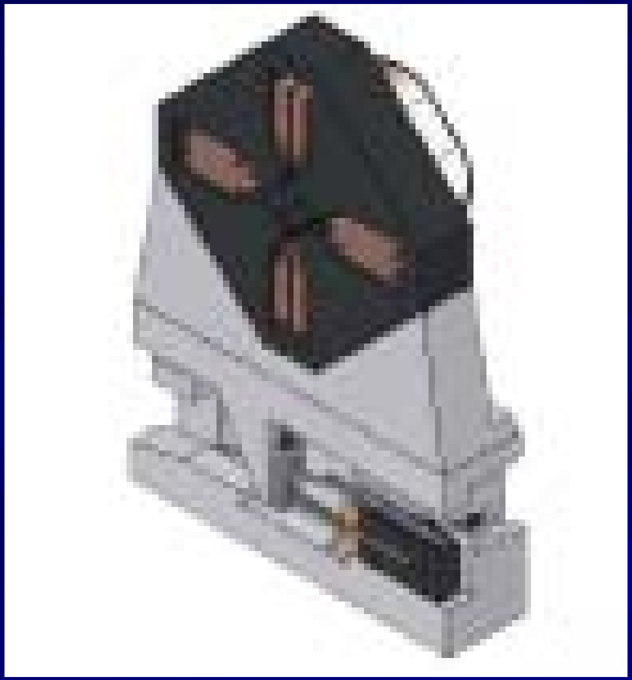


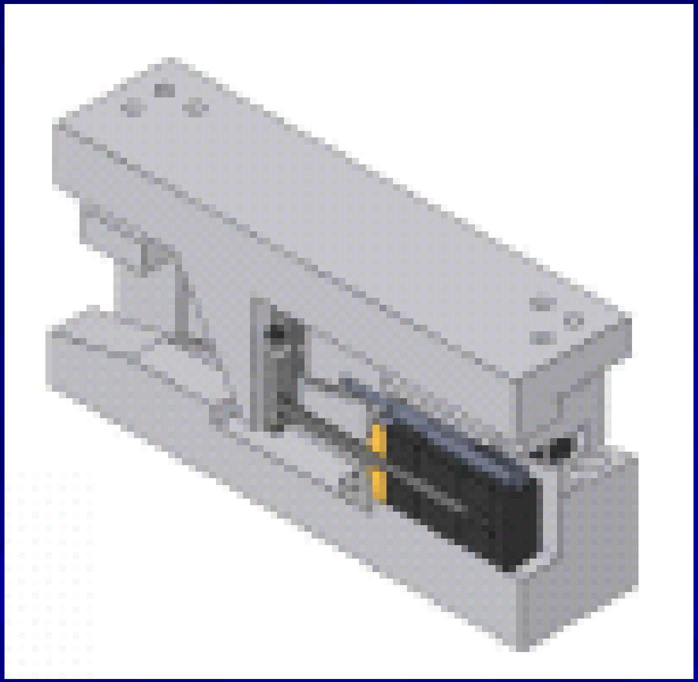
Preparation – extraction kicker magnet

- Conceptual design of kicker strip-line magnet for combiner ring made by CIEMAT following detailed discussions with INFN concerning specifications, geometries, simulations and fabrication.
- Installed HFSS - made first calculations and simulations of real magnet.
- Although behind schedule by ~ 4 months - planned to complete kicker by end of 2006.
- Following discussions in US - original idea to collaborate with LLNL on kicker pulser now looks very improbable.
- Decision on how to proceed with this development has to be decided soon since Spain does not have expertise to go it alone.



