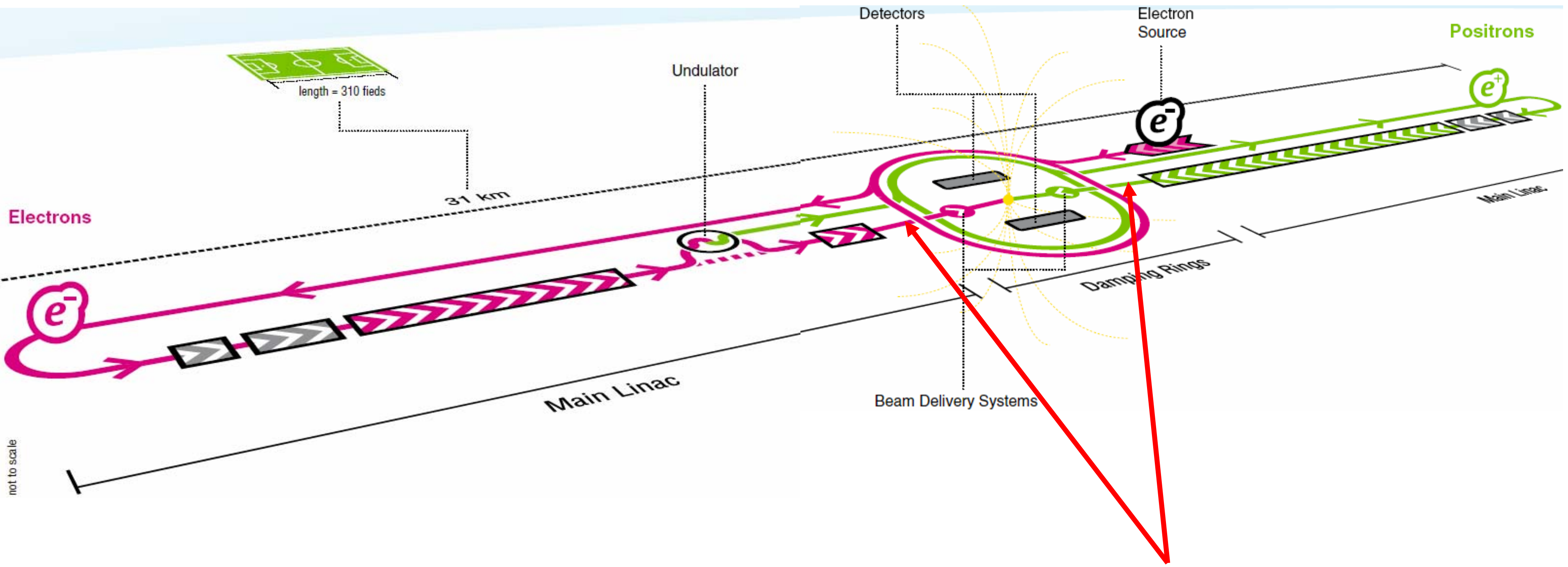
# Design of the Beam Delivery System for the International Linear Collider

Andrei Seryi, SLAC,
for the ILC BDS team
CLIC meeting, November 16, 2007

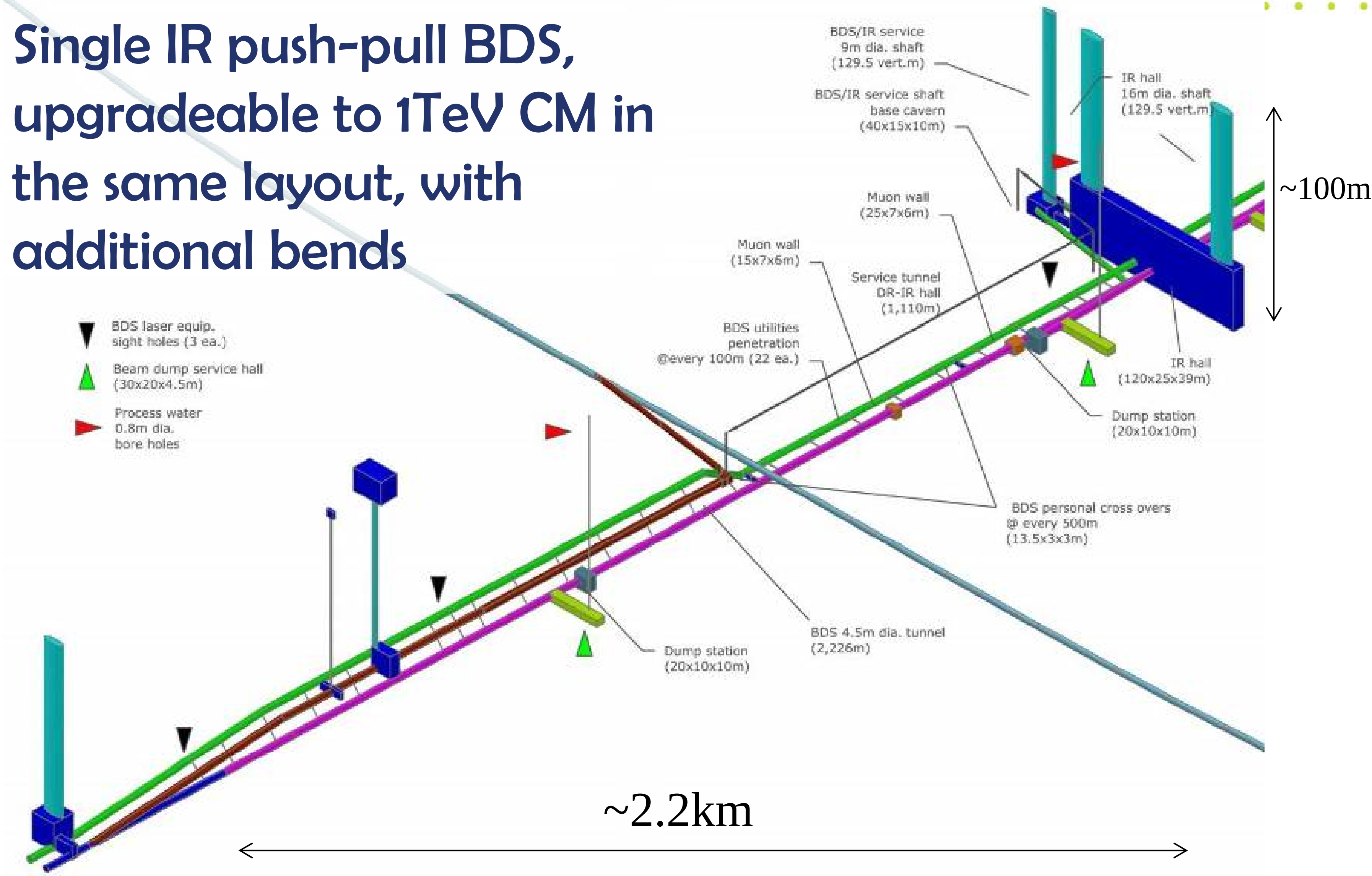
# BDS: from end of linac to IP, to dumps



Beam Delivery System (BDS)

# Layout of Beam Delivery tunnels

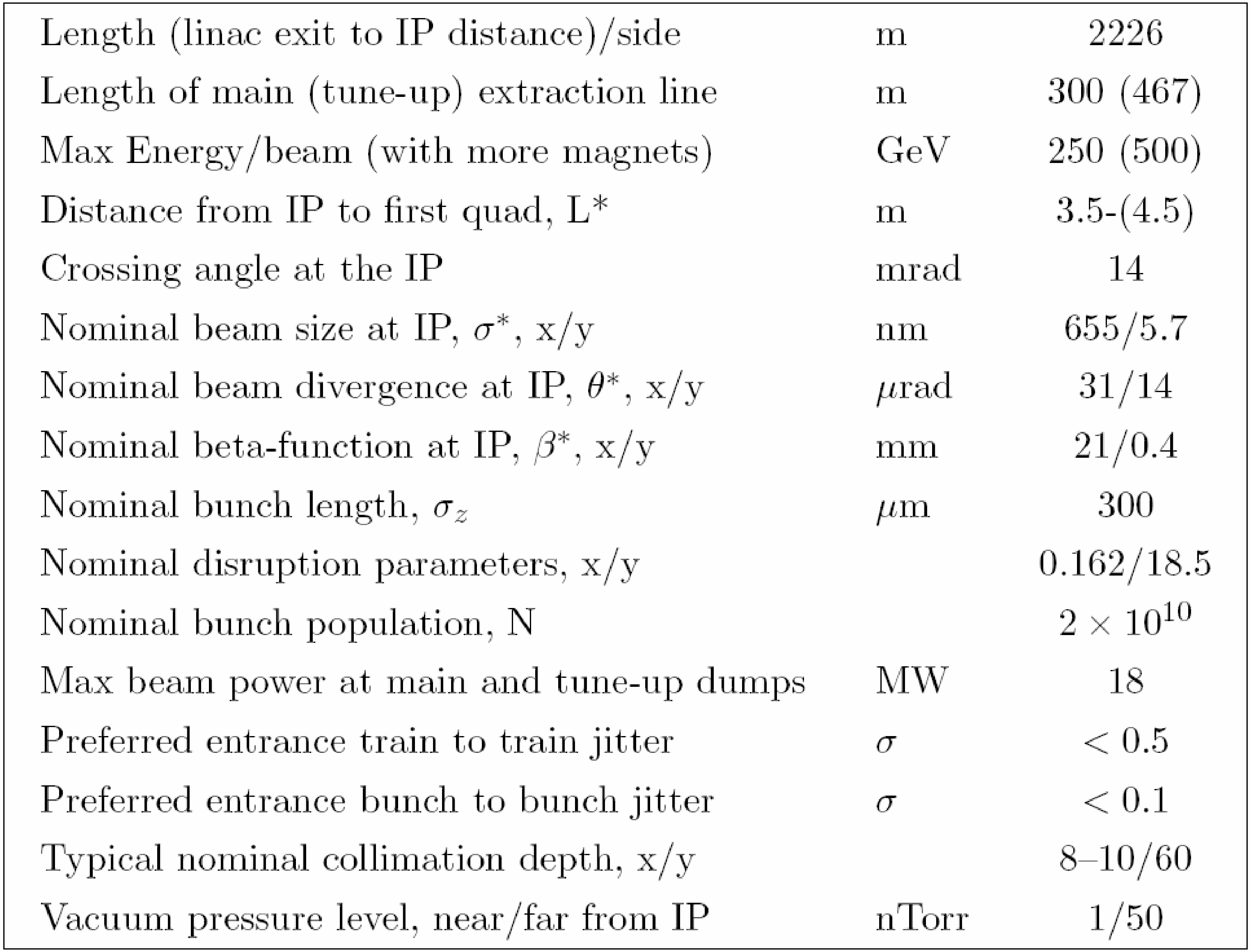
- Single IR push-pull BDS, upgradeable to 1TeV CM in the same layout, with additional bends



# Beam Delivery System tasks

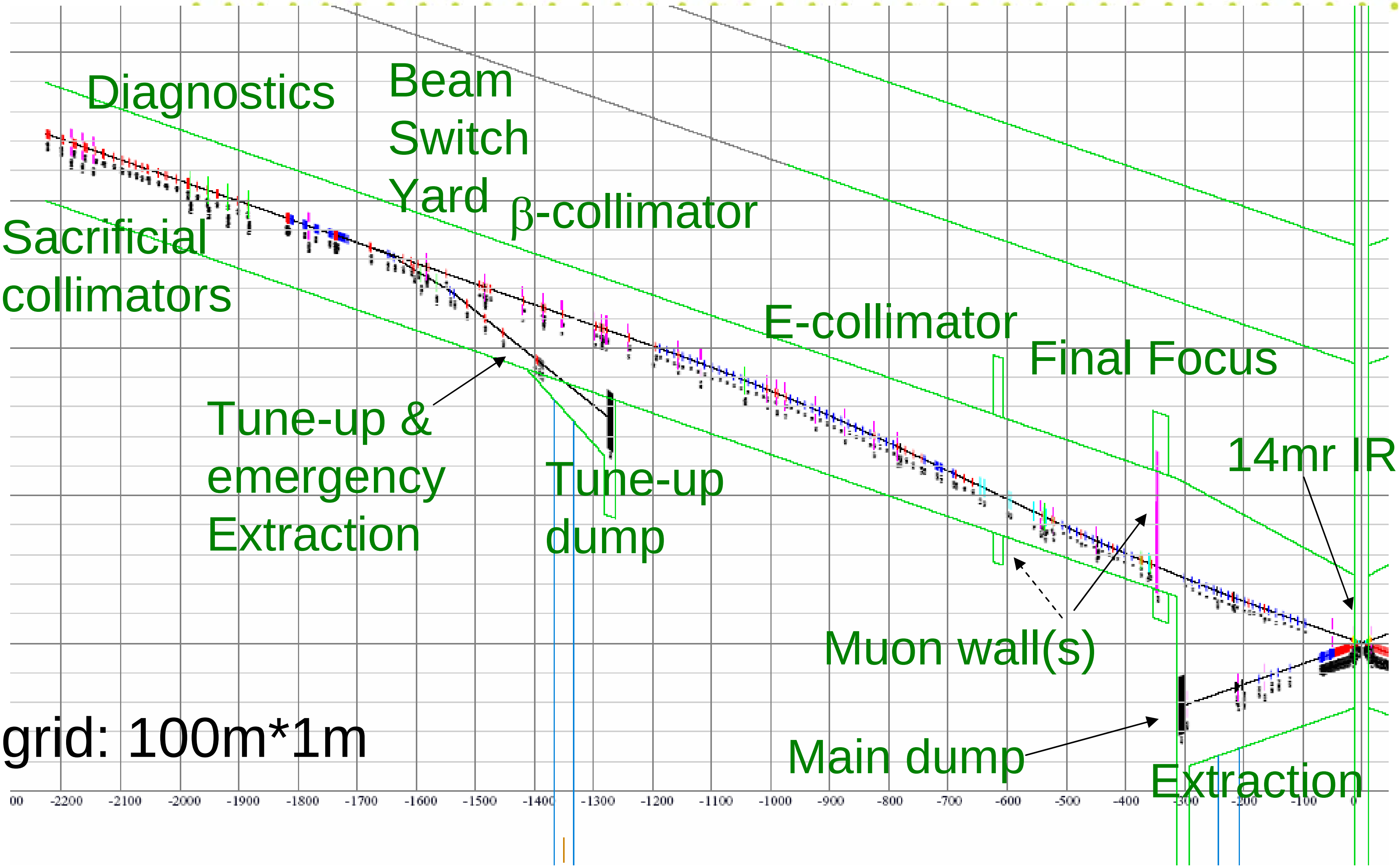
- measure the linac beam and match it into the final focus
- remove any large amplitude particles (beam-halo) from the linac to minimize background in the detectors
- measure the key physics parameters such as energy and polarization before and after the collisions
- ensure that the extremely small beams collide optimally at the IP
- protect the beamline and detector against mis-steered beams from the main linacs and safely extract them to beam dump
- provide possibility for two detectors to utilize single IP with efficient and rapid switch-over

# Parameters of ILC BDS



| | | |
|---|---|---|
| Length (linac exit to IP distance)/side | m | 2226 |
| Length of main (tune-up) extraction line | m | 300 (467) |
| Max Energy/beam (with more magnets) | GeV | 250 (500) |
| Distance from IP to first quad, L* | m | 3.5-(4.5) |
| Crossing angle at the IP | mrad | 14 |
| Nominal beam size at IP, $\sigma^*$, x/y | nm | 655/5.7 |
| Nominal beam divergence at IP, $\theta^*$, x/y | $\mu$rad | 31/14 |
| Nominal beta-function at IP, $\beta^*$, x/y | mm | 21/0.4 |
| Nominal bunch length, $\sigma_z$ | $\mu$m | 300 |
| Nominal disruption parameters, x/y | | 0.162/18.5 |
| Nominal bunch population, N | | $2 \times 10^{10}$ |
| Max beam power at main and tune-up dumps | MW | 18 |
| Preferred entrance train to train jitter | $\sigma$ | $< 0.5$ |
| Preferred entrance bunch to bunch jitter | $\sigma$ | $< 0.1$ |
| Typical nominal collimation depth, x/y | | 8–10/60 |
| Vacuum pressure level, near/far from IP | nTorr | 1/50 |

# Beam Delivery subsystems



Diagnostics

Beam Switch Yard

β-collimator

Sacrificial collimators

E-collimator

Final Focus

Tune-up & emergency Extraction

Tune-up dump

14mr IR

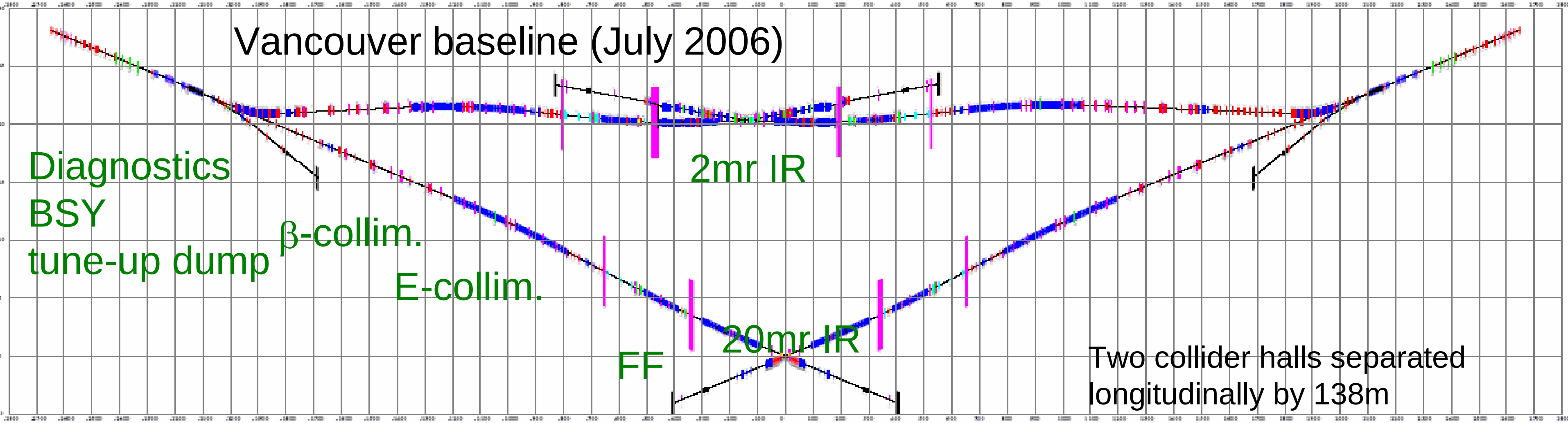
Muon wall(s)

grid: 100m*1m

Main dump

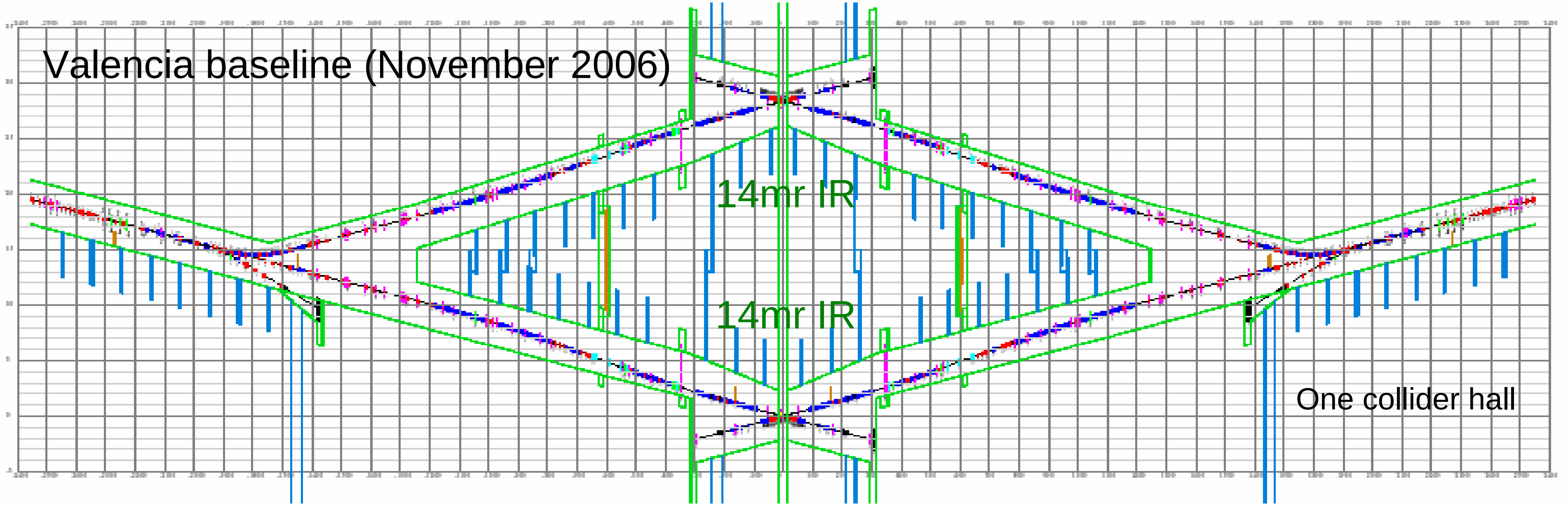
Extraction

# Earlier versions of the baseline



Vancouver baseline (July 2006)

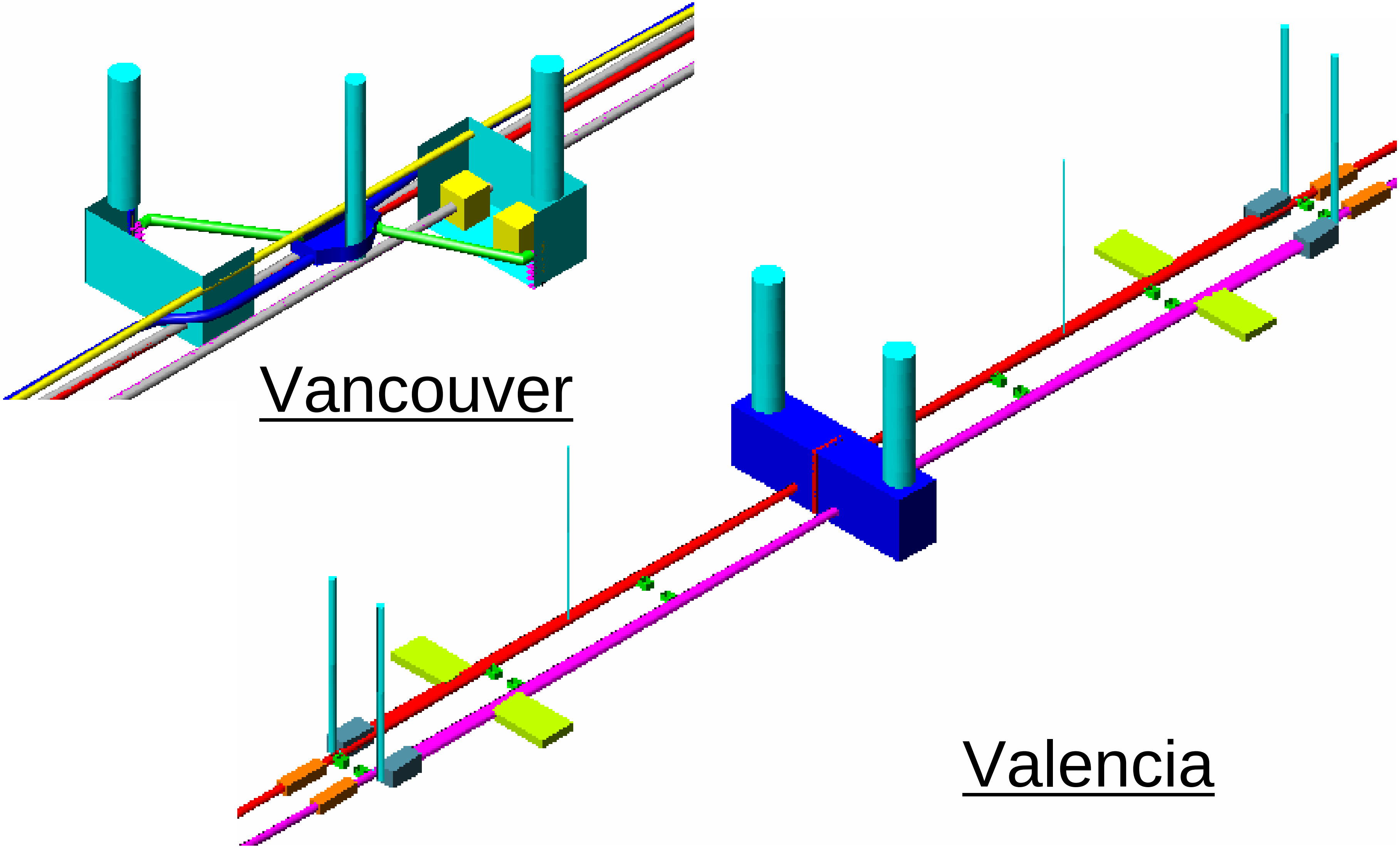
Two collider halls separated longitudinally by 138m