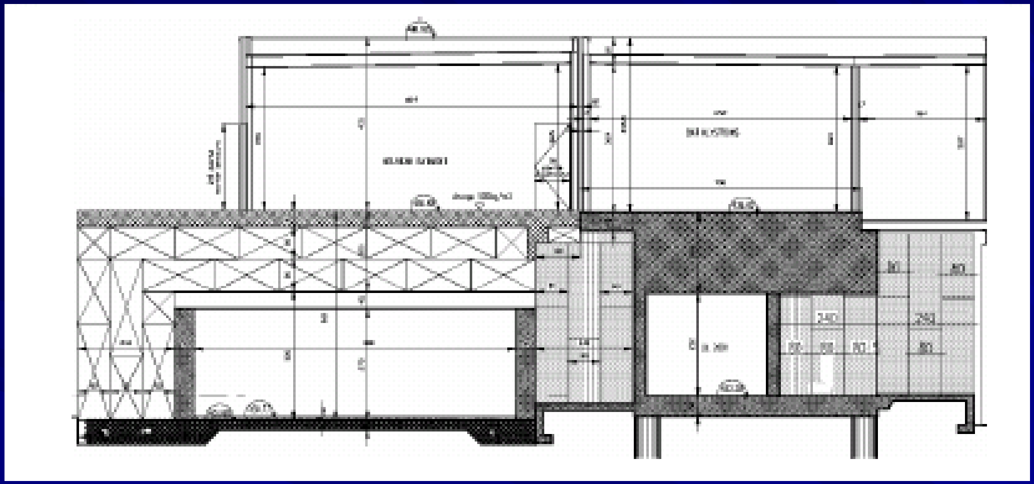
Preparation – TBL magnet movers





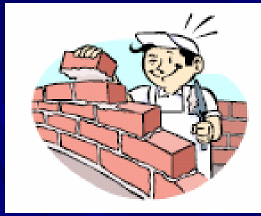
Conceptual design and drawings for fabrication of prototype quadrupole magnet mover for TBL made by CIEMAT - first prototype based on sliding inclined plane expected for early 2006.

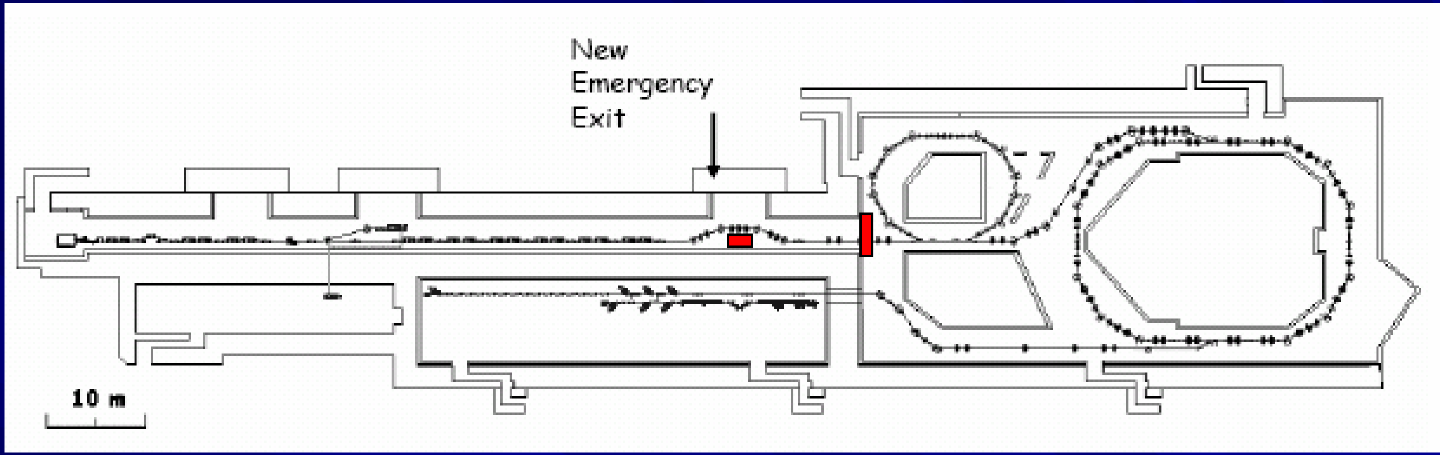
Preparation – CLEX building



- Foreseen to construct CLEX building in 2006 so that equipment can start to be installed in 2007
- Building specified to have inside dimensions of 40 x 8 x 2.75 m with no support pillars and an equipment gallery of dimensions 20 x 8 x 3.55 m with installed electrical power of about 700 kW
- CLEX floor will be 50 cm lower than floor of CR building and drive-beam linac building - since beam height of linac, delay loop, and combiner ring is 135 cm - means beam height in CLEX will be 185 cm requiring vertical bends in TL2.

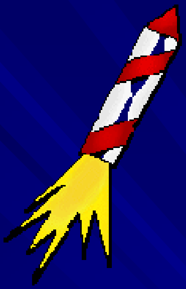
Preparation – radiation protection wall





- Radiation protection wall between linac and DL being prepared - allow high-gradient test stand to be operated during installation of CR in 2006 - will significantly increase number of test hours
- For security reasons will mean construction of new emergency exit door at end of linac and beam stopper in straight-through line of INFN chicane - for DL running - means beam will have to go via chicane at all times.

CLIC accelerated R&D programme



- Substantial progress made this year with setting-up and consolidation of multi-lateral collaboration to complete construction of CTF3 and to carry out necessary feasibility experiments to demonstrate key issues of CLIC scheme.

- MoU was circulated to all interested parties and after several iterations was finalised in March. During course of year - following laboratories or industrial partners officially committed themselves to collaboration by signing an Addendum to MoU describing their specific contributions :

  - Ankara University Group, BINP (Novosibirsk), CERN, DAPNIA (CEA), HIP (Helsinki), IAP (Nizhny Novgorod), JINR (Dubna), North Western University (Illinois), SLAC, and Uppsala University.
  - Further 4 draft addenda from other laboratories being discussed.

- Contributions cover large part of project costs but 6.9 MCHF and 40 man-years of effort still missing to complete programme.

- Ankara - 1 my per year for CTF3 operations for 2005-9.
- BINP - 11 quads and 26 sextupoles for 50% of manpower cost.
- DAPNIA (CEA) - large part of probe-beam linac.
- HIP - 3 my of effort in micro-machining for CLIC structure development.
- IAP has joined collaboration based on ISTC-sponsored development work on 30 MW 30 GHz gyro-klystrons for stand-alone 30 GHz power source
- JINR contributing 50% of manpower for development of specialised software for computer-controlled operation of high-gradient test stands.
- NW University - providing beam-loss monitors and bunch-length monitor.
- SLAC – joined on past contributions - triode and injector design work
- Uppsala University - 16 quads, 3 bending magnets and 5 steering magnets from ex-CELSIUS facility plus (i) phase monitor (ii) design and construction of two-beam test stand including optics, magnets, vacuum, beam diagnostic equipment, RF diagnostics and data handling.

- INFN Frascati - waiting for approval of proposal to continue contribution beyond delay loop to include (i) optics design for CR and TL1 (ii) vacuum chambers and beam diagnostic equipment (without electronics) for CR and TL1.
- Spain building (i) corrector magnets and waiting for approval of proposal for (ii) 2 septum magnets and an ejection kicker (iii) quads with precision movers for TBL (iv) RF structure work with aim of building one TBL PETS
- IN2P3 (LAL and LAPP) plans to contribute to design and construction of probe-beam linac together with DAPNIA and CERN.

- All the very impressive technical progress was reported at Tenth CTF3 technical collaboration meeting held at CERN from 29-30th November 2005 to which all collaborating institutes participated.
- First meeting of Coordination Committee of new CTF3 Collaboration was held on last day of this meeting (30th November) at which following collaborators officially signed MoU: Ankara University Group, CERN, CEA (DAPNIA), NW University of Illinois and SLAC.

CARE activities

- In addition to their normal activities - several members of CLIC study team now have additional commitments within so-called CARE project (Coordination in Accelerator Research in Europe) which is part of Sixth Framework Program (FP6) of European Commission.
- In particular - for CLIC - means participation in European-wide network on linear accelerators (ELAN) and in a joint research activity (PHIN) together with LAL and RAL to construct photo injector for CTF3 drive beam.
- During year ELAN associated with WIGGLE2005 workshop at Frascati, LCWS05 at SLAC, Metrology workshop at Annecy, Positron sources workshop at Daresbury, ILC meetings at London and Snowmass, and CTF3 collaboration meeting at CERN.