Valencia baseline (November 2006)

One collider hall

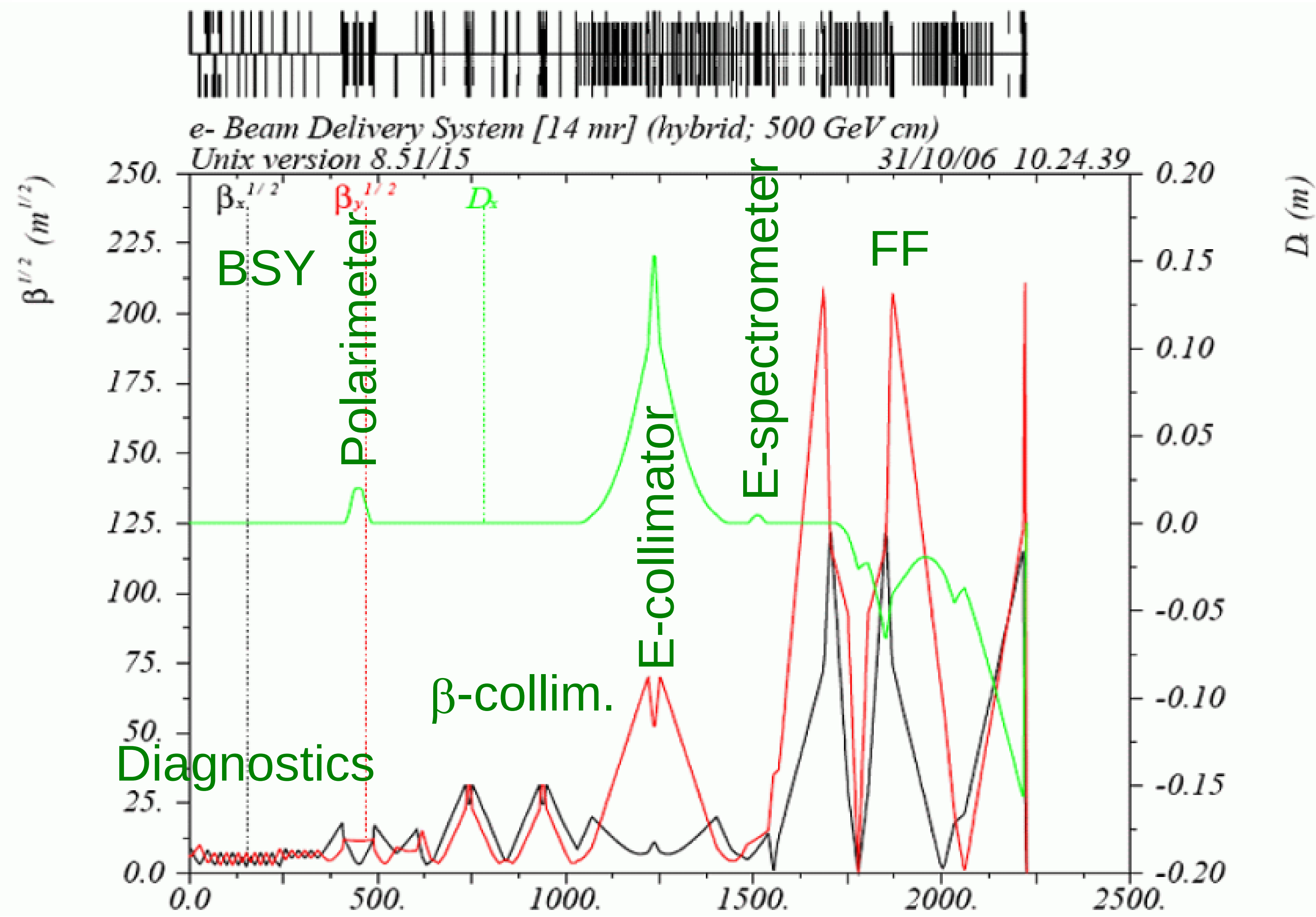
# CFS designs for earlier versions



Vancouver

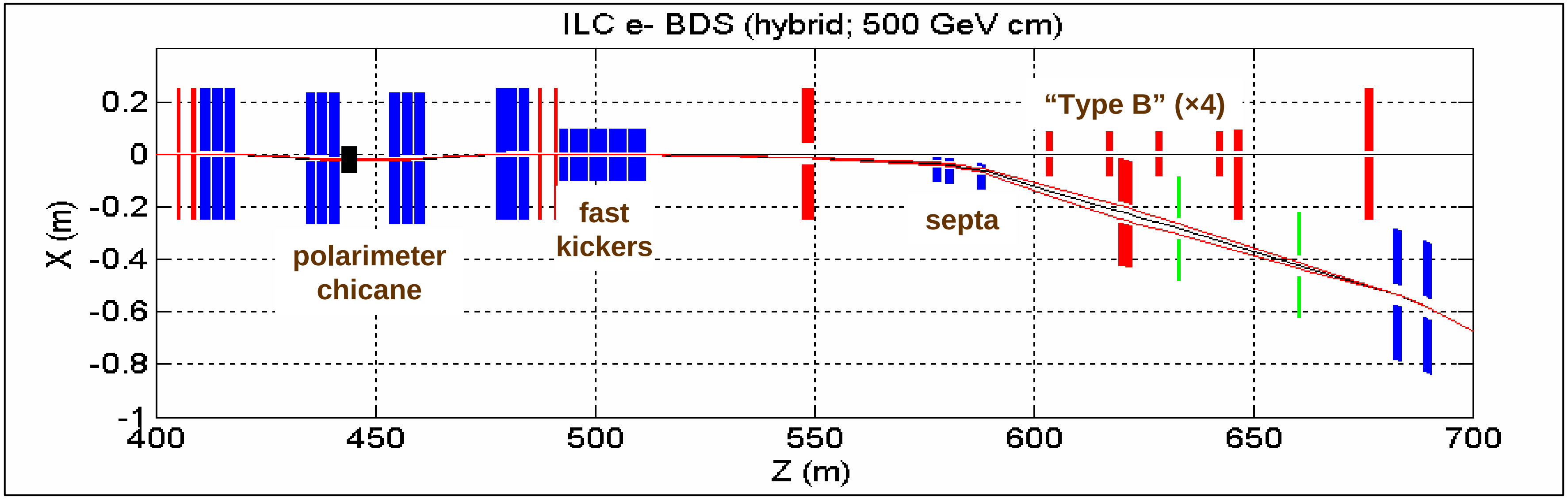
Valencia

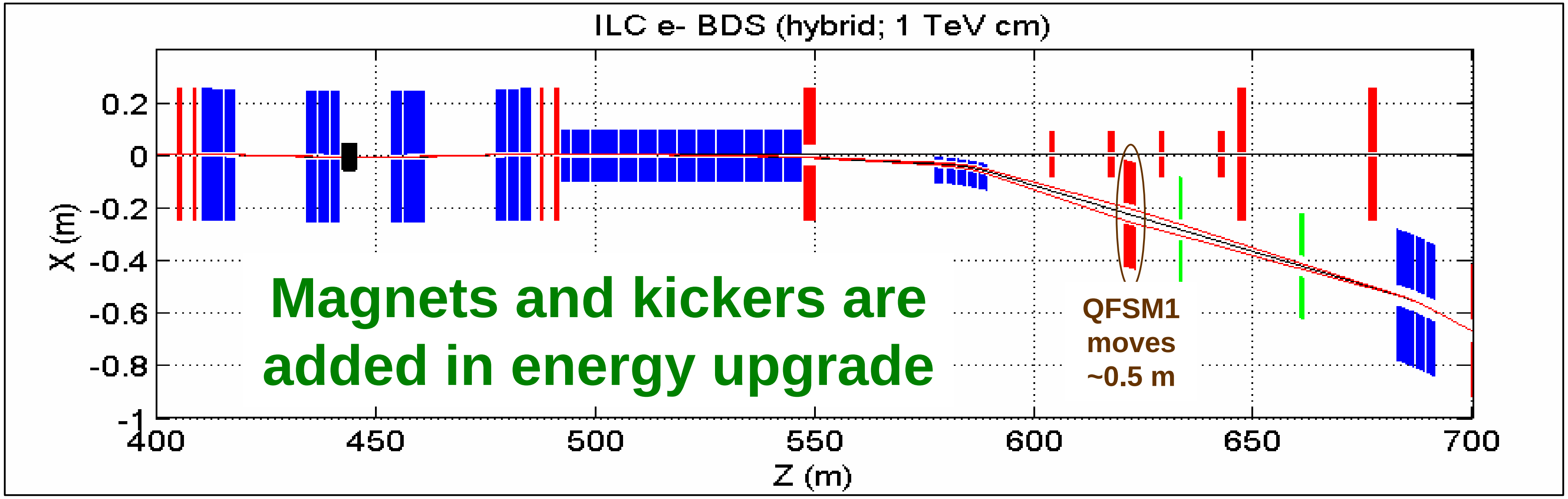
# BDS optics for incoming beam



# 500GeV => 1TeV CM upgrade

## example for BSY

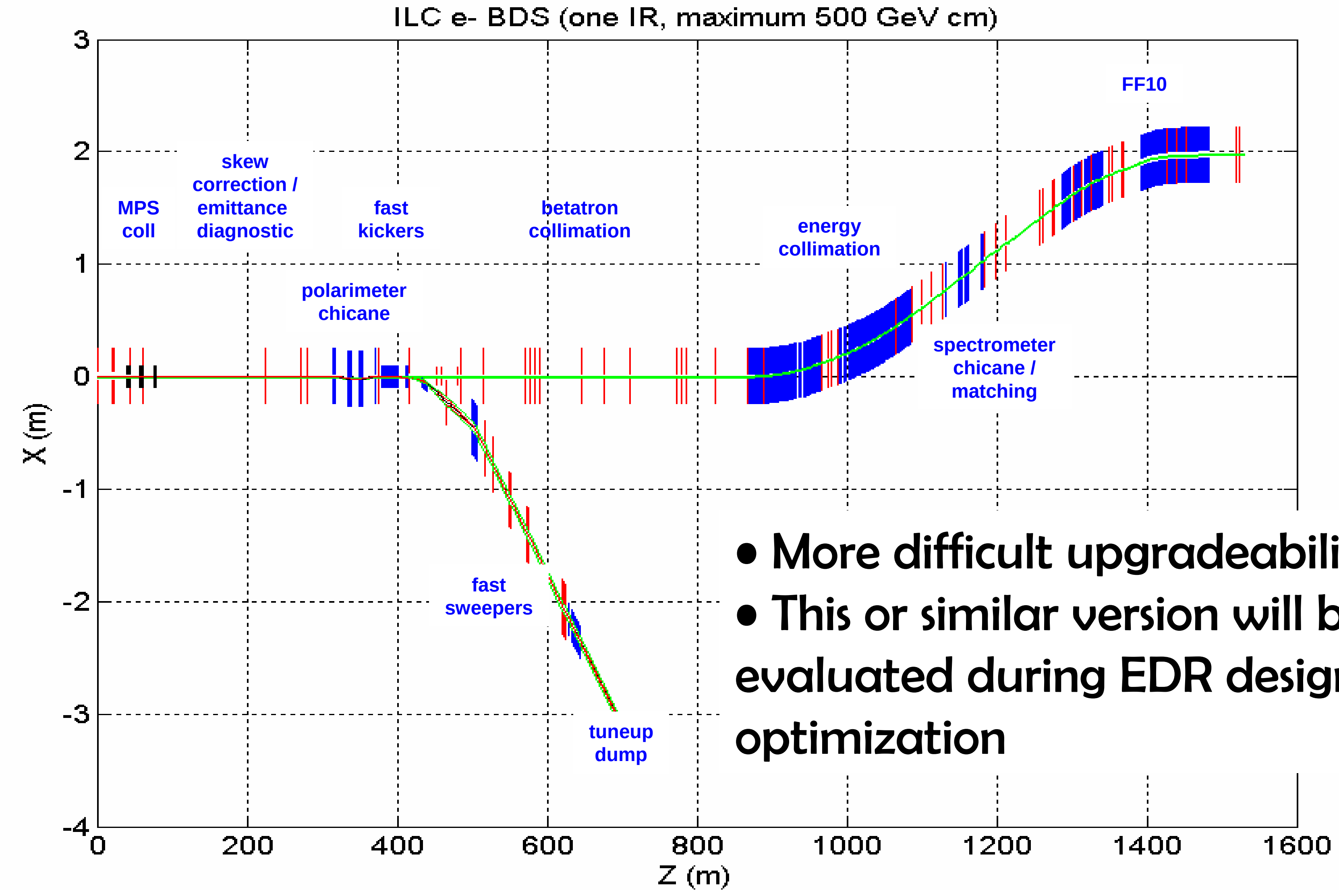




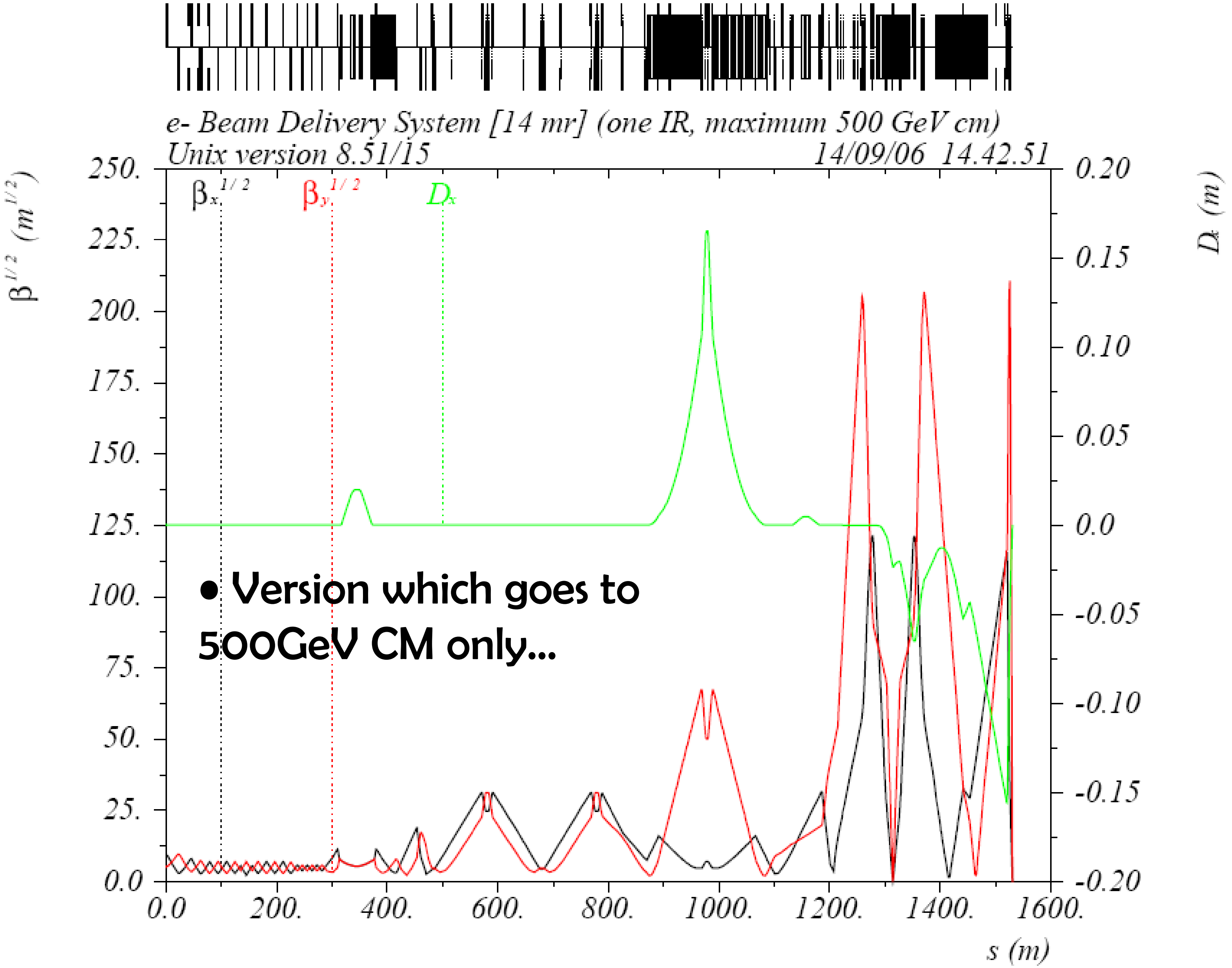
**Magnets and kickers are added in energy upgrade**

QFSM1 moves ~0.5 m

# Version which goes to 500GeV CM only

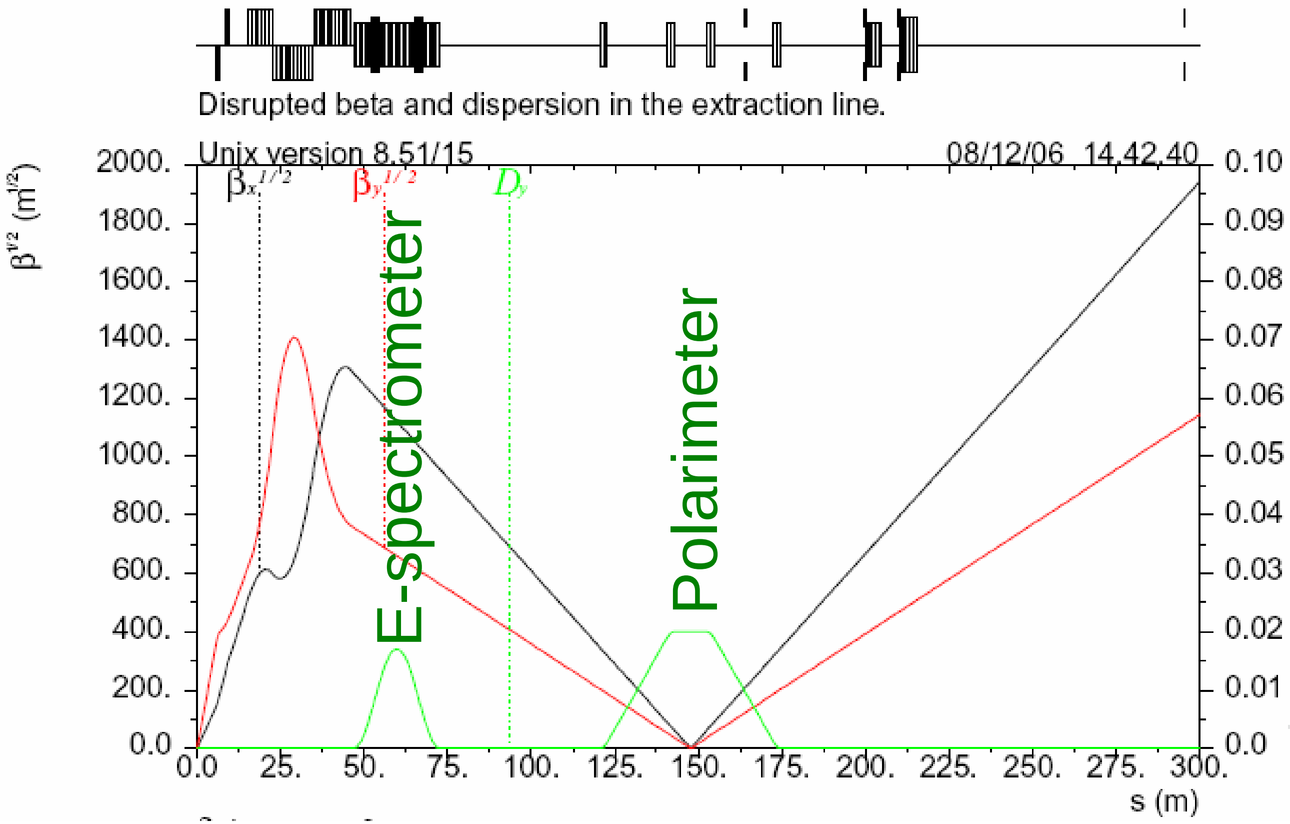


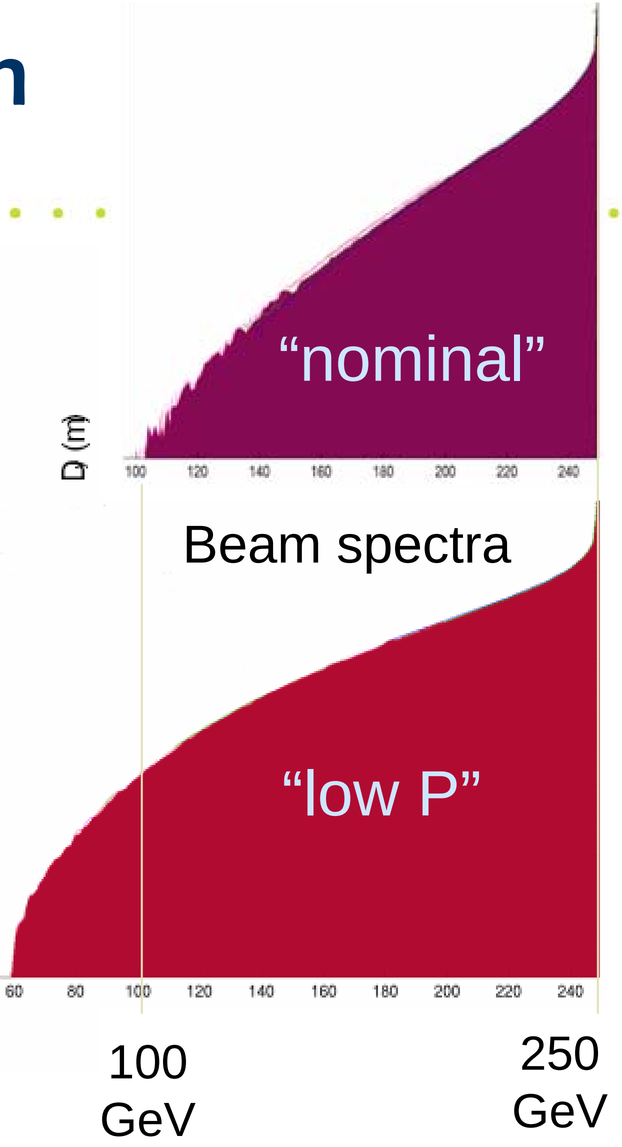
- More difficult upgradeability
- This or similar version will be evaluated during EDR design optimization



- Version which goes to 500GeV CM only...