Construction of CTF3 DB photo-injector

- In CERN/LAL/RAL collaboration on PHIN - laser being developed and built by RAL, RF gun by LAL, and photocathodes, installation and commissioning by CERN.
- Specification for 3 GHz RF gun - electron beam of 2300 pulses of 2.3 nC with emittance of 20π.mm.mrad and 10^-10 mbar at PC.
- Design of gun started from CTF2 gun IV but ended up being substantially different - notable design features include (i) reduced cathode wall angle (ii) 2 symmetric couplers to reduce transverse kicks (iii) racetrack shaped cells (iv) elliptical-shaped irises (v) full beam loading compensation by delayed filling (vi) 3 coils close to cathode to reduce emittance growth from space charge (vii) over-coupling (β=2.9) to match beam (3.51 A – 1.5μs) (viii) 42 vacuum pumping holes (Φ=4mm) in cells plus NEG-coated surfaces
- Measurement and re-machining of cold model now in progress but have been problems and plan to order gun before end of 2005 didn't work out.

- Design of main parts of laser completed but several features at edge of technology and require components not previously existing on market including high frequency oscillator, fast switching electronics for Pockelscells and ultra stable drives for pumping diodes.

- Specifications on amplitude stability (<0.25% rms) and time jitter from pulse to pulse (<1ps rms) - particularly tight.
  Oscillator and preamplifier - made by Austrian firm HighQLaser - been installed and commissioned.

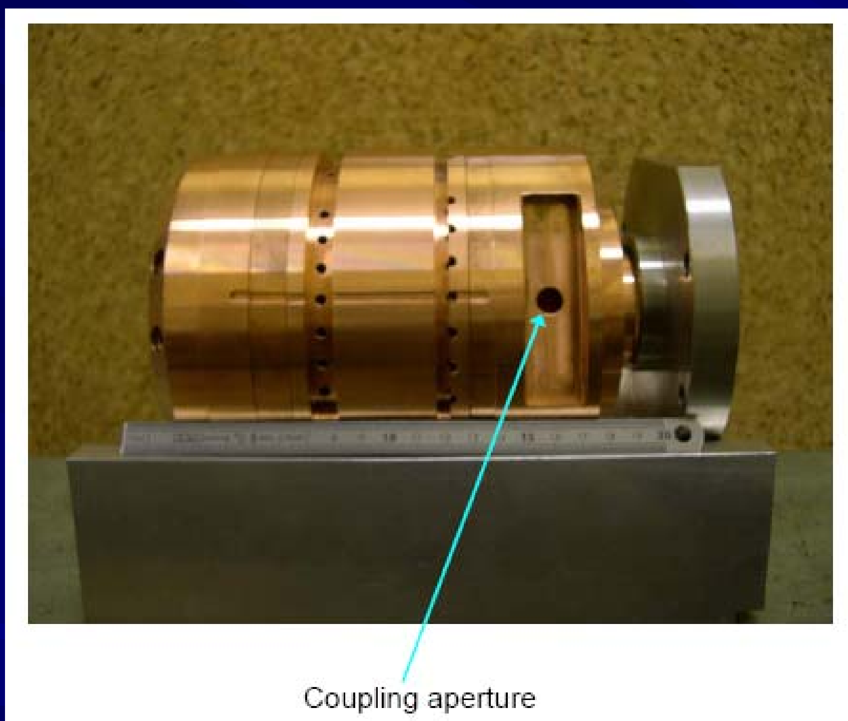
- Optical pumping of amplifiers will be made with laser diodes with total power > 35 kW QCW - mechanical design of amplifier completed, orders for diode stacks placed and many delivered.

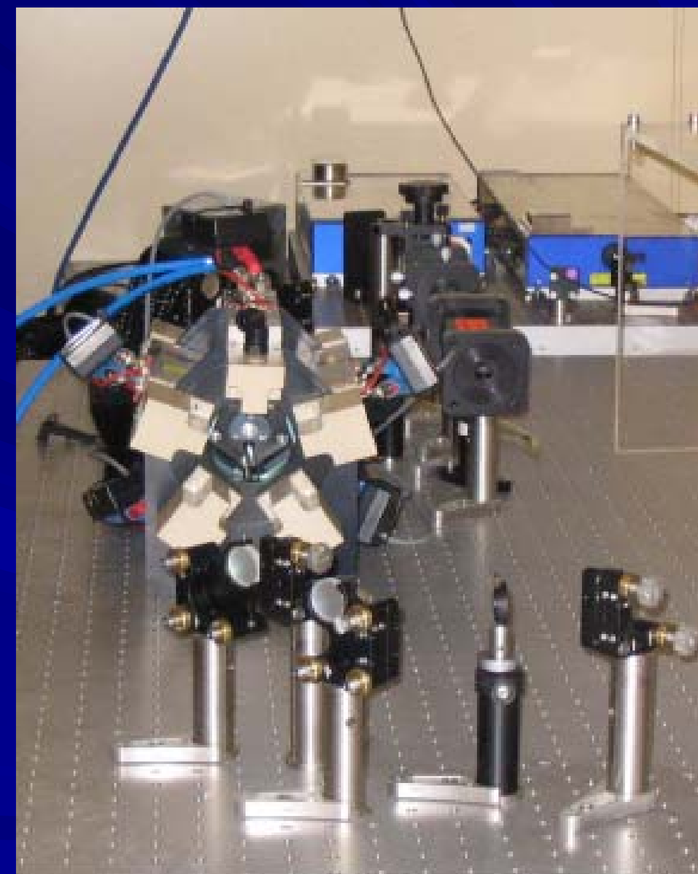
- Suitable driver (5 kV in 333 ps) remains to be found for Pockelscells. Studies on stabilization feedback and phase coding started at RAL.

- On CERN side - equipment for PC production rejuvenated – in particular installation of new evaporators and improved vacuum pressure measurement and new rest gas analysis system.

- New informal collaboration set-up up with CEA-SP2A (CEA Bruyères-le-Châtel F) to study and to exchange new photocathodes of Secondary Emission Enhanced (SEE) type proposed by BNL (Upton NY - USA).

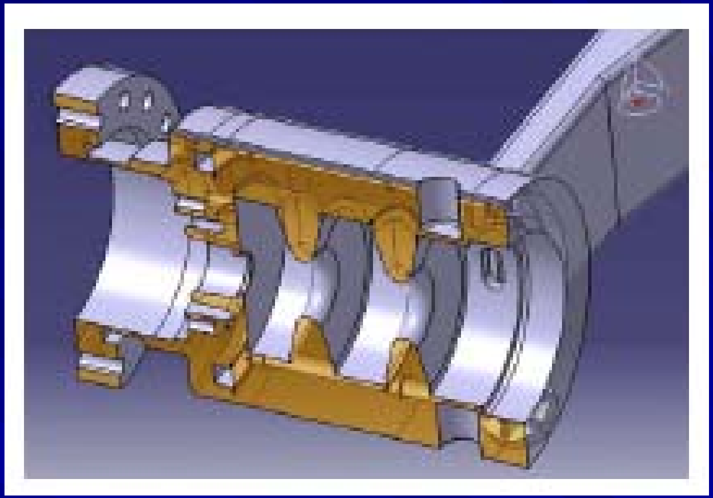
CTF3 drive beam photo-injector





Construction of CTF3 probe-beam photo-injector

- Same collaboration group also responsible for CTF3 probe-beam photo-injector.
- For cost reasons- specification revised (down-sized) enabling probe-beam laser pulse to be derived from unused part of drive-beam laser pulse, and enabling use of former-CTF2 in-situ photo-cathode preparation chamber to produce up to 105 electron bunches with a charge of 0.2 nC at rep rate of 5 Hz.