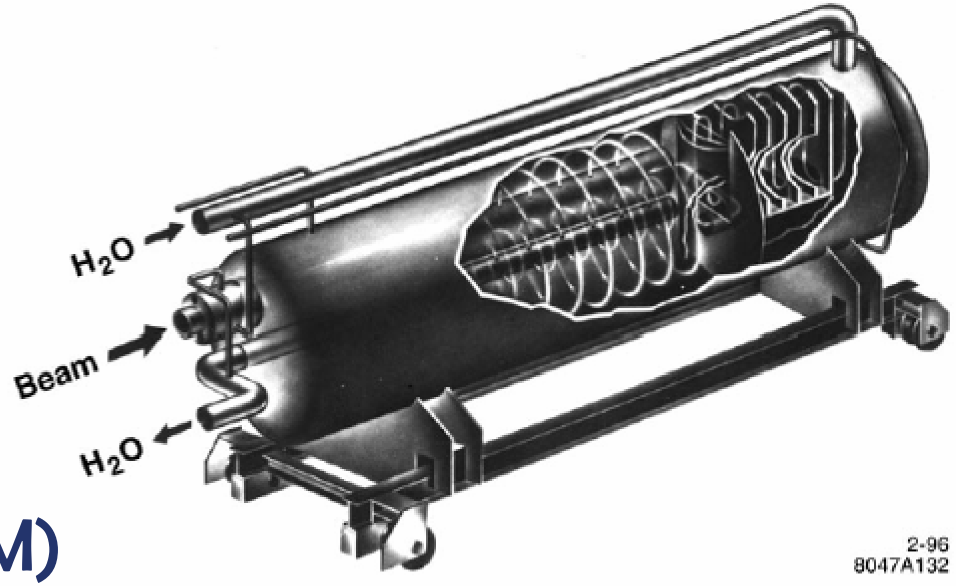
# Optics for outgoing beam





Extraction optics can handle the beam with ~60% energy spread, and provides energy and polarization diagnostics

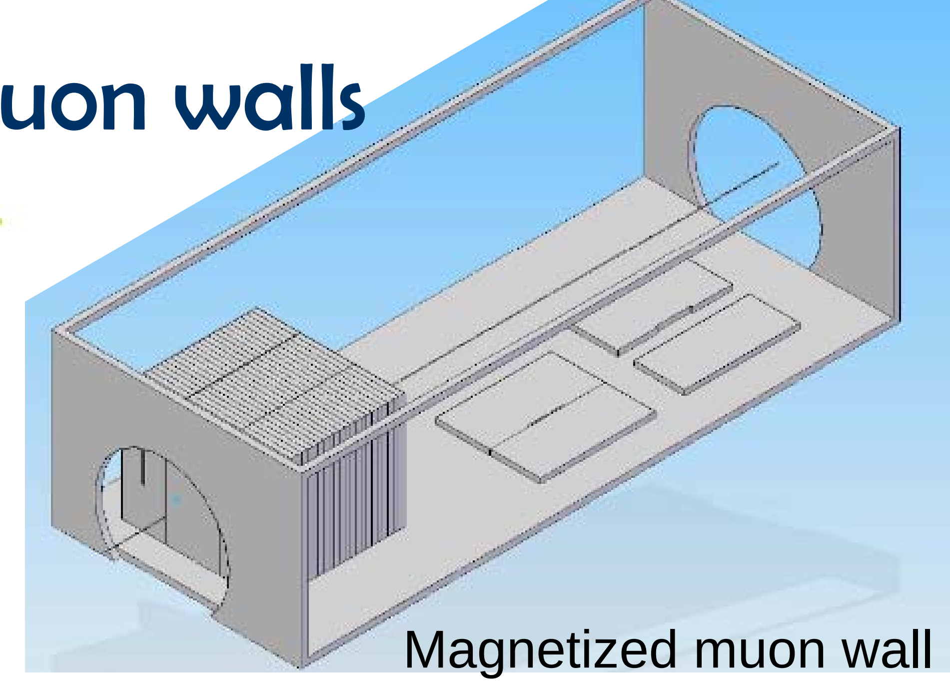
# Beam dump



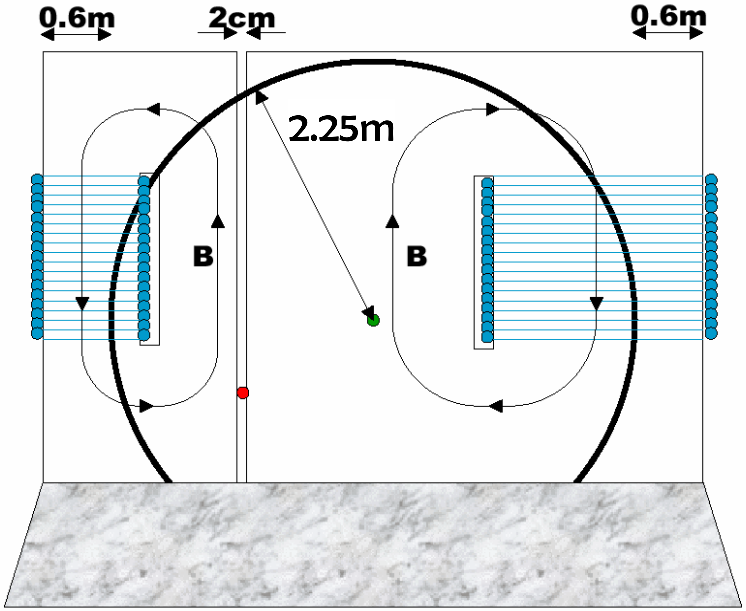
- 17MW power (for 1TeV CM)
- Rastering of the beam on 30cm double window
- 6.5m water vessel; ~1m/s flow
- 10atm pressure to prevent boiling
- Three loop water system
- Catalytic $H_2$-$O_2$ recombiner
- Filters for 7Be
- Shielding 0.5m Fe & 1.5m concrete

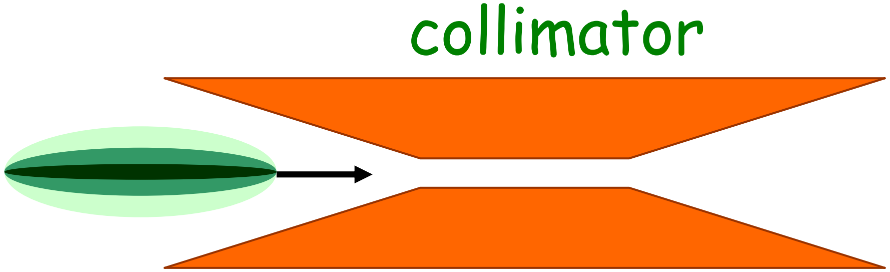
# Collimators & muon walls

- Collimators: spoiler-absorber pairs
- In Final Doublet & IP phase
- Spoilers can survive direct hit of two bunches
- Can collimate 0.1% of the beam
- Muons are produced during collimation
- Muon walls reduce muon background in the detectors

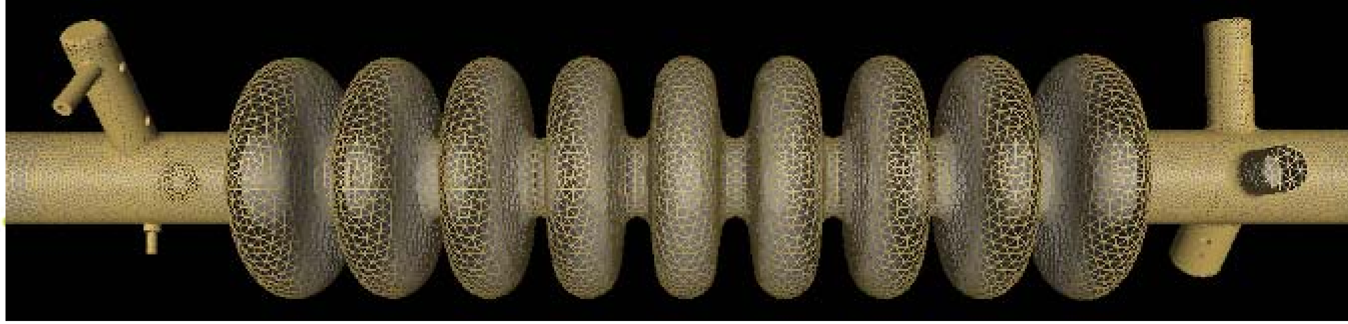


Magnetized muon wall





# Crab cavity design



FNAL 3.9GHz 9-cell cavity in Opega3p. *K.Ko, et al*

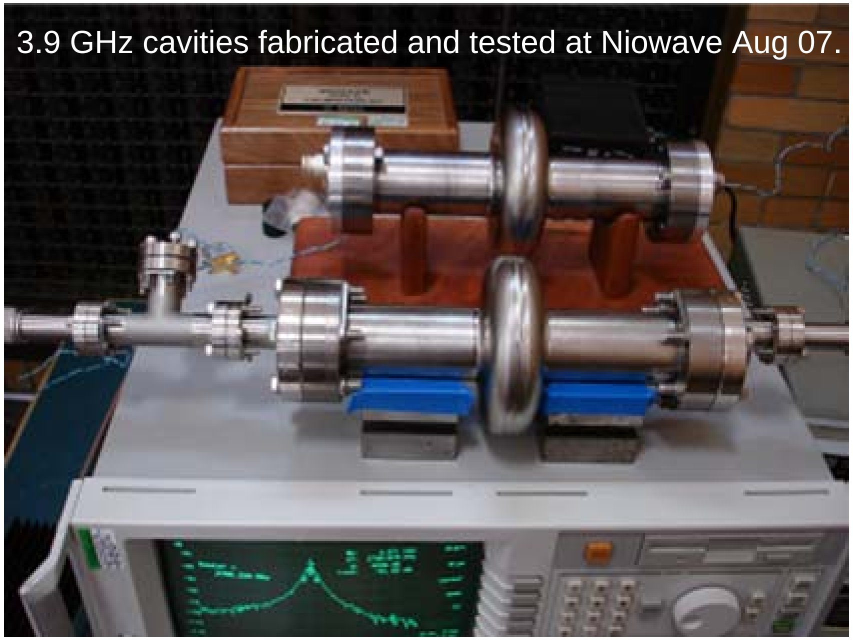
old / new
HOM coupler
Z.Li et al

3.9GHz cavity achieved 7.5 MV/m (FNAL)

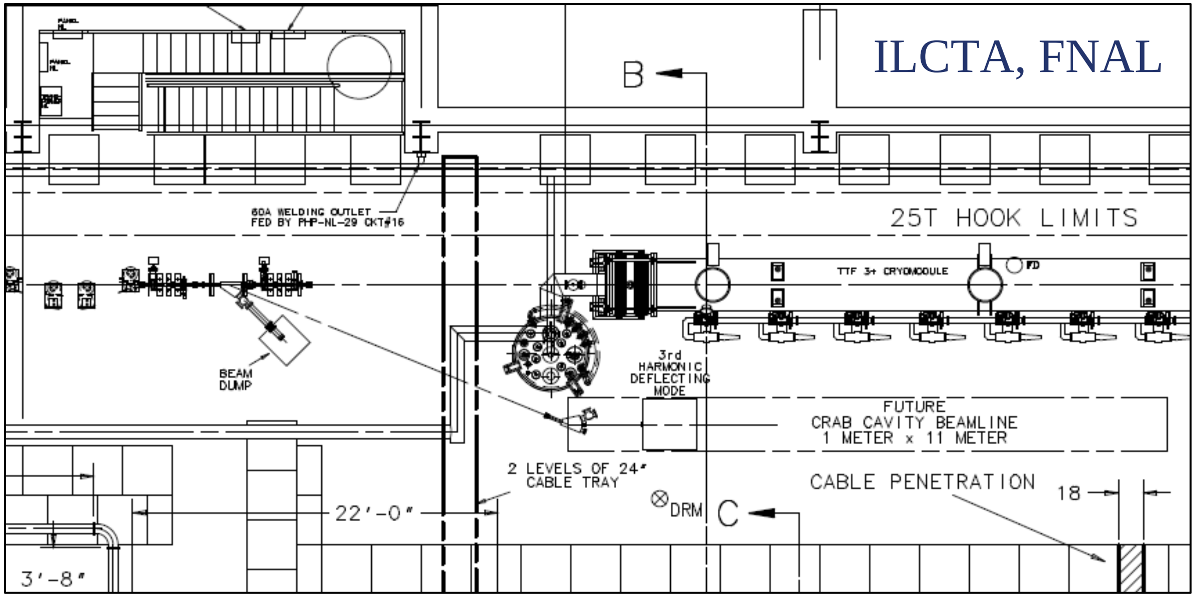
- Based on FNAL design of 3.9GHz CKM deflecting cavity
- Initial design been optimized now to match ILC requirements on damping of parasitic modes, and to improve manufacturability
- Design & prototypes been done by UK-FNAL-SLAC collaboration

# Crab cavity tests & prototypes

- LLRF phase and synchronization stability required: ~67fsec or 0.09° for <2% luminosity loss
- Scheduled to test system with 2 x single-cell SRF 3.9 GHz cavities in beginning of 2008
- Then – multi cell cavity and eventually two cavities to be tested at ILCTA



3.9 GHz cavities fabricated and tested at Niowave Aug 07.

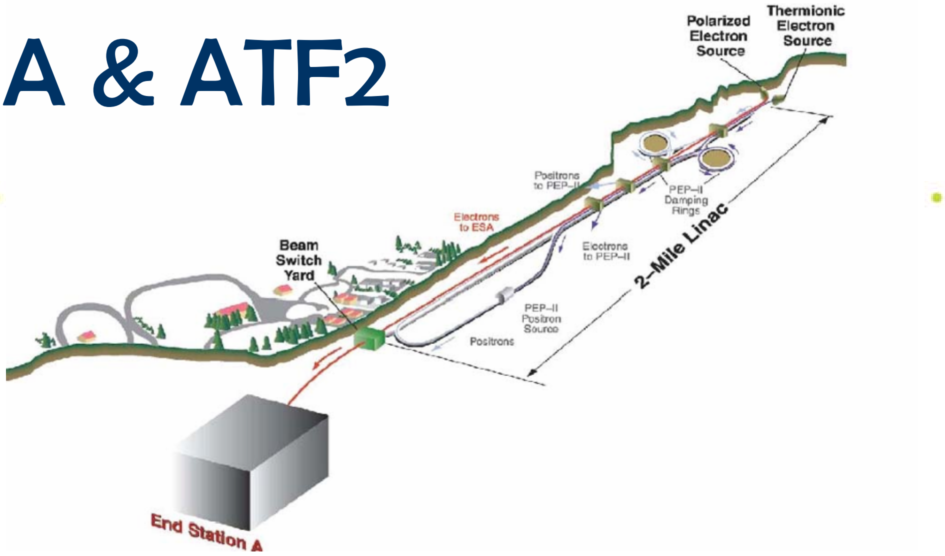


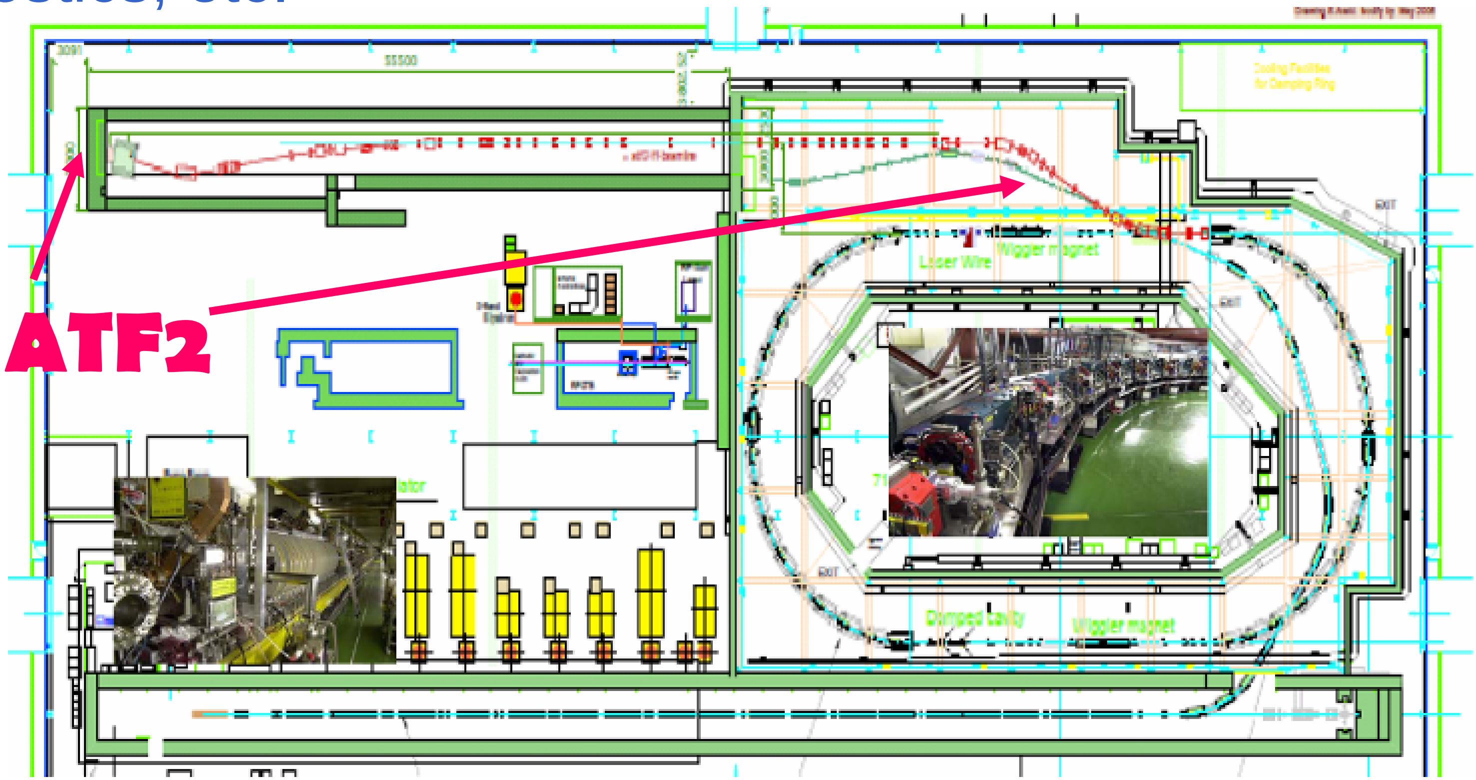
ILCTA, FNAL

# Test facilities: ESA & ATF2

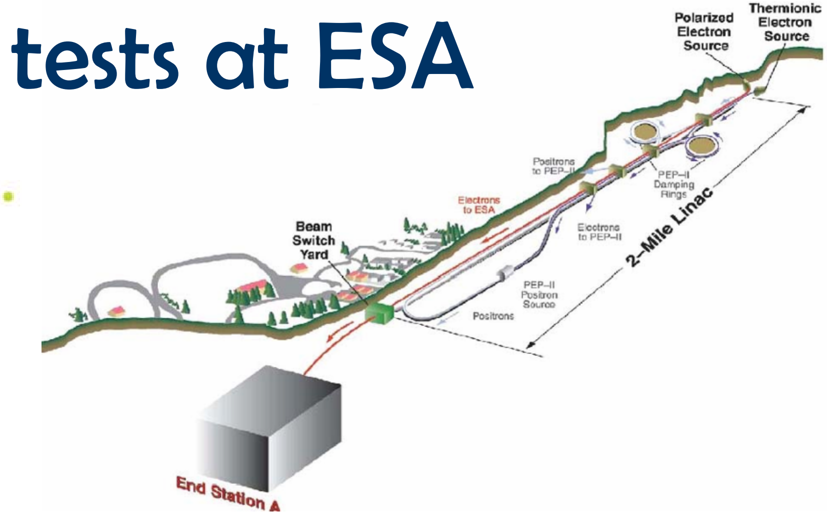
ESA: machine-detector tests; energy spectrometer; collimator wake-fields, etc.

ATF2: prototype FF, develop tuning, diagnostics, etc.





# BDS beam tests at ESA



Study:

BPM energy spectrometer

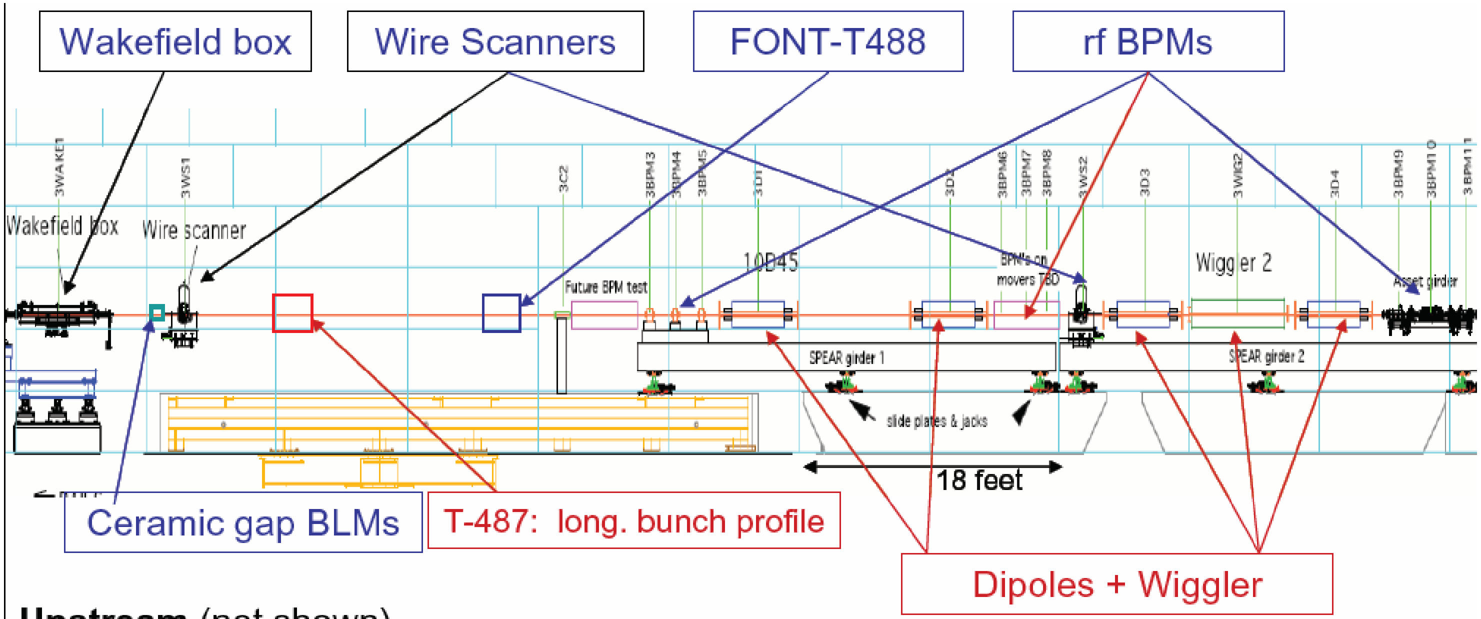
Synch Stripe energy spectrometer

Collimator design, wakefields

IP BPMs/kickers—background studies

EMI (electro-magnetic interference)

Bunch length diagnostics



Wakefield box

Wire Scanners

FONT-T488

rf BPMs

Ceramic gap BLMs

T-487: long. bunch profile

Dipoles + Wiggler

**Upstream** (not shown)

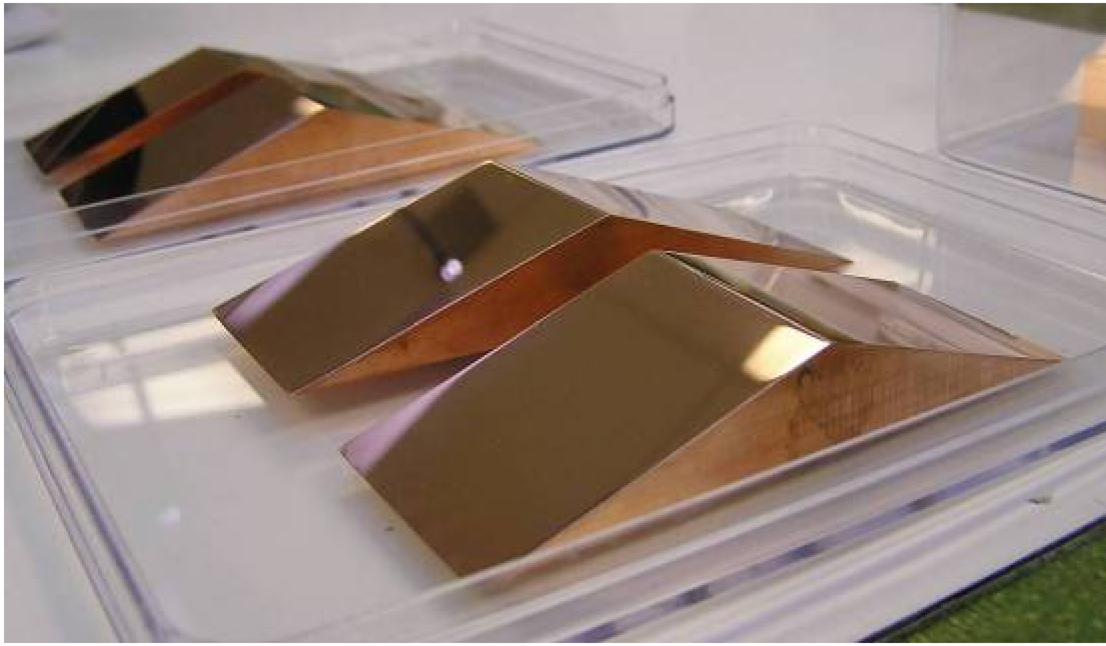
4 rf BPMs for incoming trajectory
Ceramic gap w/ rf diode detectors (16GHz, 23GHz, and 100GHz) and 2 EMI antennas

**Downstream** (not shown)

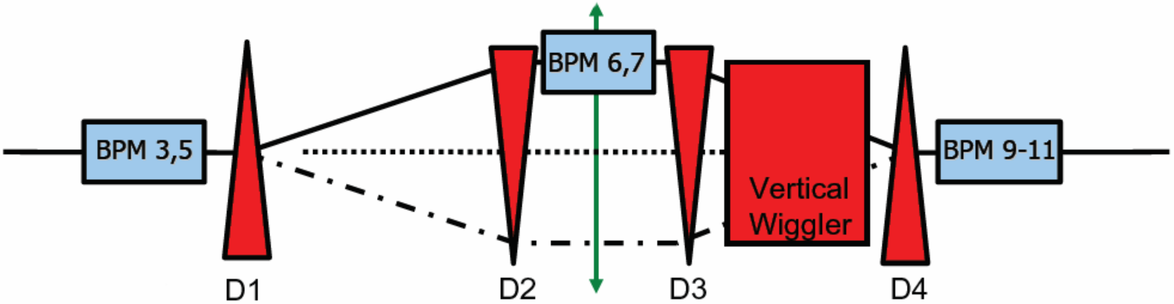
Ceramic gap for EMI studies
T475 Detector for Wiggler SR stripe

# Collimator Wakefield study at ESA

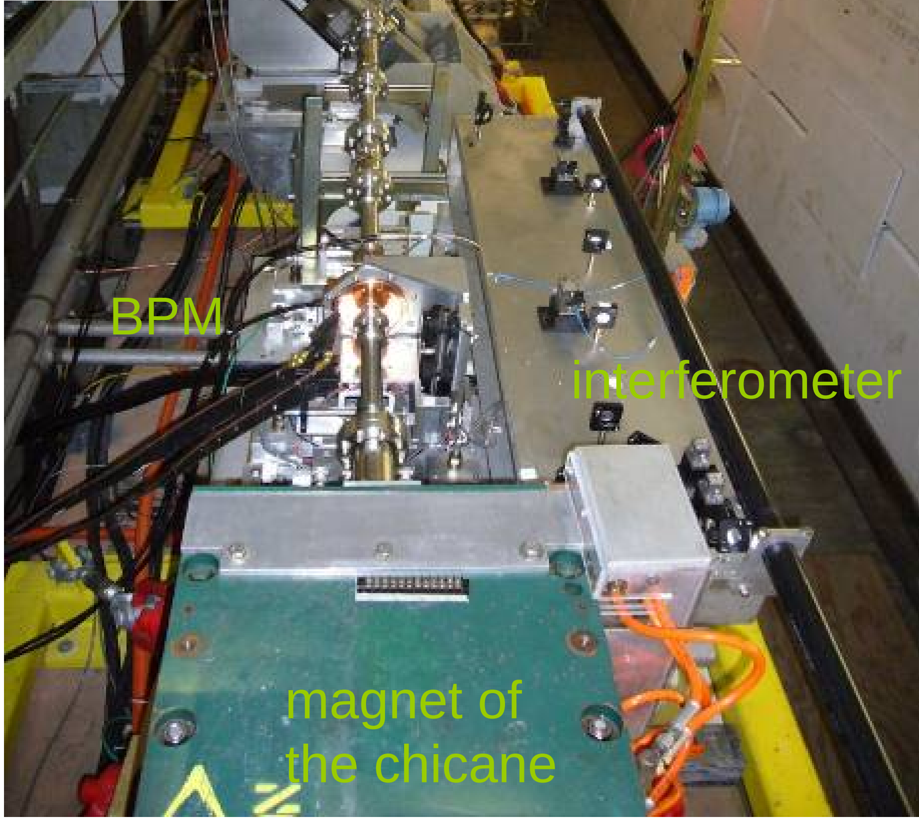
- Spoilers of different shape investigated at ESA (N.Watson et al)
- Theory, 3d modeling and measurements are so far within a factor of ~2 agreement



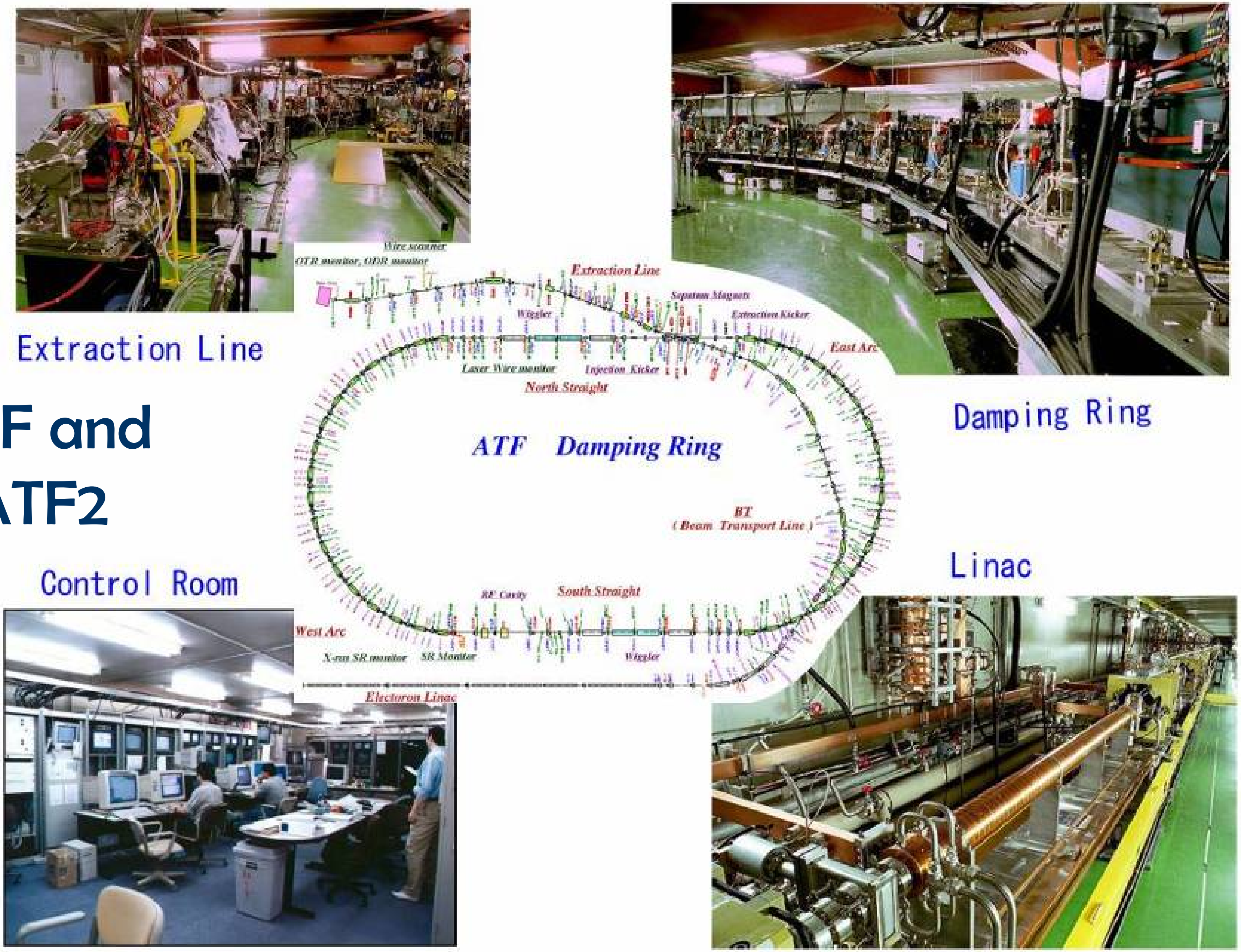
# Energy spectrometer at ESA



- BPM & SR based
- Interferometer grid for BPMs
- NMR probes in magnets
- 0.5um BPMs with $\eta$=5mm => 1e-4 energy resolution
- Study calibrations, systematics, stability



# ATF and ATF2

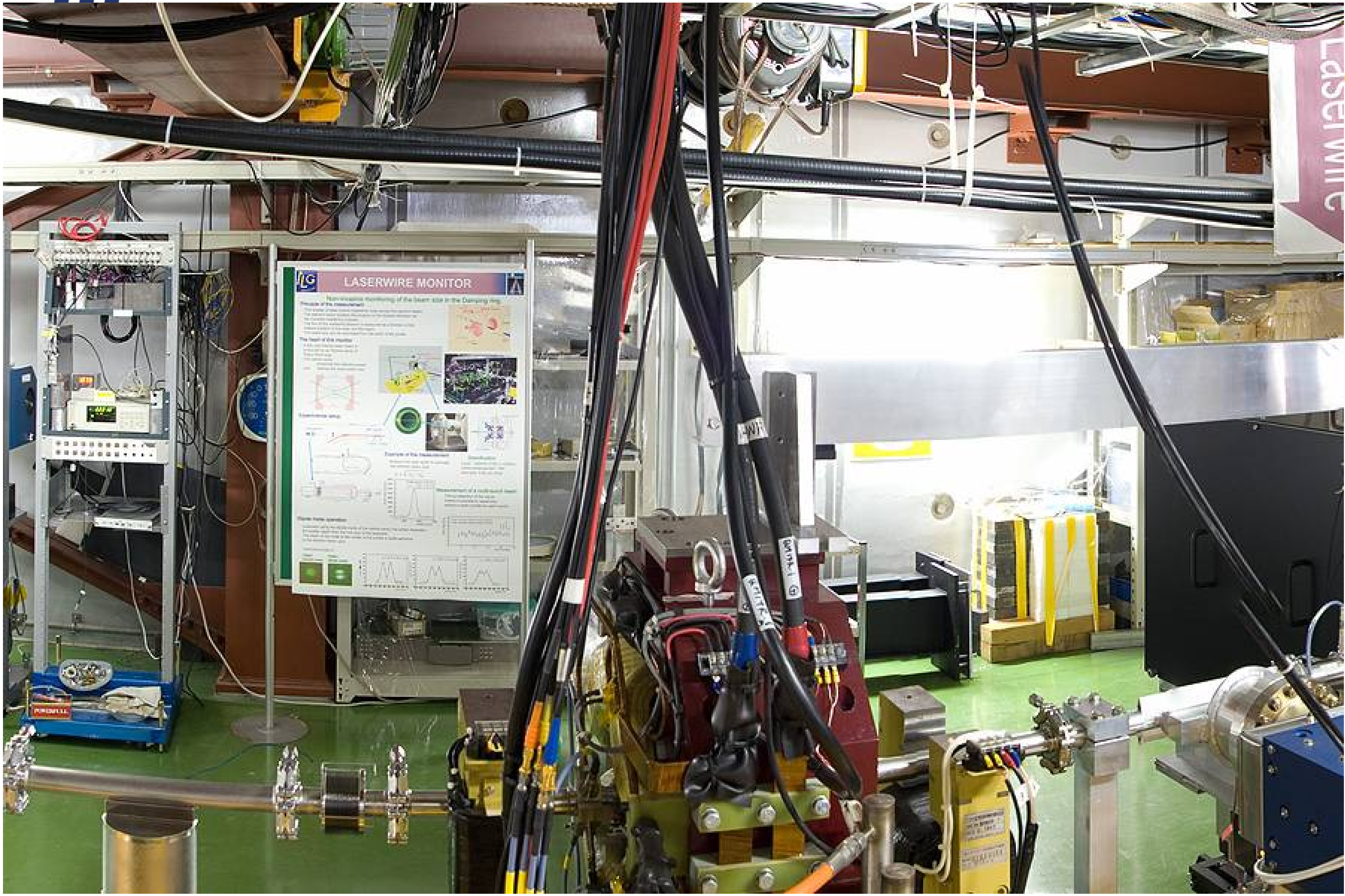


Extraction Line

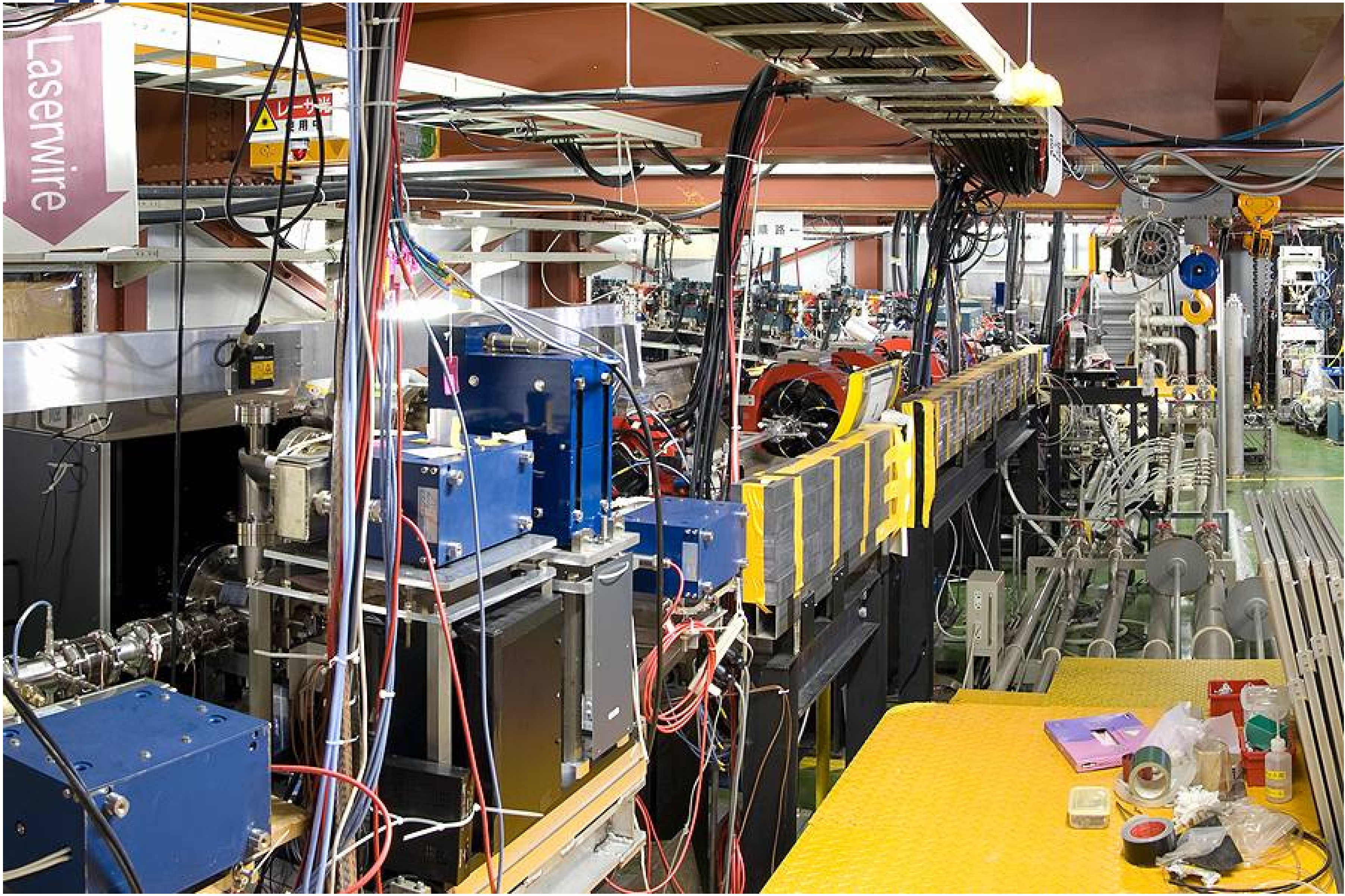
Damping Ring

Control Room

Linac



Panoramic photo of ATF beamlines, N.Toge



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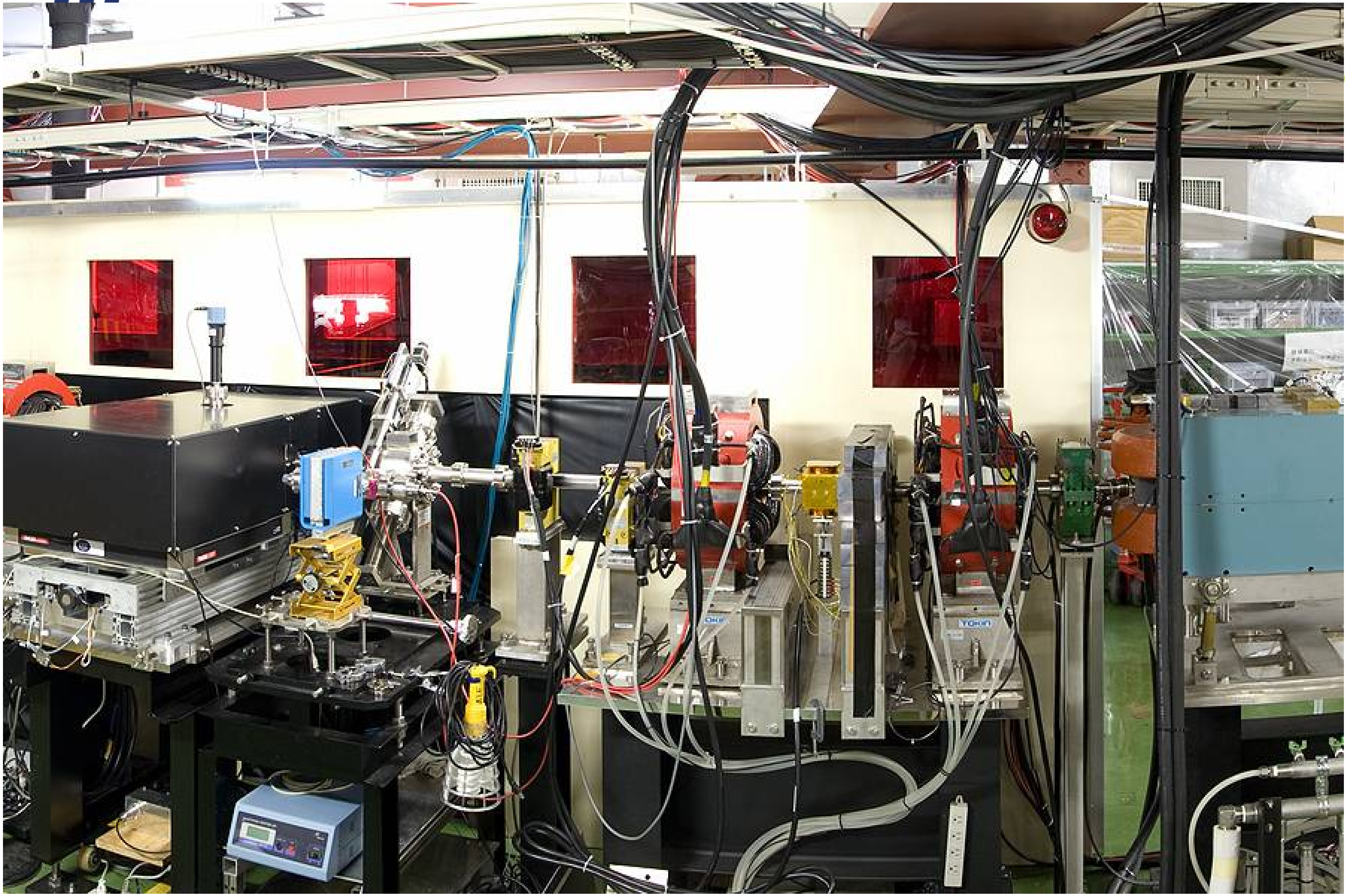