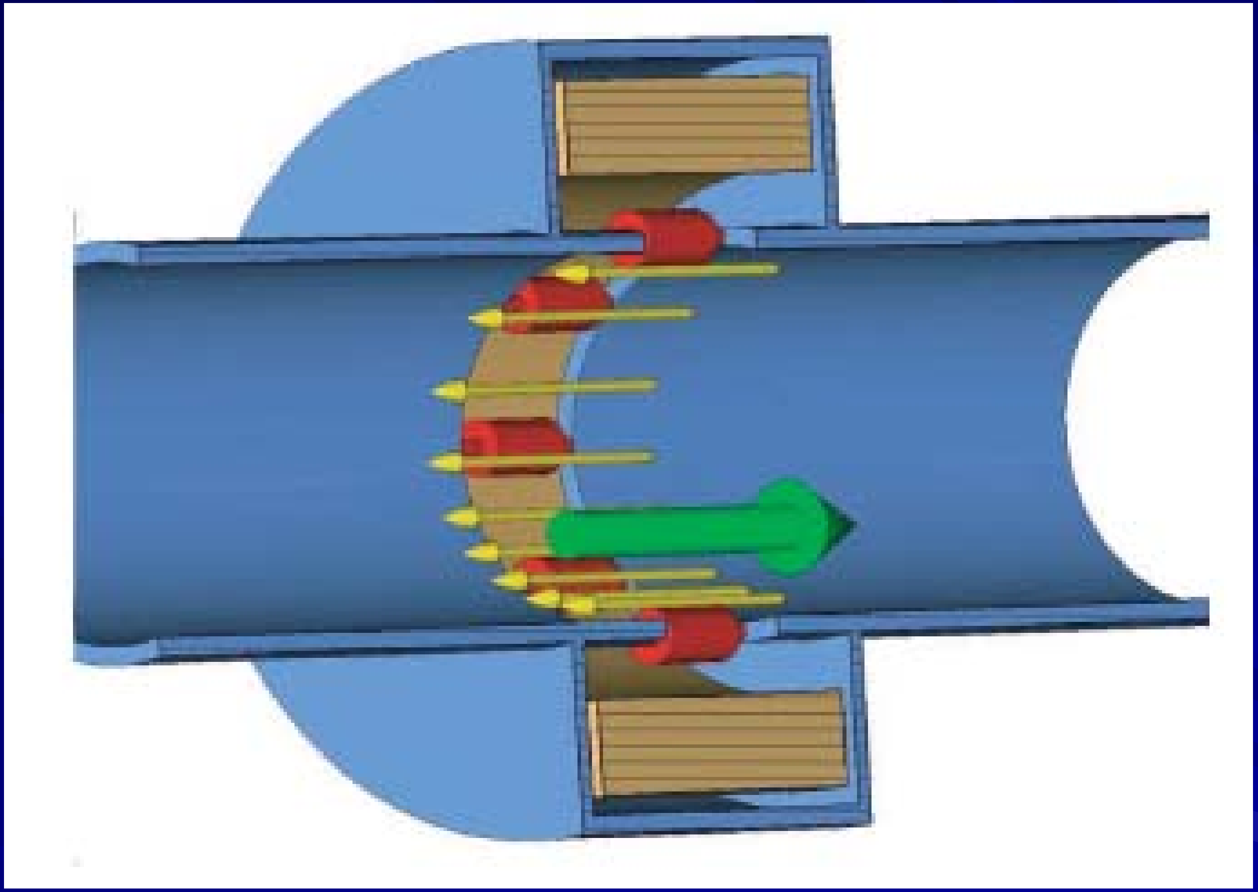


EUROTeV activities

- New Eurotev DS - which approved in 2004 at level of 9 M Euros - which runs for 3 years from 1st Jan 2005 - 31st Dec 2007 - further increased commitments of CLIC study team members to FP6.