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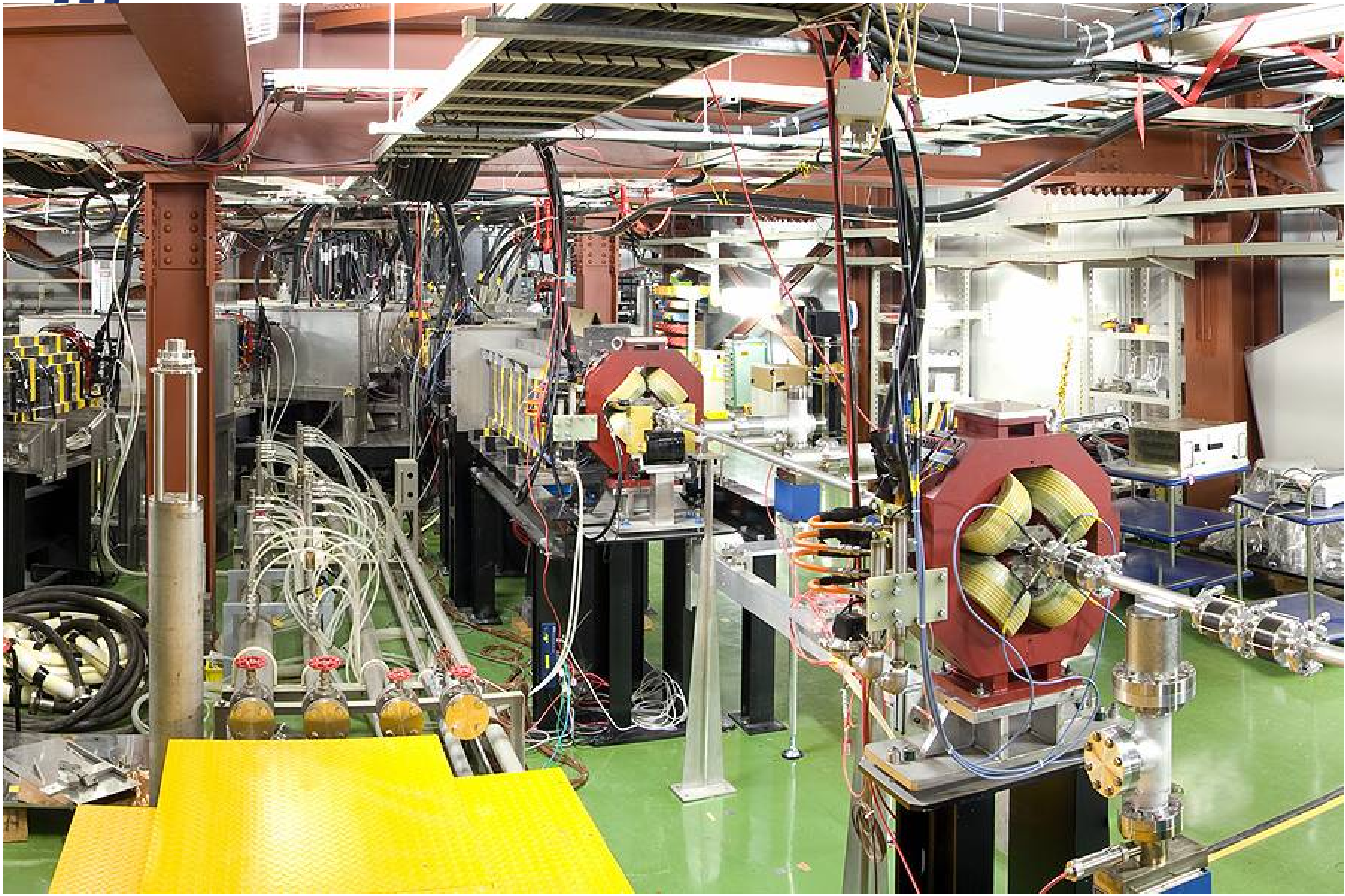
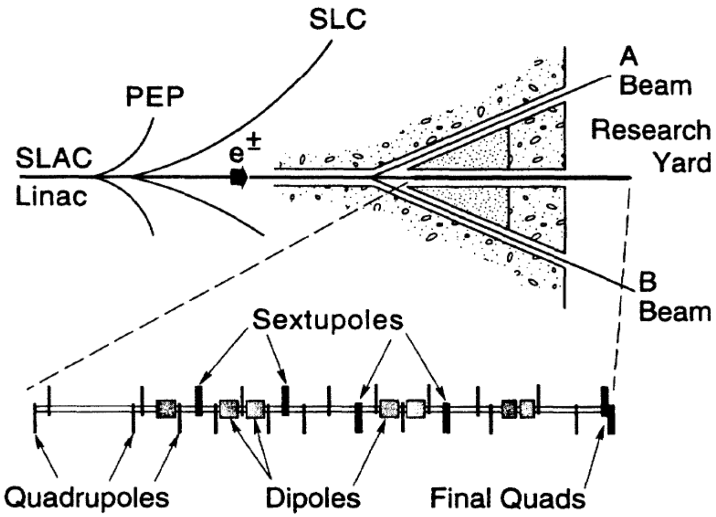
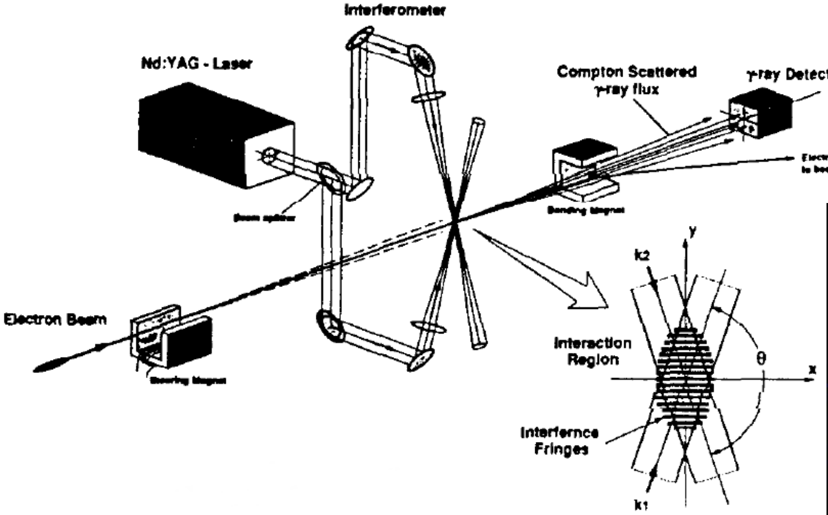
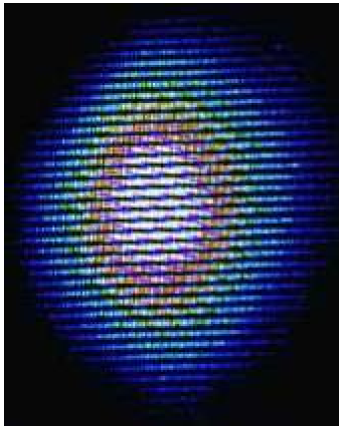


Panoramic photo of ATF beamlines, N.Toge

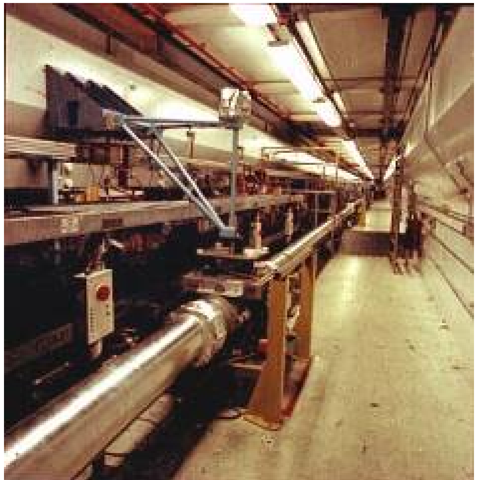
# Final Focus Test Beam

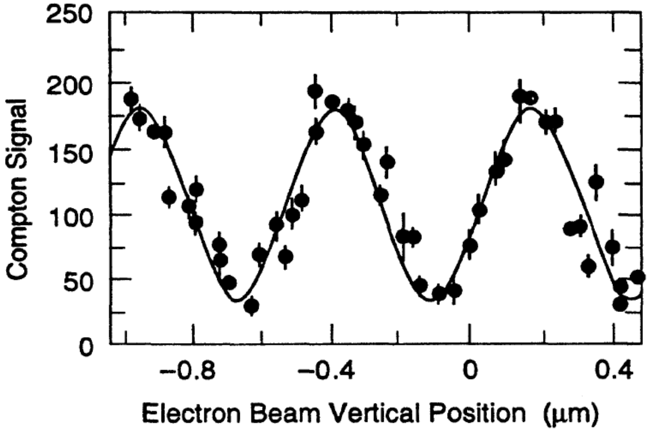




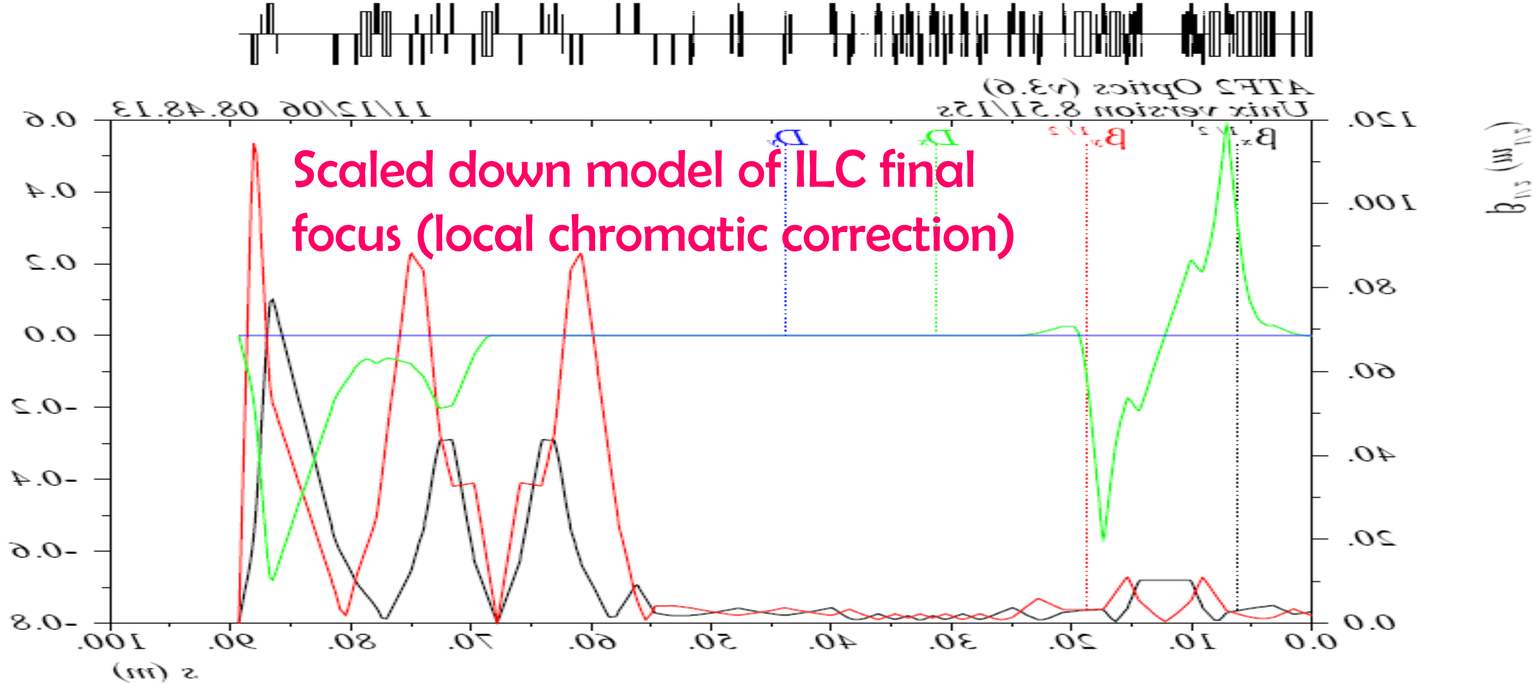


Achieved ~70nm vertical beam size

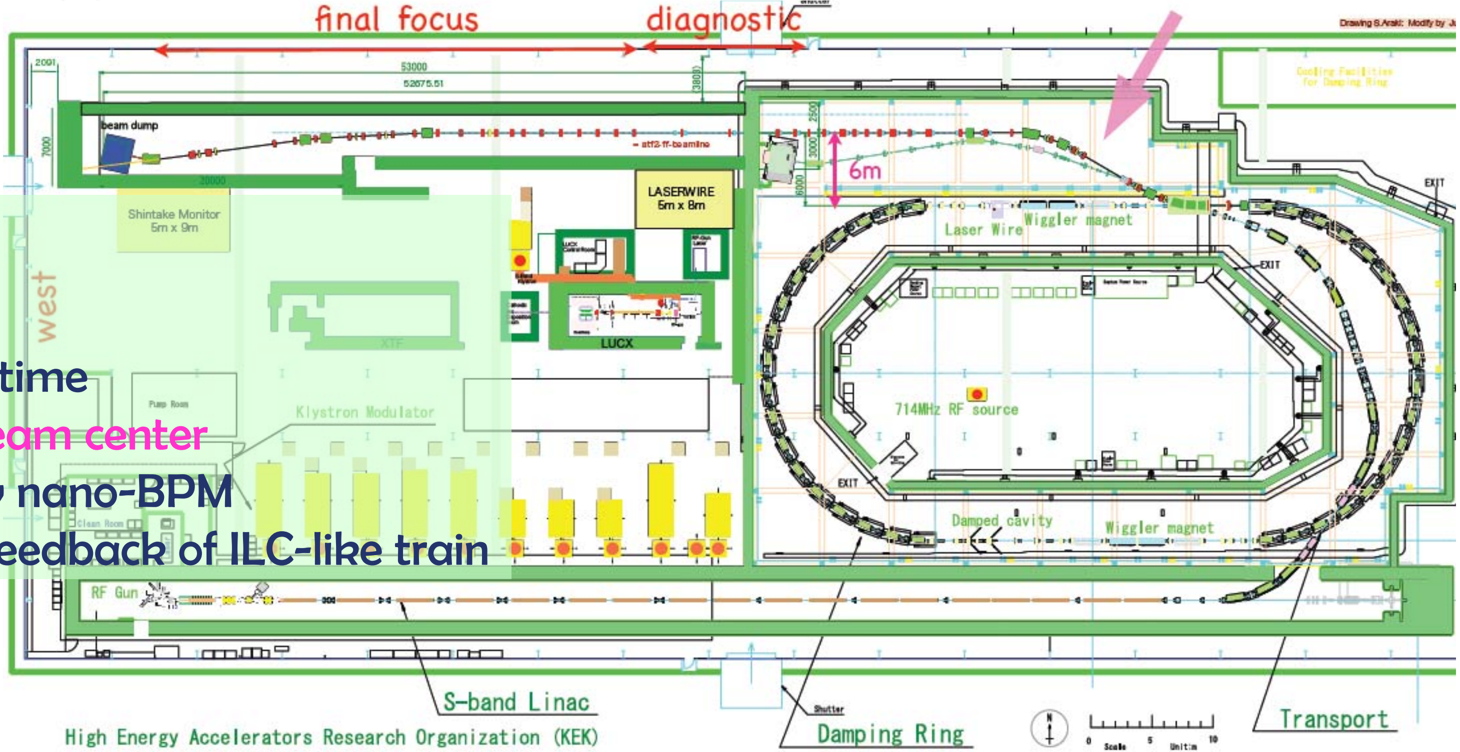




# ATF2 – model of ILC BDS



Scaled down model of ILC final focus (local chromatic correction)



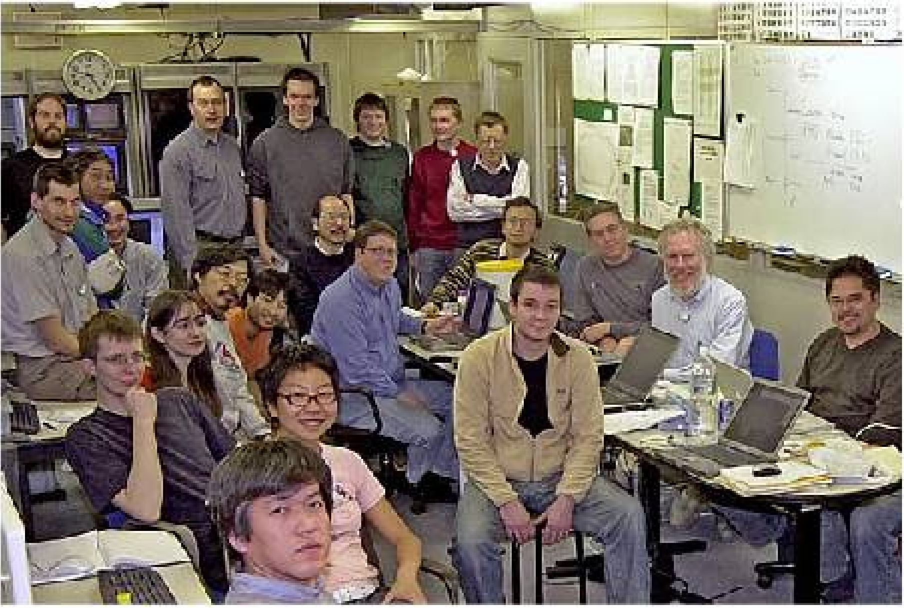
**ATF2 goals**

(A) Small beam size
Obtain $\sigma_y \sim 35$nm
Maintain for long time

(B) Stabilization of beam center
Down to < 2nm by nano-BPM
Bunch-to-bunch feedback of ILC-like train

# ATF collaboration & ATF2 facility

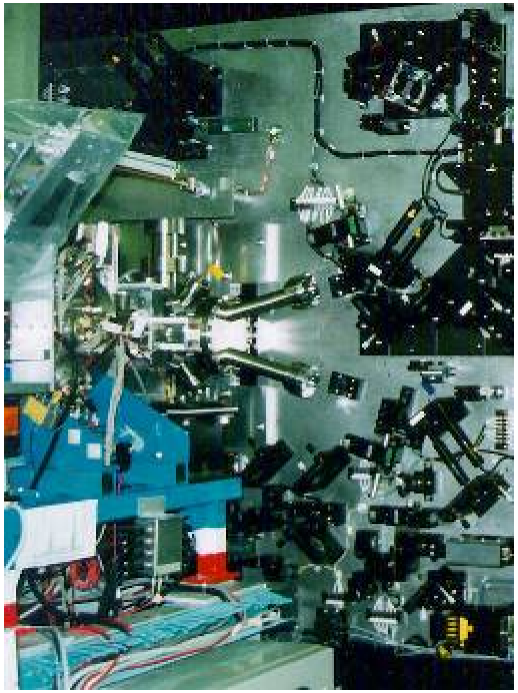
- ATF2 will prototype FF,
- help development tuning methods, instrumentation (laser wires, fast feedback, submicron resolution BPMs),
- help to learn achieving small size & stability reliably,
- potentially able to test stability of FD magnetic center.



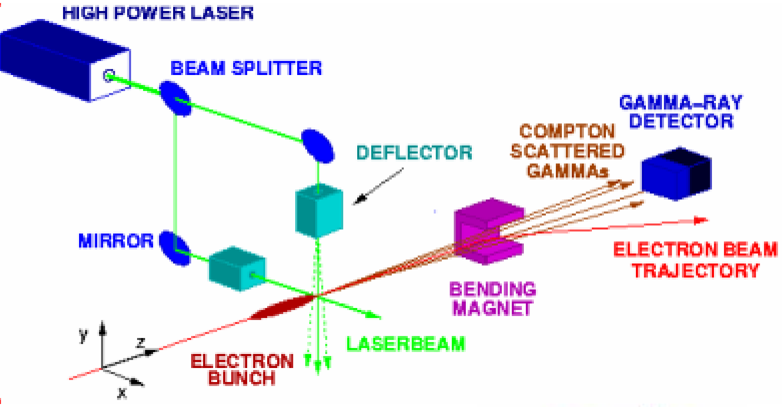
- ATF2 is one of central elements of BDS EDR work, as it will address a large fraction of BDS technical cost risk.
- Constructed as ILC model, with in-kind contribution from partners and host country providing civil construction
- ATF2 commissioning will start in Autumn of 2008

# Advanced beam instrumentation at ATF2

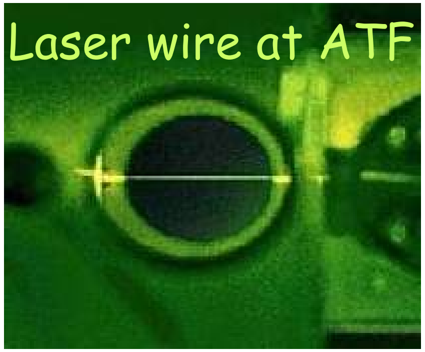
- BSM to confirm 35nm beam size
- nano-BPM at IP to see the nm stability
- Laser-wire to tune the beam
- Cavity BPMs to measure the orbit
- Movers, active stabilization, alignment system
- Intratrain feedback, Kickers to produce ILC-like train

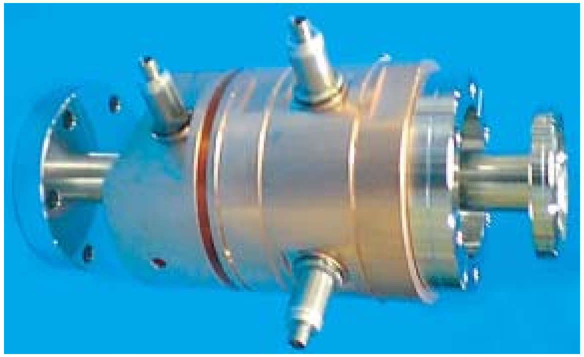


IP Beam-size monitor (BSM) (Tokyo U./KEK, SLAC, UK)

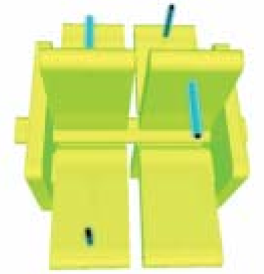


Laser-wire beam-size Monitor (UK group)





Cavity BPMs, for use with Q magnets with 100nm resolution (PAL, SLAC, KEK)



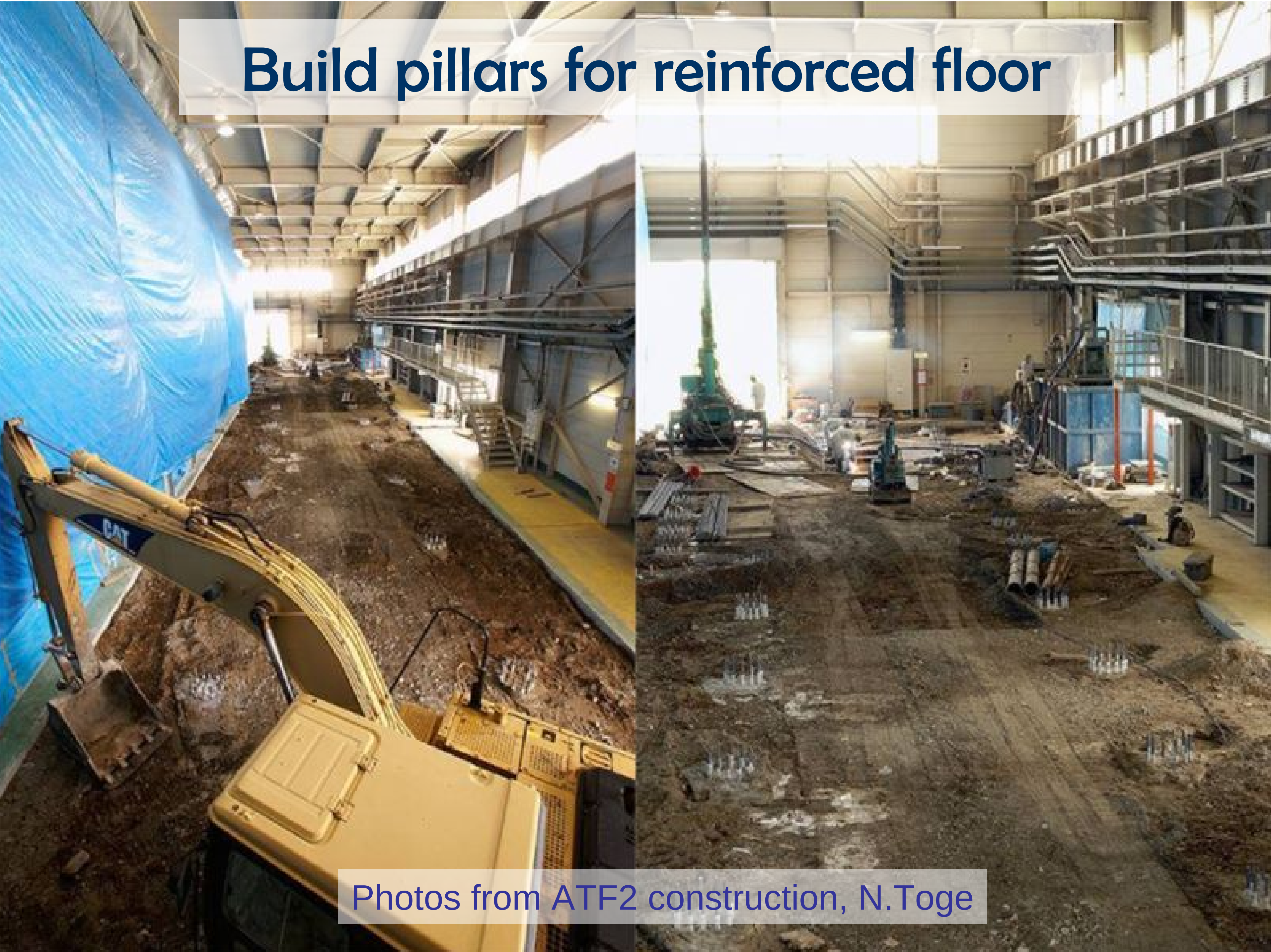
Cavity BPMs with 2nm resolution, for use at the IP (KEK)

# ATF hall before ATF2 construction

# ATF hall emptied

Photos from ATF2 construction, N.Toge

# Build pillars for reinforced floor

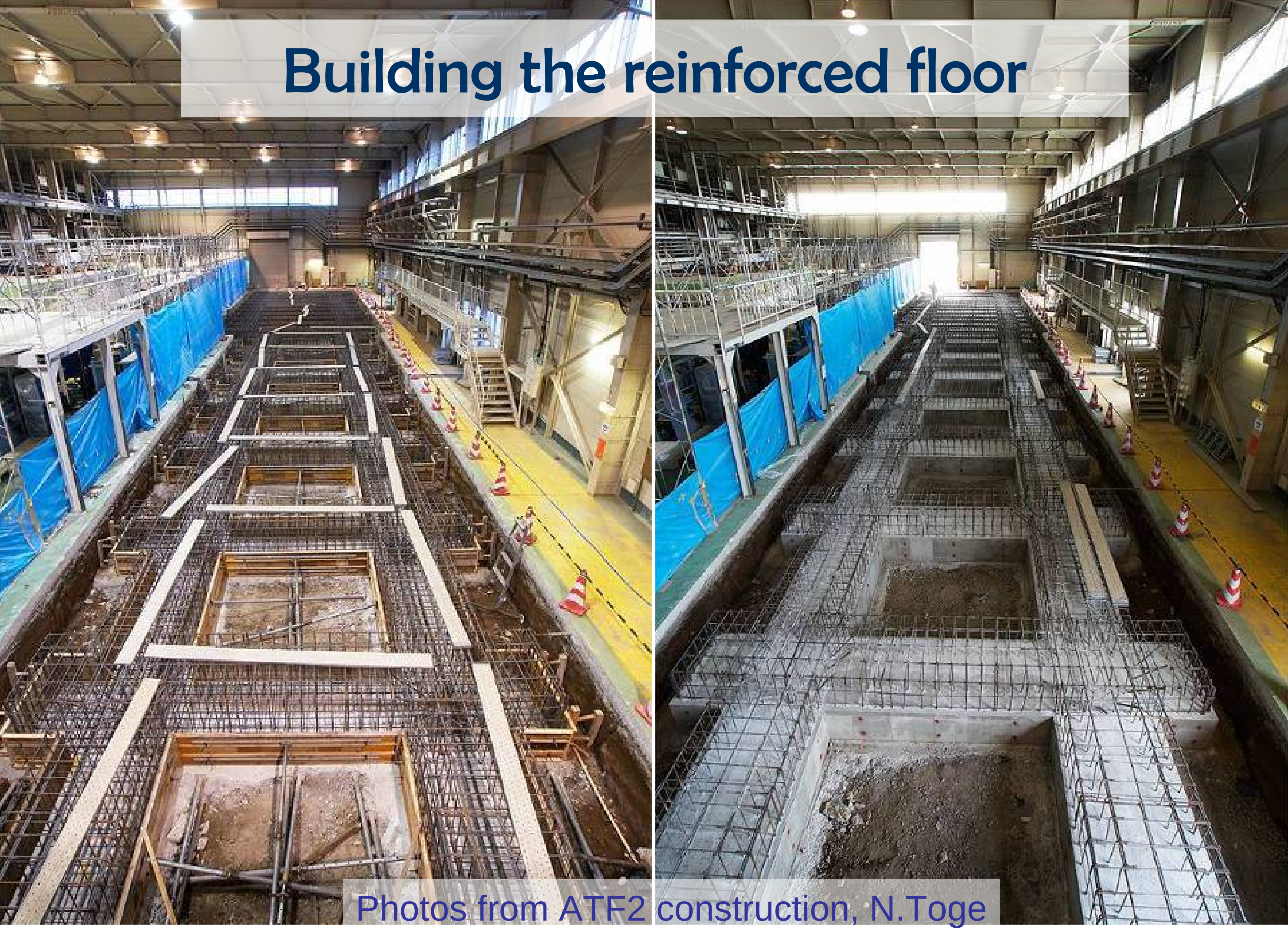


Photos from ATF2 construction, N.Toge

# Build pillars for reinforced floor

Photos from ATF2 construction, N.Toge

# Building the reinforced floor

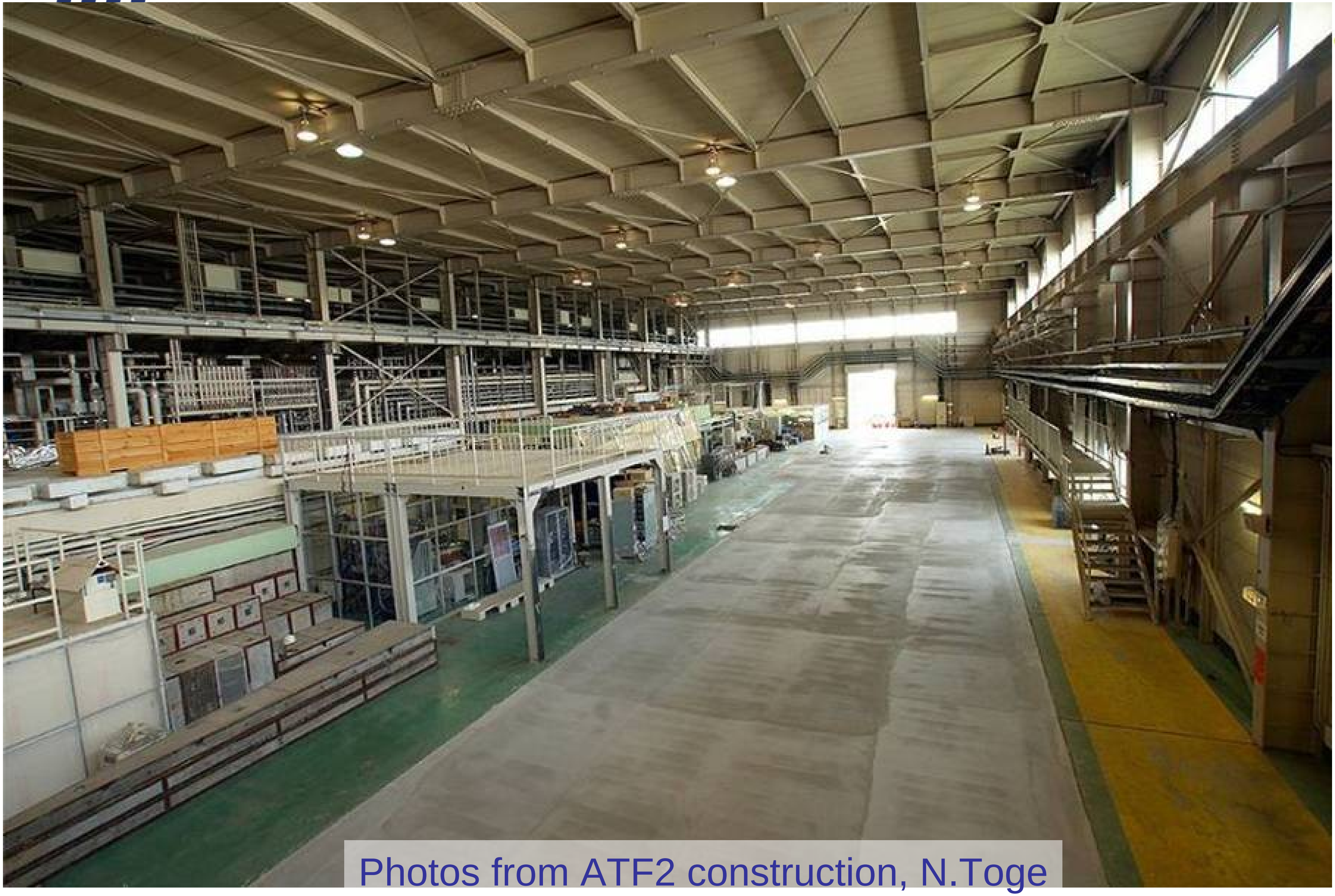


Photos from ATF2 construction, N.Toge

# Finishing the reinforced floor for ATF2

Photos from ATF2 construction, N.Toge

# Finished reinforced floor for ATF2



Photos from ATF2 construction, N.Toge

# Prepare ATF2 shielding construction

Photos from ATF2 construction, N.Toge

# Shielding construction at ATF2

Photos from ATF2 construction, N.Toge

# Shielding construction at ATF2

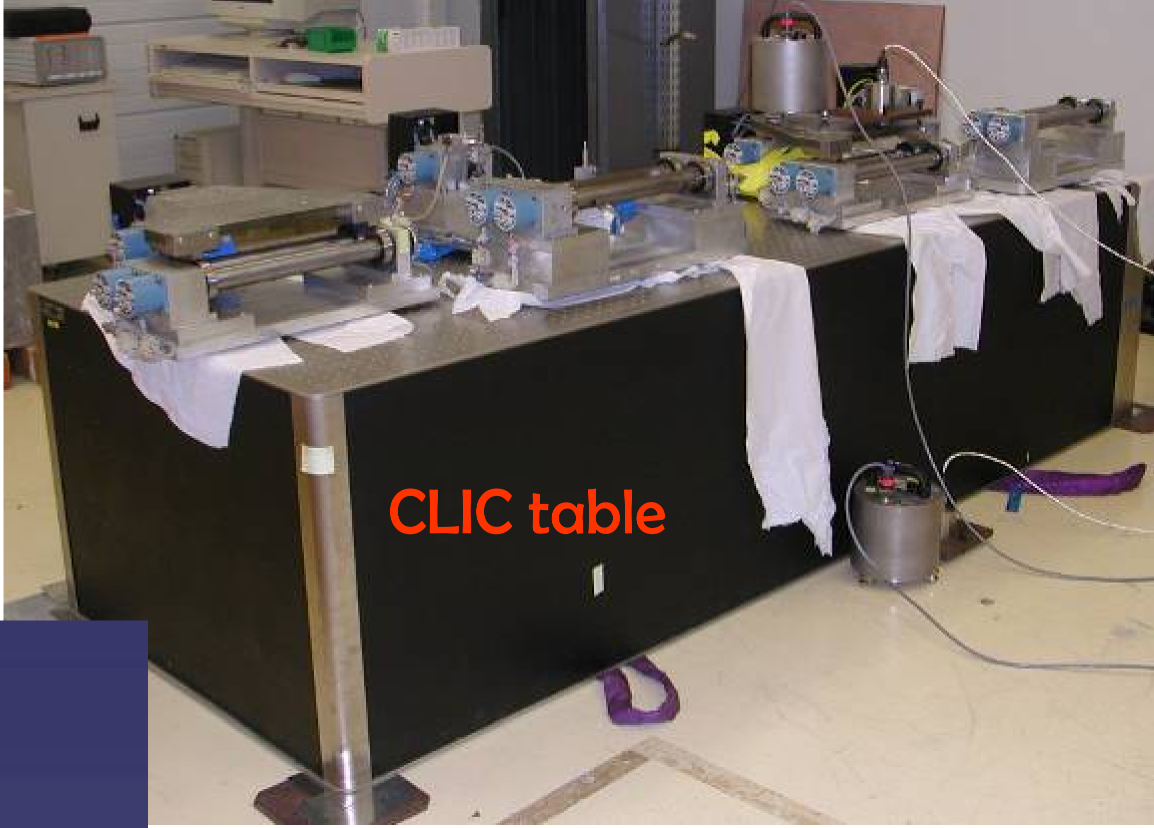
Magnets for ATF2 beamline installed

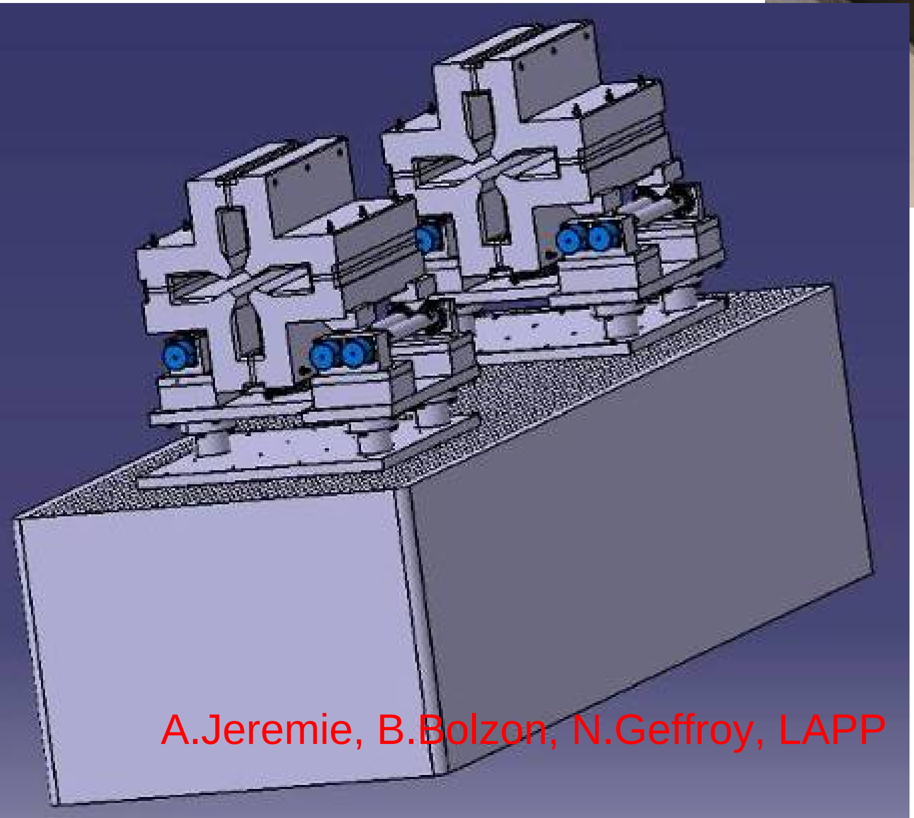
Photos from ATF2 construction, N.Toge

# Shielding construction at ATF2

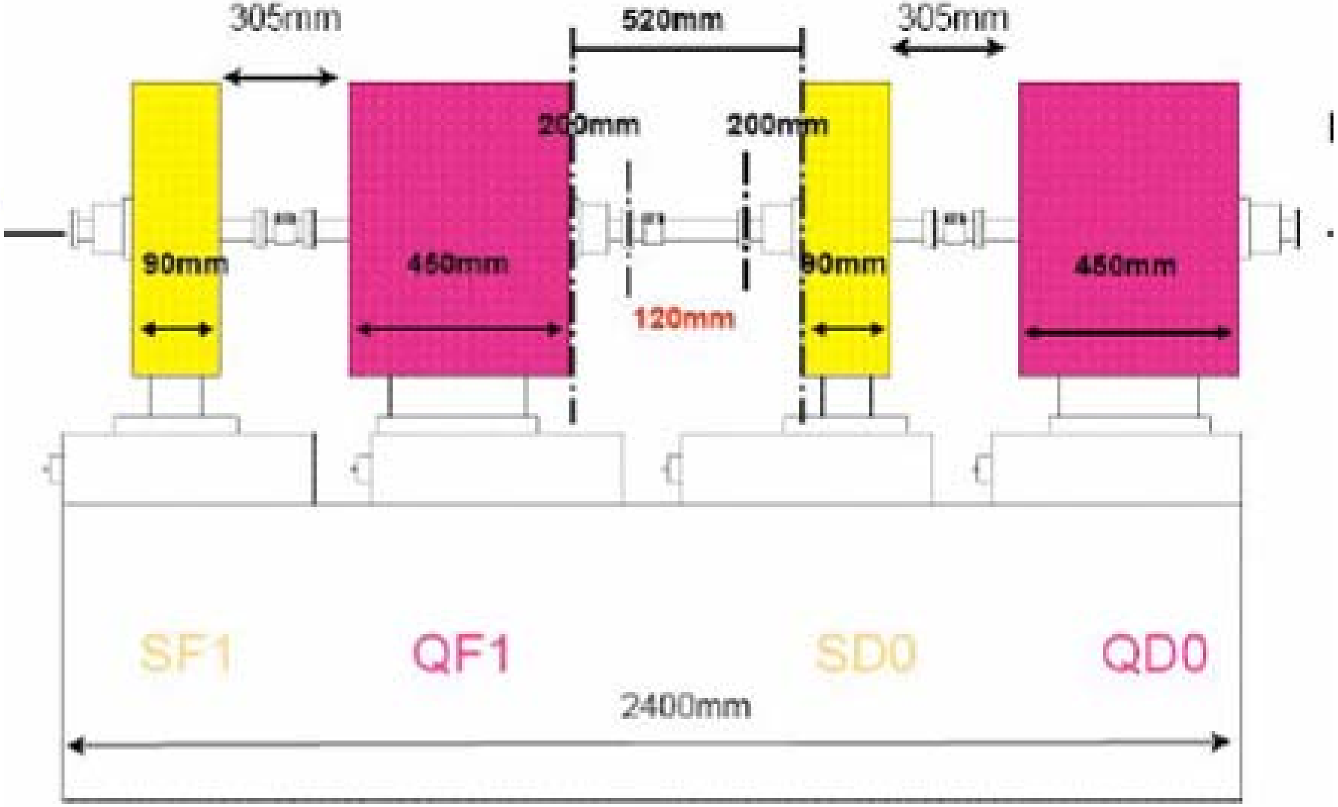
Photos from ATF2 construction, N.Toge

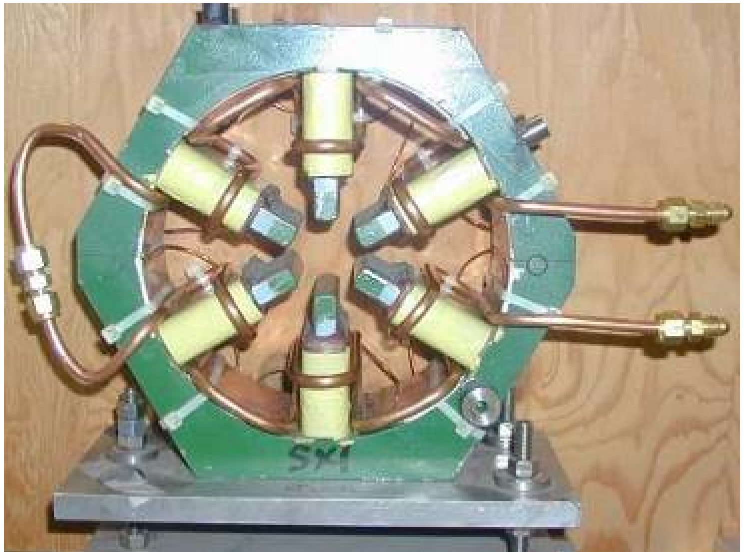
# Integration of FD in Annecy




A.Jeremie, B.Bolzon, N.Geffroy, LAPP

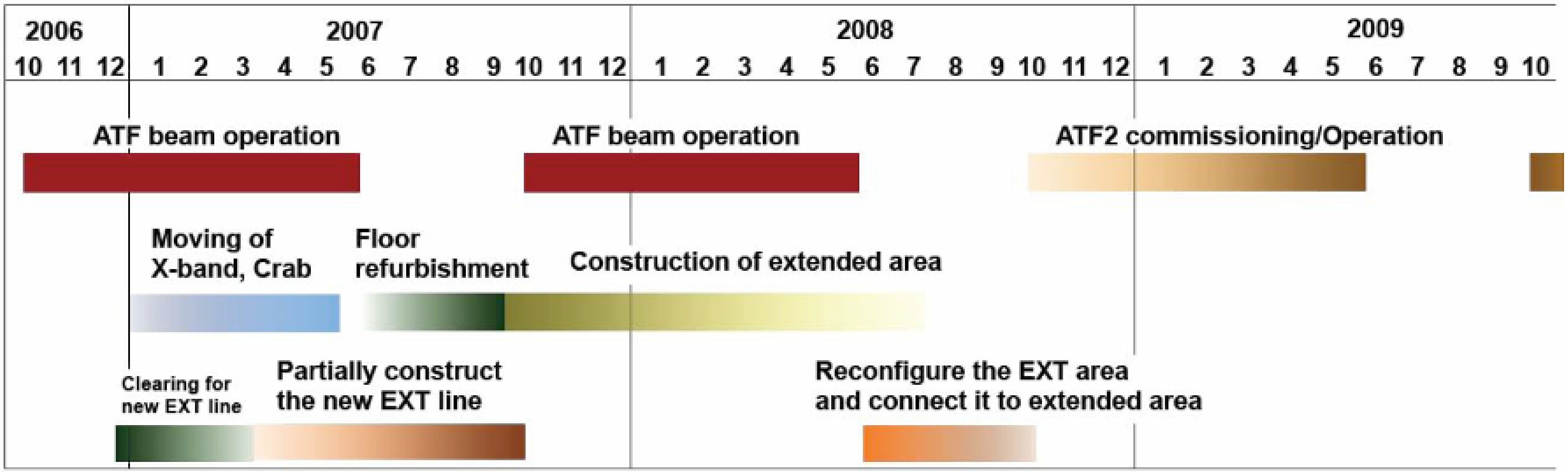
- Integration of ATF2 Final Doublet will be done in LAPP, Annecy
- Assembled FD to be sent to KEK in May-June 2008