- Foreseen Eurotev will concentrate on issues common to all LC proposals - DS structured around 7 scientific work-packages and CLIC study members participating in number of areas considered of critical importance. These include
  - study of electron cloud build-up in DR
  - potential to provide timing stability at level of 15 fs
  - development of wide-band beam current monitor
  - high precision BPMs with reduced sensitivity to beam losses
  - provision of beam time for instrumentation tests at CTF3
  - study of beam halo generation
  - study of failure modes and their impact on machine design
  - study of integrated L performance including dynamic and static effects
  - study of beam delivery and collimation system and spent beam lines

- As well as contributing to study itself CERN is contributing to management of study by participating in overall scientific coordination and by coordinating WP on integrated luminosity performance studies.



Operating principle of precision transformer beam-position monitor

EUROTeV activities (2)

- In DR work-package CERN focusing on development of new code (HEADTAIL) to simulate electron cloud build-up - code able to simulate arbitrary beam pipe shapes and to track electrons and ions – the machine experiments made in SPS in 2004 - used to benchmark code - being updated to handle more realistic models of both electron cloud distribution and the machine.

- In TPMON activity - major task to build electronics for high precision RF-based bunch timing measurement system - scheme requires measurement of phase of bunch train at 30 GHz with accuracy of 10 fs using single-shot wideband system – essential part of this work is to test system on working accelerator - planned to do this in CTF3.

- In beam halo generation work package a list of all known halo and tail generation processes being compiled - codes when missing being written to simulate their behaviour and proposals of how to benchmark them being formulated.

EUROTeV activities (3)

- In integrated luminosity performance work package - studies at CERN focused this year on effects of static and dynamic imperfections on luminosity, and proposals for correction, feedback and tuning strategies.

  The performance of beam-based dispersion-free-steering alignment procedure been simulated allowing optimum gain factors to be established and better understanding of which imperfections are most relevant. Found these alignment procedures alone not sufficient to ensure preservation of beam quality.

  Study of performance of main-linac emittance-tuning bumps for static machines shown - newly-proposed system of 5 bumps not only gives better performance than previous 10-bump system but performance achieved is significantly better than required.

EUROTeV activities (4)

- CLIC collision parameters, such as collision offset, collision angle and longitudinal position of beam waists, need to be carefully tuned in order to maximize luminosity. In order to optimize these parameters fast luminosity signal needed - unfortunately no signal available which directly proportional to luminosity and therefore different strategy has to be found.

  Proposal - to find and use signal will allow optimum choice of number of beam parameters to be made during systematic scans - possible fast signals for this include signals coming from incoherent pair creation, beamstrahlung of each beam and coherent pair creation - first simulations using beamstrahlung signal to optimize beam parameters look promising.

- In beam delivery and collimation work package - studies focused on optimizing and getting better understanding of nonlinear collimation systems with aim of either improving performance or reducing length.

  First attempt made to implement octupole tail folding by placing an octupole doublet at entrance of final focus - octupoles efficiently folded beam tails inside final quadrupoles - but unfortunately also resulted in 30% luminosity loss.

- Best non-linear design found to date uses skew sextupoles to blow up vertical beam size at spoiler so as to guarantee collimator survival in case of beam impact but has only been implemented in energy collimation section - although collimation efficiency been improved - does not quite achieve same luminosity as linear system. More work on this clearly needed.

EUROTeV activities (5)

- Comprehensive survey of wake field effects in beam delivery performed, which addressed, among other topics, balance of geometric and resistive-wall wake field, optimization of collimator taper angle, and various regimes of resistive- wall wake fields relevant for CLIC short bunches.

- Simulations tools set up for modelling beam loss in extraction line.