305mm
520mm
305mm
200mm
200mm
90mm
450mm
120mm
90mm
450mm
SF1
QF1
SD0
QD0
2400mm


SX1


1.38 Q 17.72

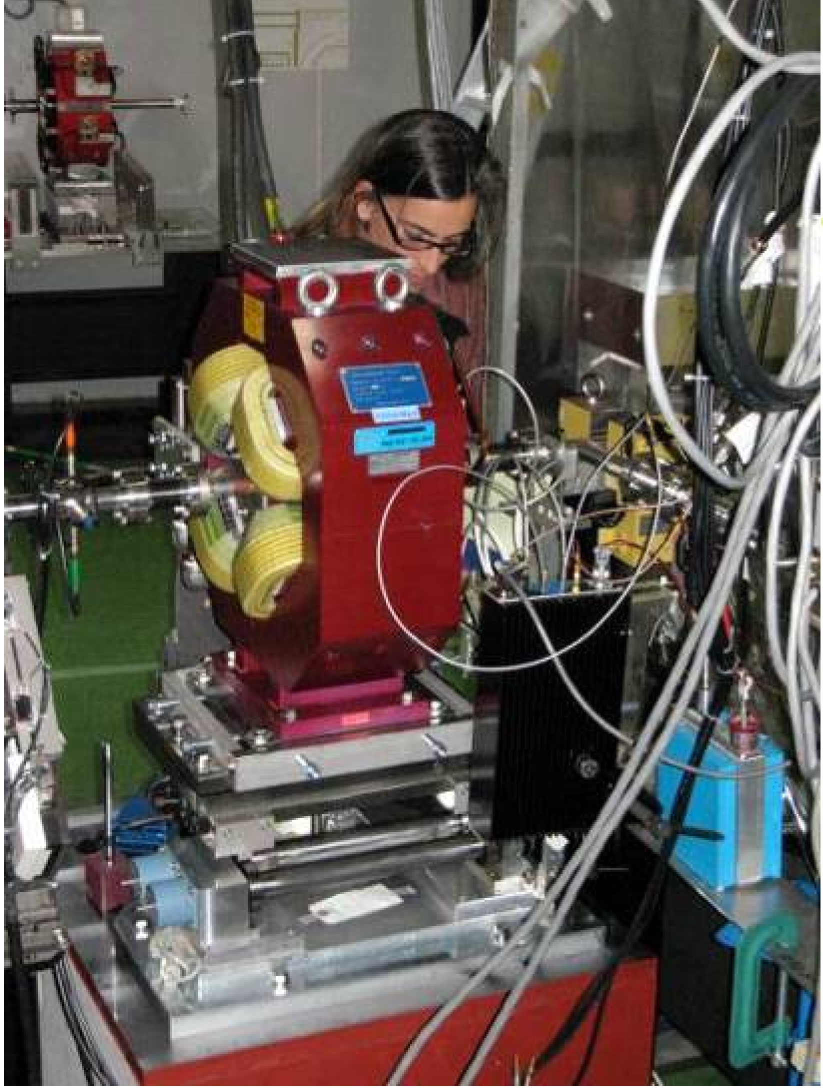
# ATF2 schedule



- **Construction of the extended shield area for final focus system can be done during the ATF beam operation.**
- Partial construction beside the current EXT line in shutdown week will release the work load for reconfiguration of the EXT line in summer of 2008.
- **ATF2 beam will come in October, 2008.**

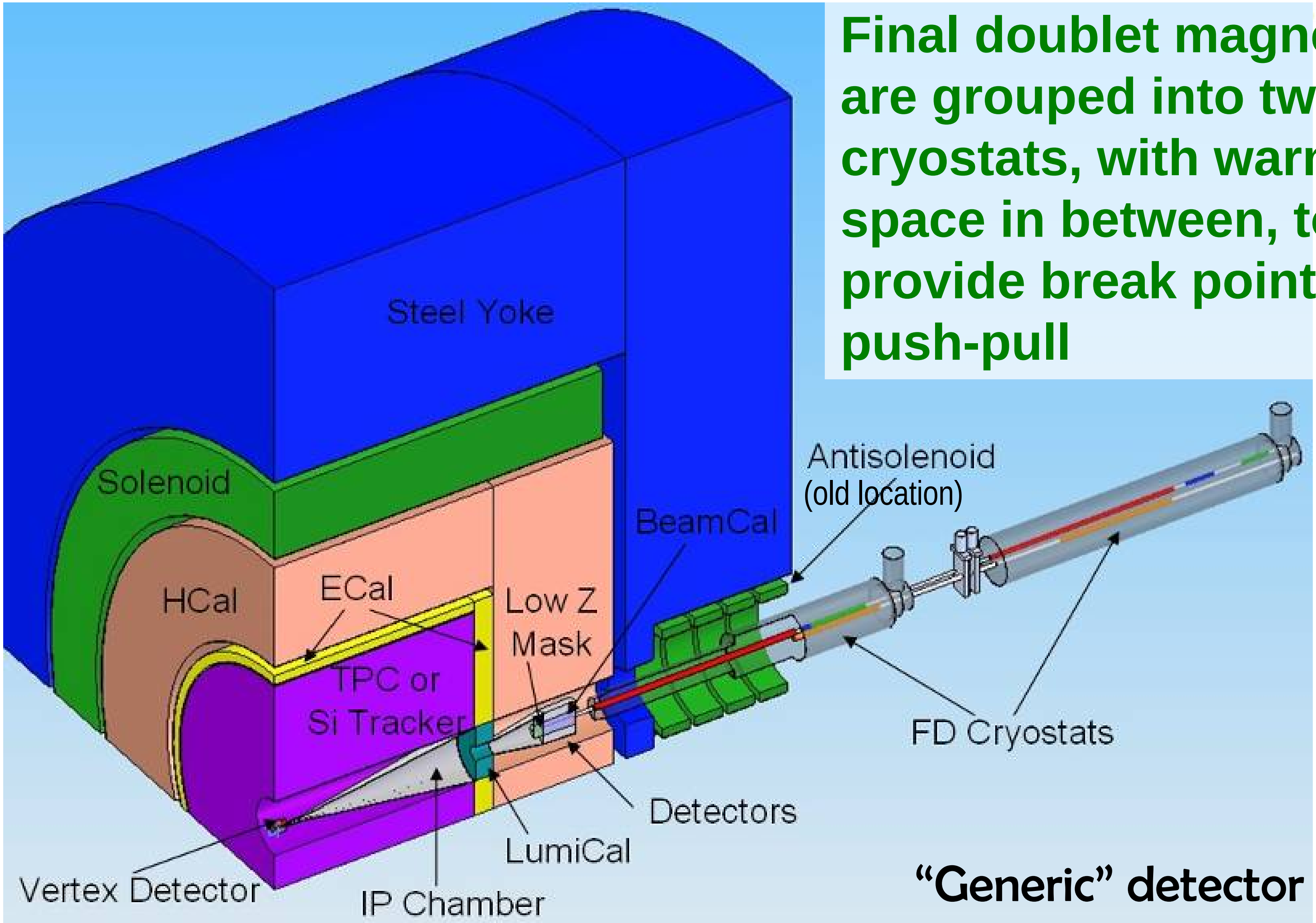
# ATF & ATF2

J.Nelson (at SLAC) and T.Smith (at KEK) during recent "remote participation" shift. Top monitors show ATF control system data. The shift focused on BBA, performed with new BPM electronics installed at ATF by Fermilab colleagues.



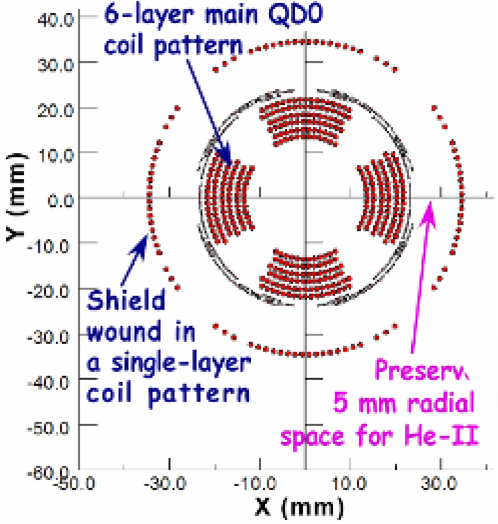
T.Smith is commissioning the cavity BPM electronics and the magnet mover system at ATF beamline

# IR integration



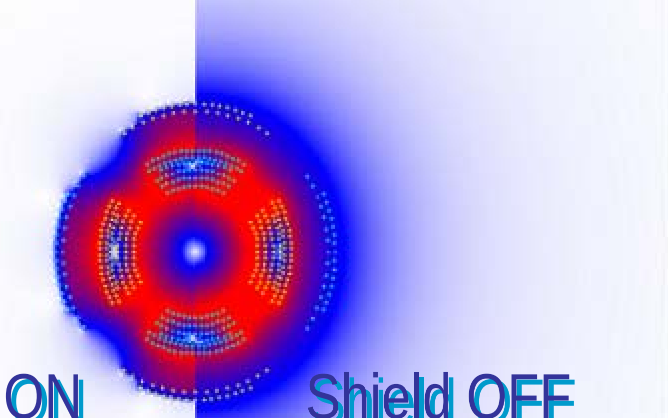
**Final doublet magnets are grouped into two cryostats, with warm space in between, to provide break point for push-pull**

“Generic” detector



# Actively shielded QD0

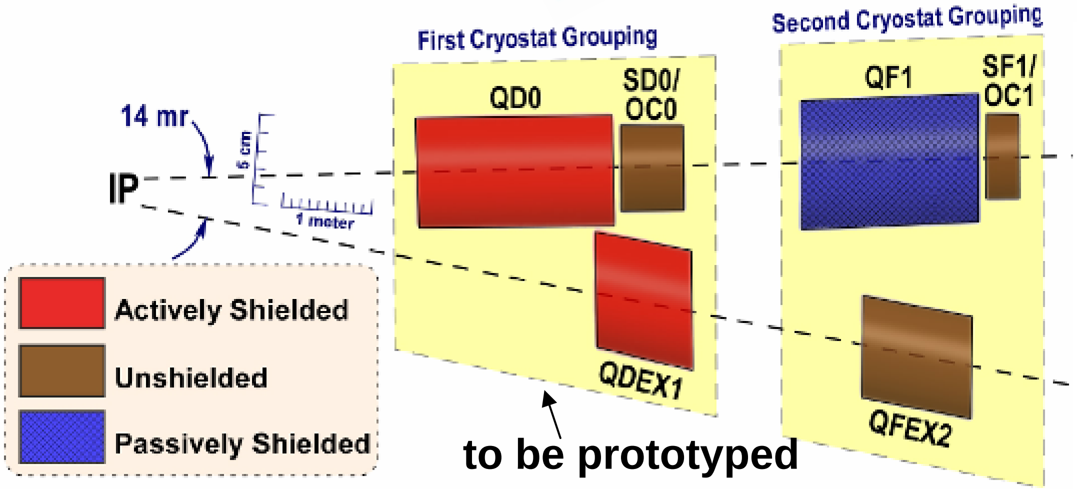
**BNL**



Shield ON

Shield OFF

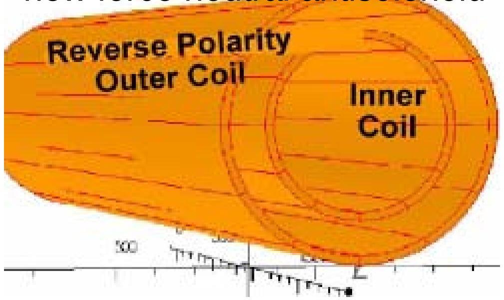
Intensity of color represents value of magnetic field.



to be prototyped during EDR

**Two Coils; Different Radii**

new force neutral antisolenoid

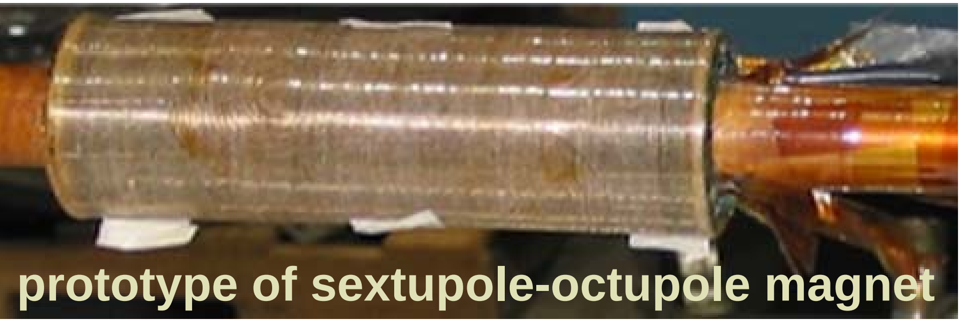


- Interaction region uses compact self-shielding SC magnets
- Independent adjustment of in- & out-going beamlines
- Force-neutral anti-solenoid for local coupling correction

# IR magnets prototypes at BNL

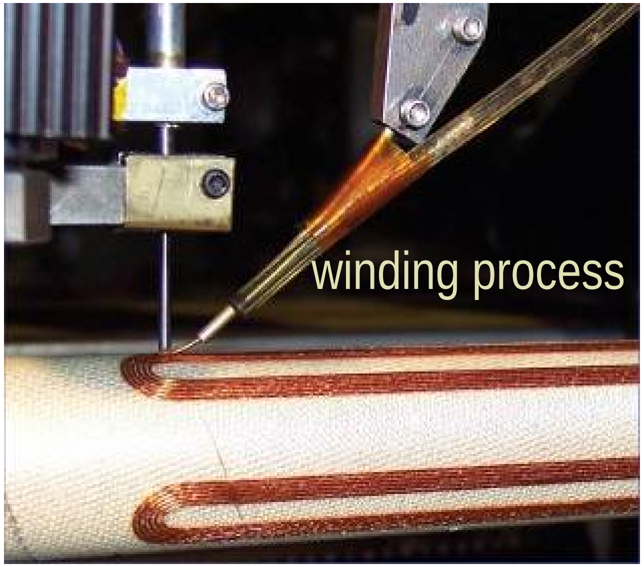
BNL prototype of self shielded quad

cancellation of the external field with a shield coil has been successfully demonstrated at BNL



prototype of sextupole-octupole magnet

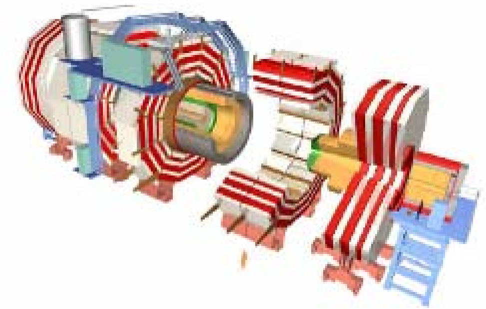
Coil integrated quench heater

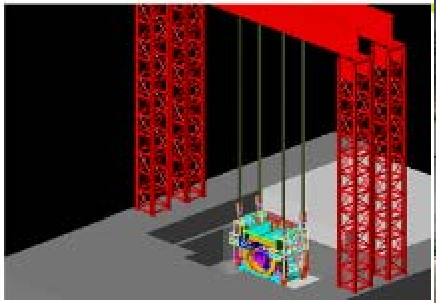


winding process

- Engineering design & prototype will show that compact direct wound magnets can provide independent incoming and outgoing apertures separated by mere 49mm defined by 14mrad crossing angle over the L* distance of 3.5m
- The prototype is also aimed for studies of mechanical stability of the magnets, when integrated into cryostats, and connected to cryogenic system

# Detector assembly





- CMS detector assembled on surface in parallel with underground work, lowered down with rented crane
- Adopted this method for ILC, to save 2-2.5 years that allows to fit into 7 years of construction

photos courtesy CERN colleagues

# IRENG07 Workshop

ILC INTERACTION REGION ENGINEERING DESIGN WORKSHOP

SLAC

- Home
- Goals
- Registration
- Payment Information
- Agenda
- Organizing Committees
- The Charge to the IPAC
- Accommodations
- Travel and Directions
- Visa Information
- Social Events
- Contact

## ILC Interaction Region Engineering Design Workshop

**September 17-21, 2007**

**Stanford Linear Accelerator Center**

**Menlo Park, California**

Please join us to review and advance the design of the subsystem of the Interaction Region of ILC, focusing in particular on their integration, engineering design and arrangements for push-pull operation.

http://www-conf.slac.stanford.edu/ireng07/

**RECENT NEWS**

**- Agenda has been updated.**

**REGISTRATION**

Registration is necessary to participate in the workshop.

Registration fee is $30 and reception fee is $20.

→ **Register**

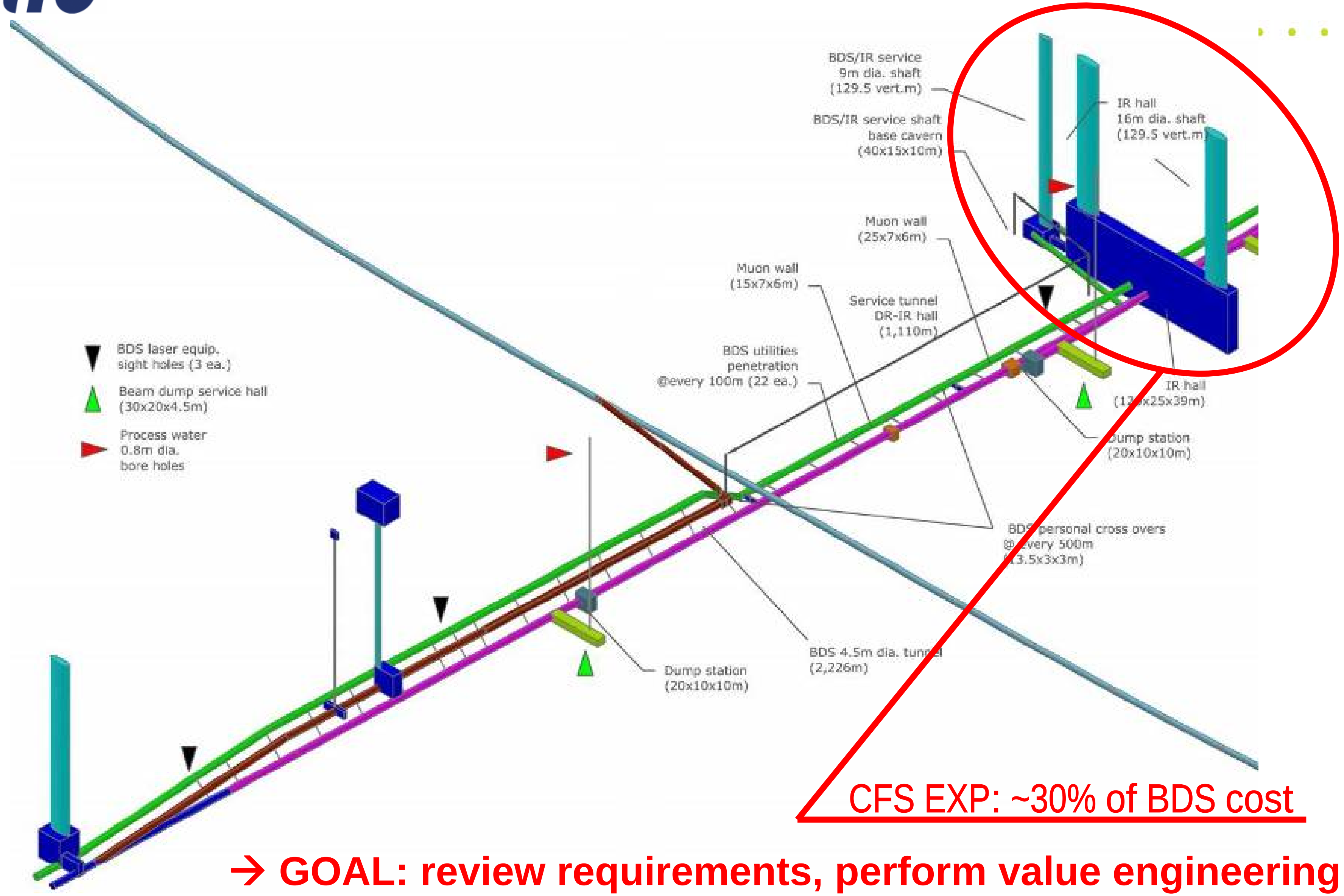
**ACCOMMODATIONS**

A block of 40 rooms is reserved until July 15, 2007 at the **Stanford Guest House**. Please reserve your room early and mention that you are attending this workshop.

→ **More Information**

Graphics logo based on generic IR design made by John Amann, SLAC

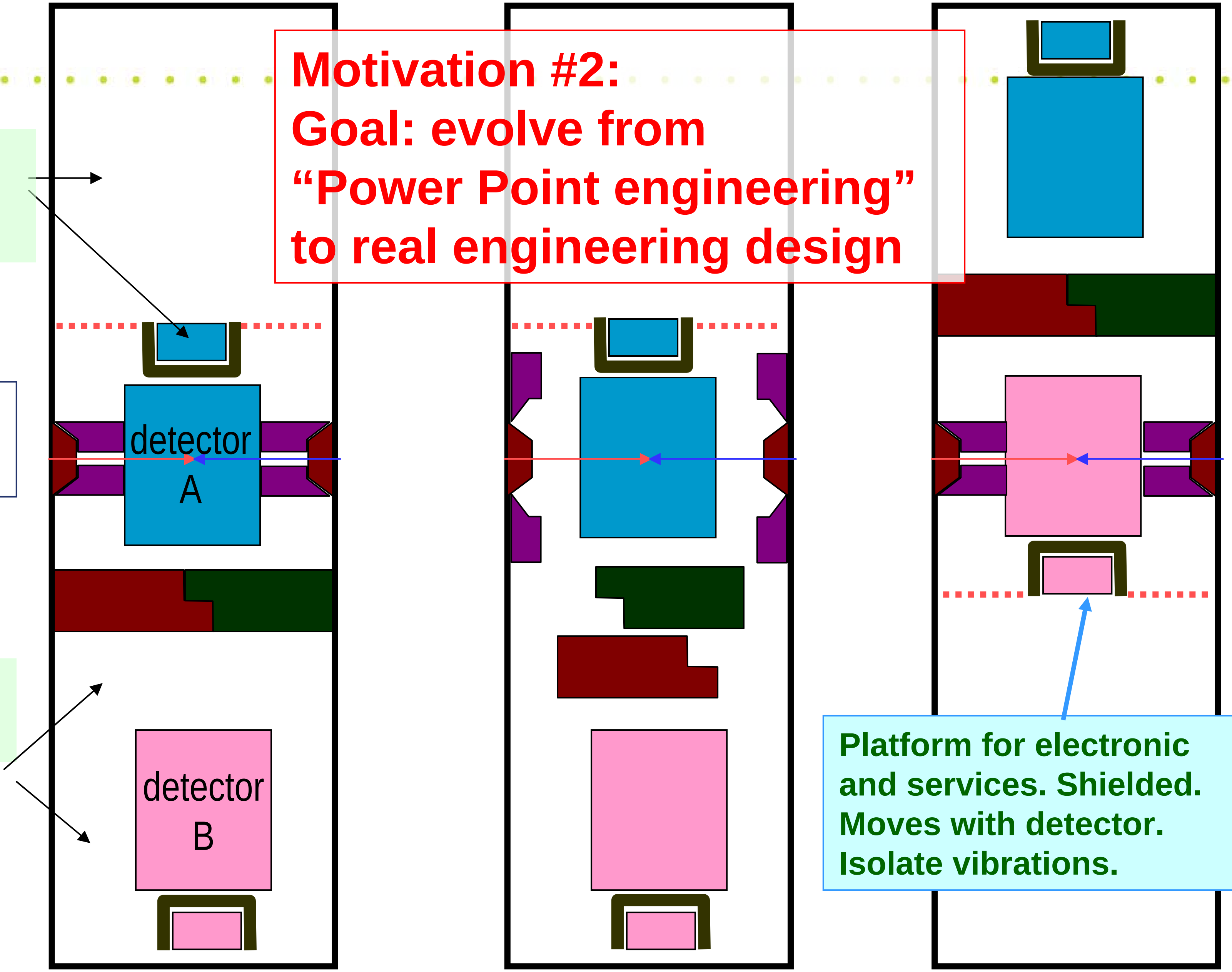
# IRENG07 motivations



CFS EXP: ~30% of BDS cost

**→ GOAL: review requirements, perform value engineering**

# Concept of single IR with two detectors



**Motivation #2:**
**Goal: evolve from "Power Point engineering" to real engineering design**

may be accessible during run

Slide as of ~Oct 2006

accessible during run

Platform for electronic and services. Shielded. Moves with detector. Isolate vibrations.