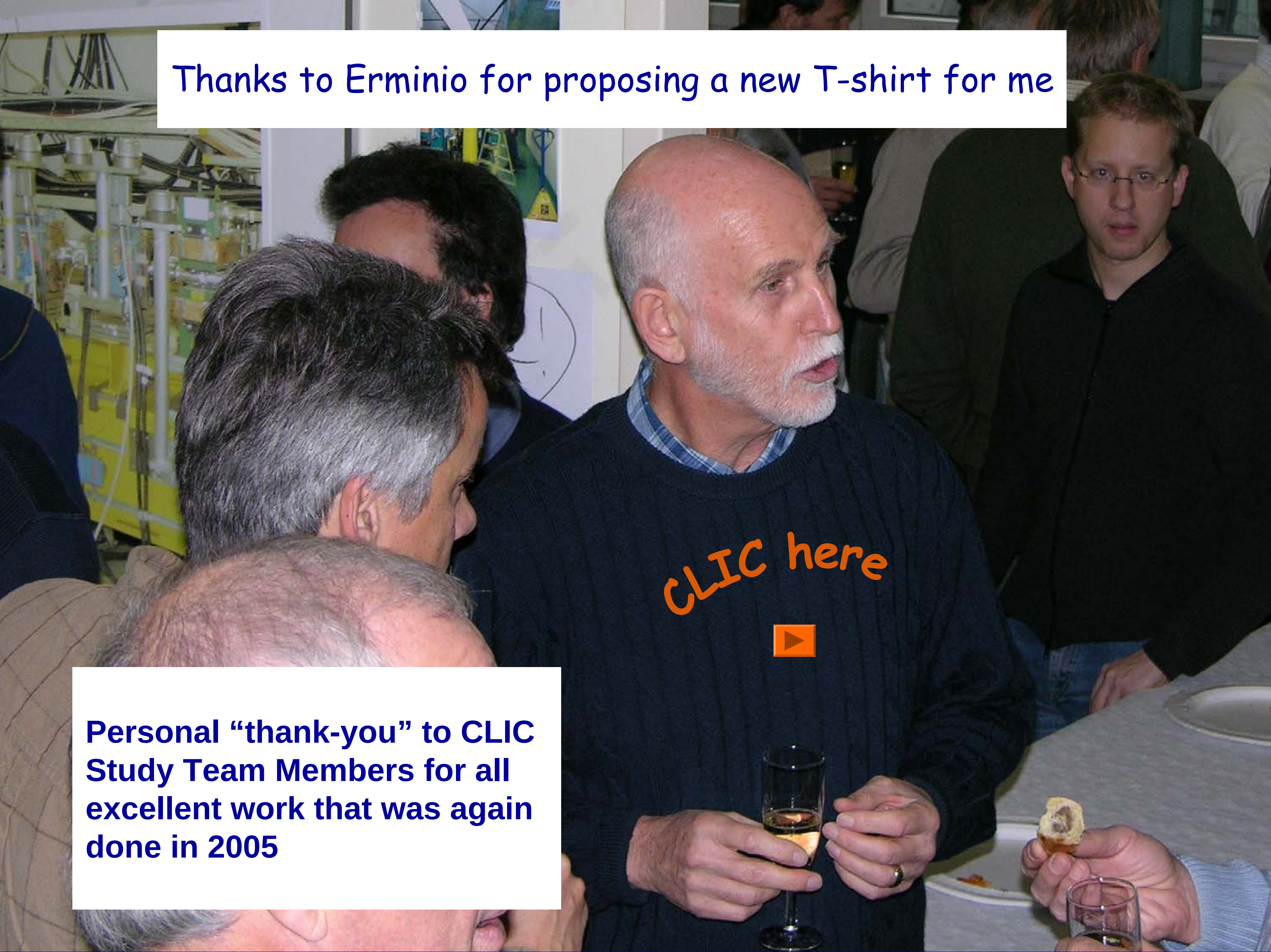
- CERN tracking code PLACET - extended to simulate effect of collimator wakefields, and linacs that follow curvature of earth - further PLACET updates being developed including (i) module that implements different analytical wakefield calculations (ii) module that enables more sophisticated feedback and tuning to be simulated including possibility to input real data (iii) modules to simulate bunch compressors, beam-gas scattering, and bremsstrahlung.

  An interface also being created to allow PLACET to use new precise and very fast synchrotron radiation spectrum generator - developed to speed-up GEANT calculations.

  Finally also foreseen to adapt PLACET to run on parallel computer systems - should enlarge scope of problems that can be handled and reduce computing time.

……and that's it for 2005

Thanks to Erminio for proposing a new T-shirt for me



Personal "thank-you" to CLIC Study Team Members for all excellent work that was again done in 2005