# Work in preparation for IRENG07

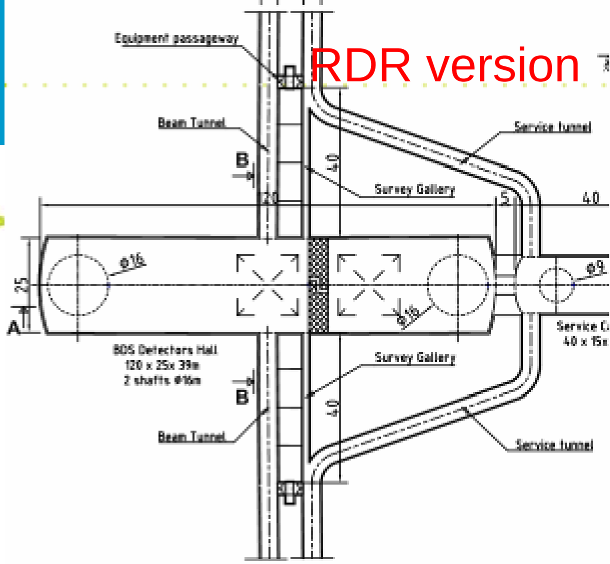
- **WG-A: Overall detector design, assembly, detector moving, shielding.**
  - Including detector design for on-surface assembly and underground assembly procedures. Beamline pacman & detector shielding…
    - **Conveners: Alain Herve (CERN), Tom Markiewicz (SLAC), Tomoyuki Sanuki (Tohoku Univ.), Yasuhiro Sugimoto (KEK)**
- **WG-B: IR magnets design and cryogenics system design.**
  - Including cryo system, IR magnet engineering design, support, integration with IR, masks, Lumi & Beamcals, IR vacuum chamber...
    - **Conveners: Brett Parker (BNL), John Weisend (SLAC/NSF), Kiyosumi Tsuchiya (KEK)**
- **WG-C: Conventional construction of IR hall and external systems.**
  - Including lifting equipment, electronics hut, cabling plant, services, shafts, caverns, movable shielding; solutions to meet alignment tolerances...
    - **Conveners: Vic Kuchler (FNAL), Atsushi Enomoto (KEK), John Osborne (CERN)**
- **WG-D: Accelerator and particle physics requirements.**
  - Including collimation, shielding, RF, background, vibration and stability and other accelerator & detector physics requirements…
    - **Conveners: Deepa Angal-Kalinin (STFC), Nikolai Mokhov (FNAL), Mike Sullivan (SLAC), Hitoshi Yamamoto (Tohoku Univ.)**

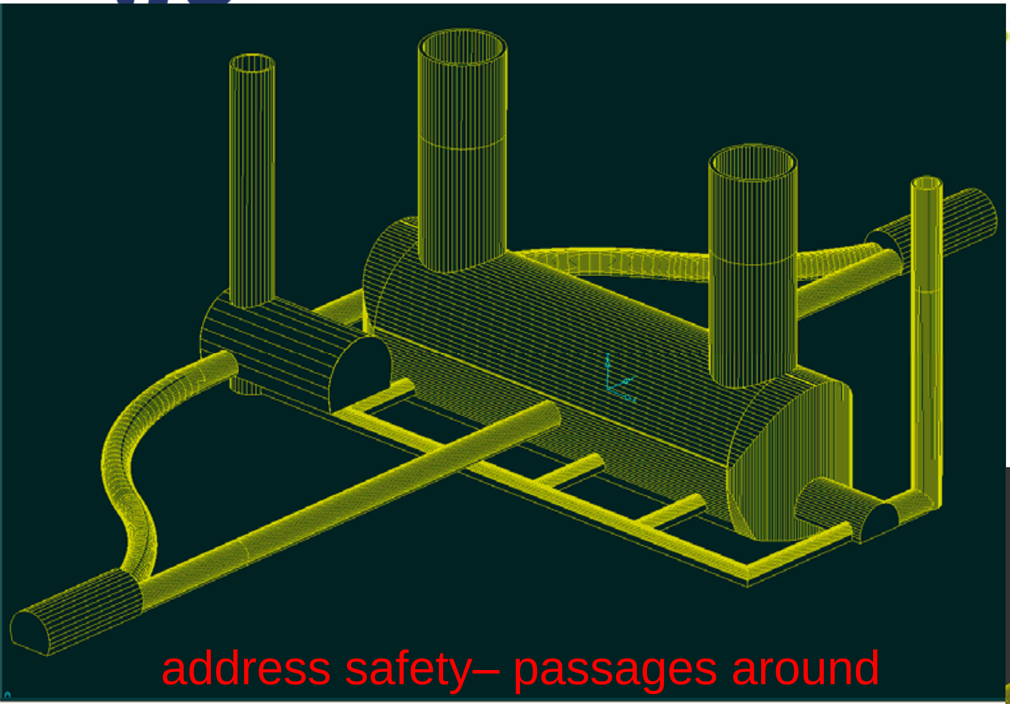
- WG-A, conveners meeting, July 5
- WG-D, conveners meeting, July 11
- WG-A, group meeting, July 12
- WG-B, conveners meeting, July 13
- WG-C, group meeting, July 17
- WG-B, group meeting, July 23
- WG-C, group meeting, July 24
- WG-A, group meeting, July 30
- WG-C, group meeting, July 31
- WG-D, group meeting, August 1
- WG-B, group meeting, August 2
- WG-A, group meeting, August 6
- WG-C, group meeting, August 7
- WG-A, group meeting, August 13
- WG-D, group meeting, August 15
- WG-B, group meeting, August 16
- WG-A, group meeting, August 20
- WG-C, group meeting, August 21
- WG-A, group meeting, August 27
- WG-C, group meeting, August 28
- Conveners and IPAC mtg, August 29
- WG-B, group meeting, August 30
- WG-B, group meeting, September 13

ILC Interaction Region Engineering Design Workshop

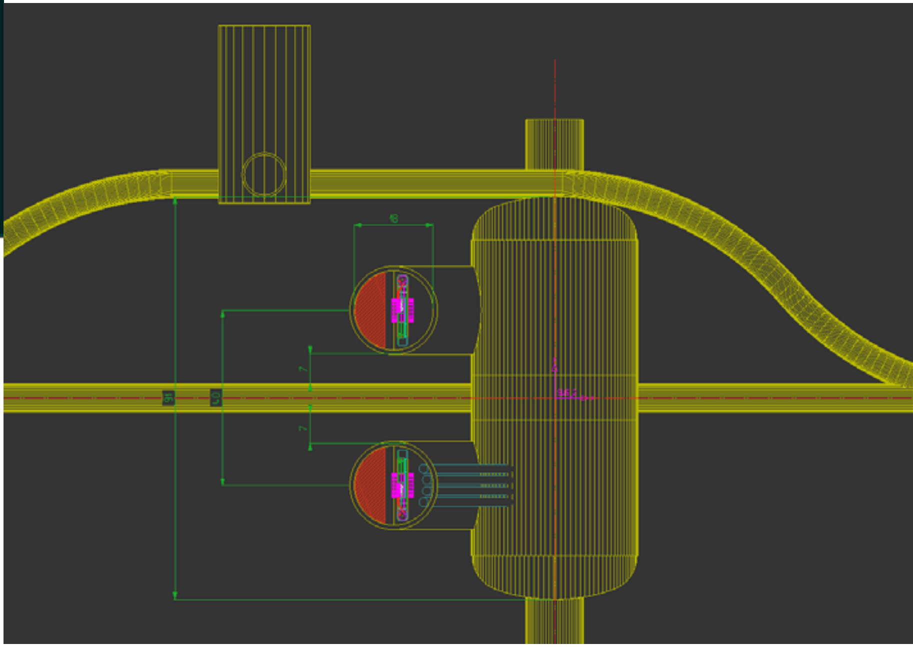
September 17-21, 2007
Stanford Linear Accelerator Center

# Explore optimization of IR arrangements during IRENG07 workshop

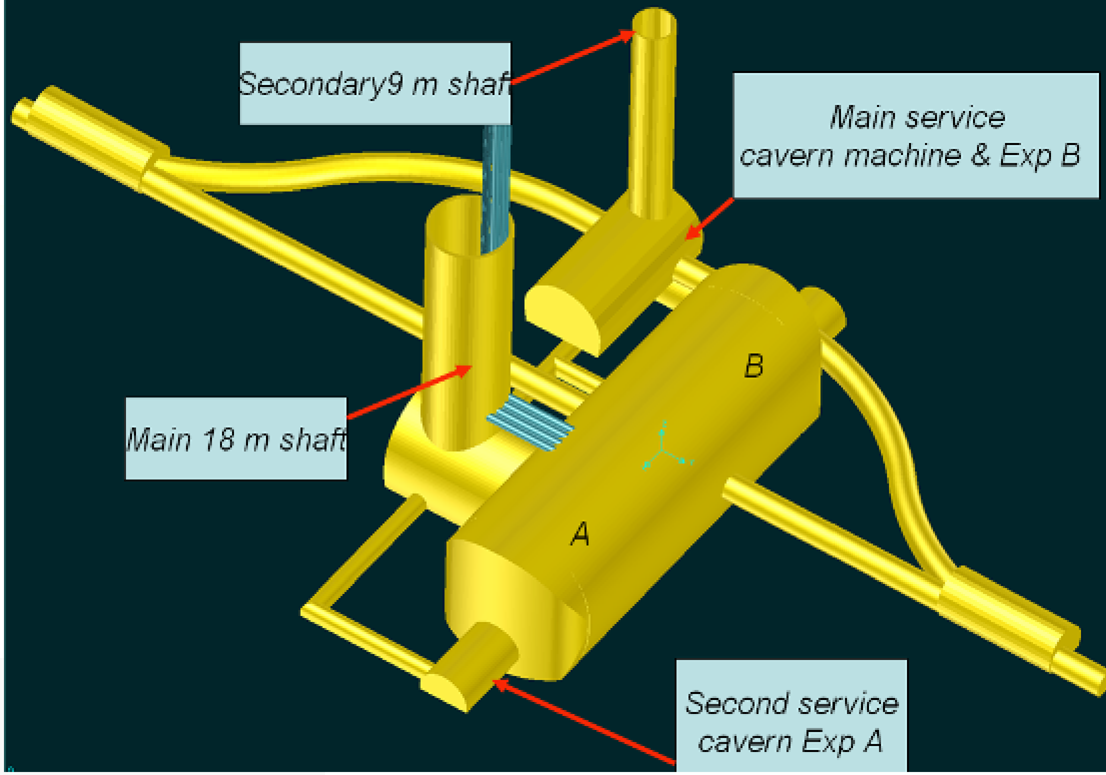

RDR version

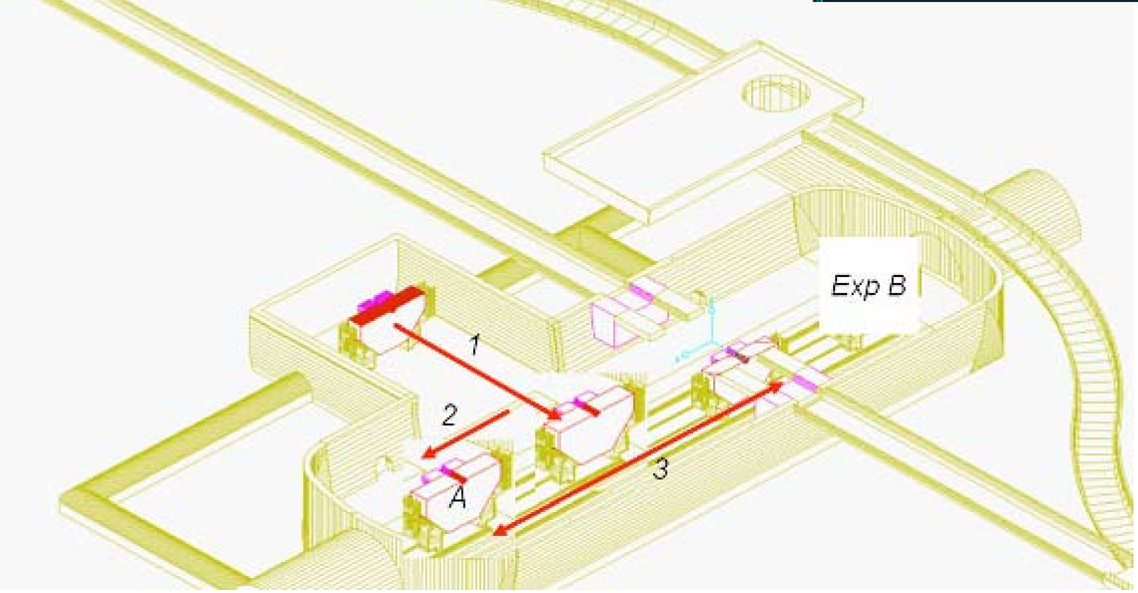

address safety– passages around

Optimization was possible due to work of IRENG07 participants, conveners, CFS group and in particular CERN’s Alain Herve, John Osborne and their colleagues


address safety and interference – offset the shafts

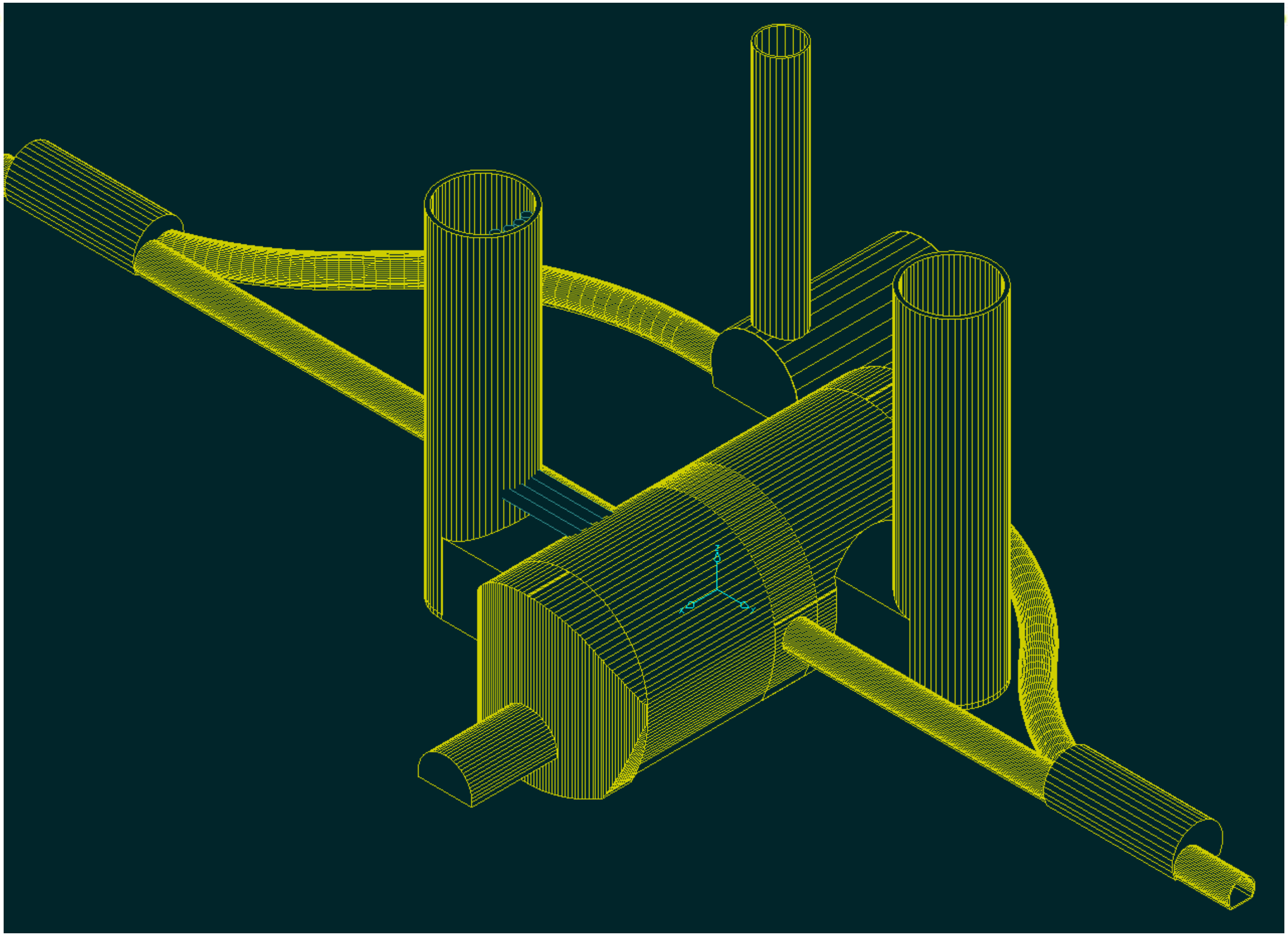
# Single detector access shaft





Was considered as value engineering exercise. Was found in principle possible. However it would create disadvantages for one of experiments and severe interference between them.

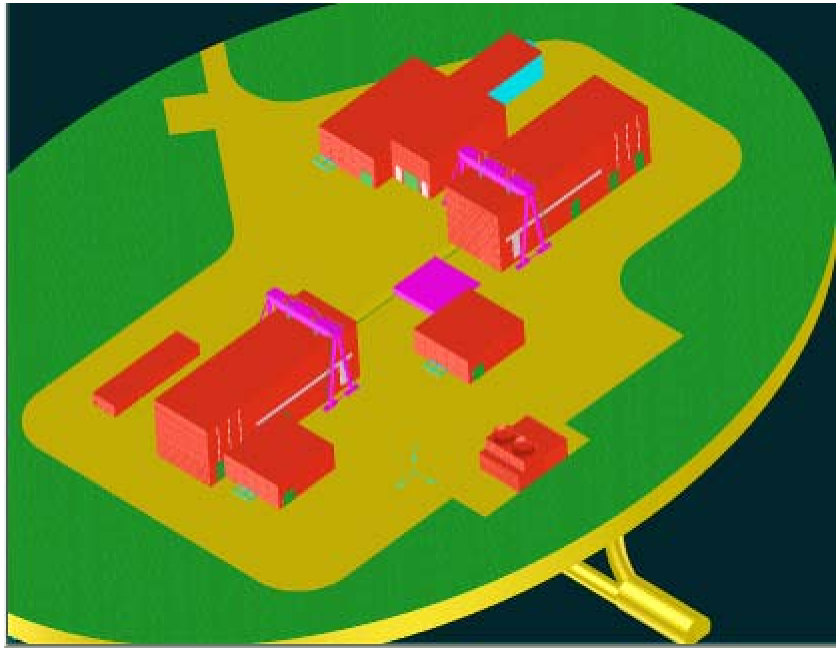
# To be considered as an alternative for IR layout during EDR:



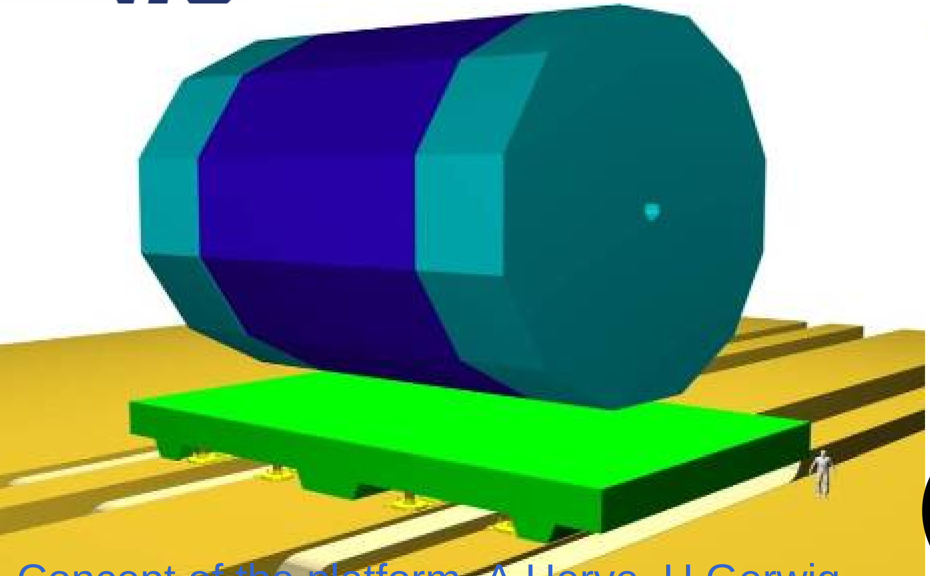
Two shafts offset from the main cavern on the diagonal, to address interferences (in safety and schedule) between loading/unloading areas and working areas

# Optimization of surface buildings

Considering common or independent building for surface assembly of two detectors. Shared or independent rented gantry cranes, shared shaft cover, etc.

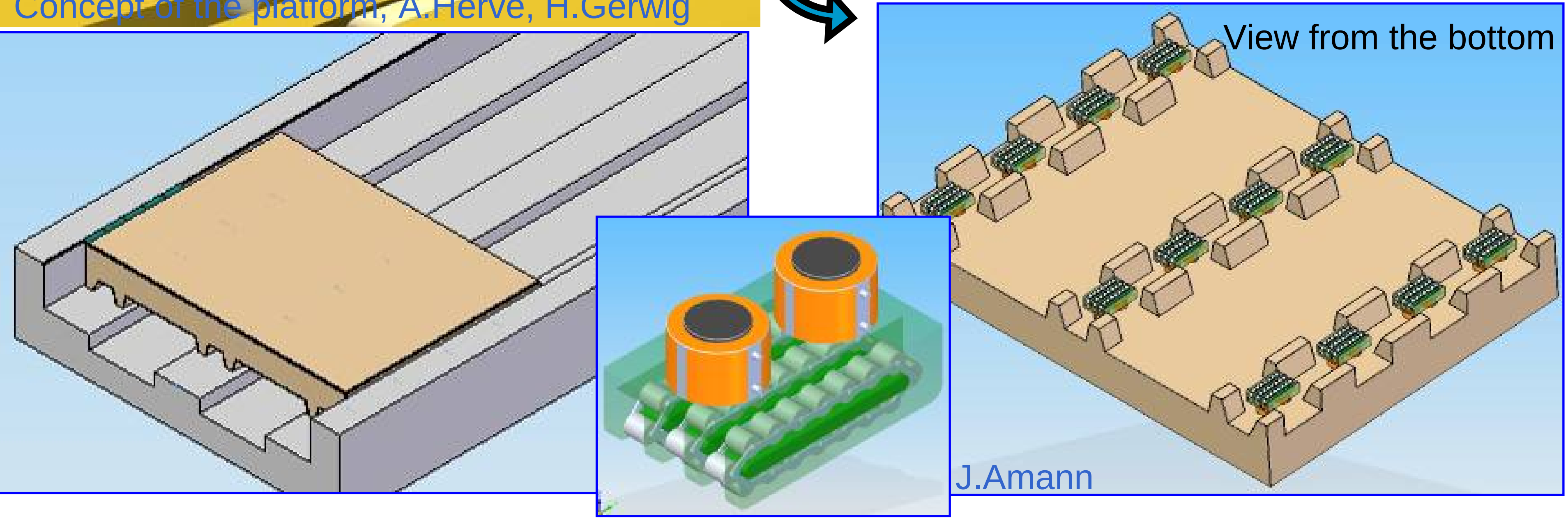


# Moving the detector



Concept of the platform, A.Herve, H.Gerwig

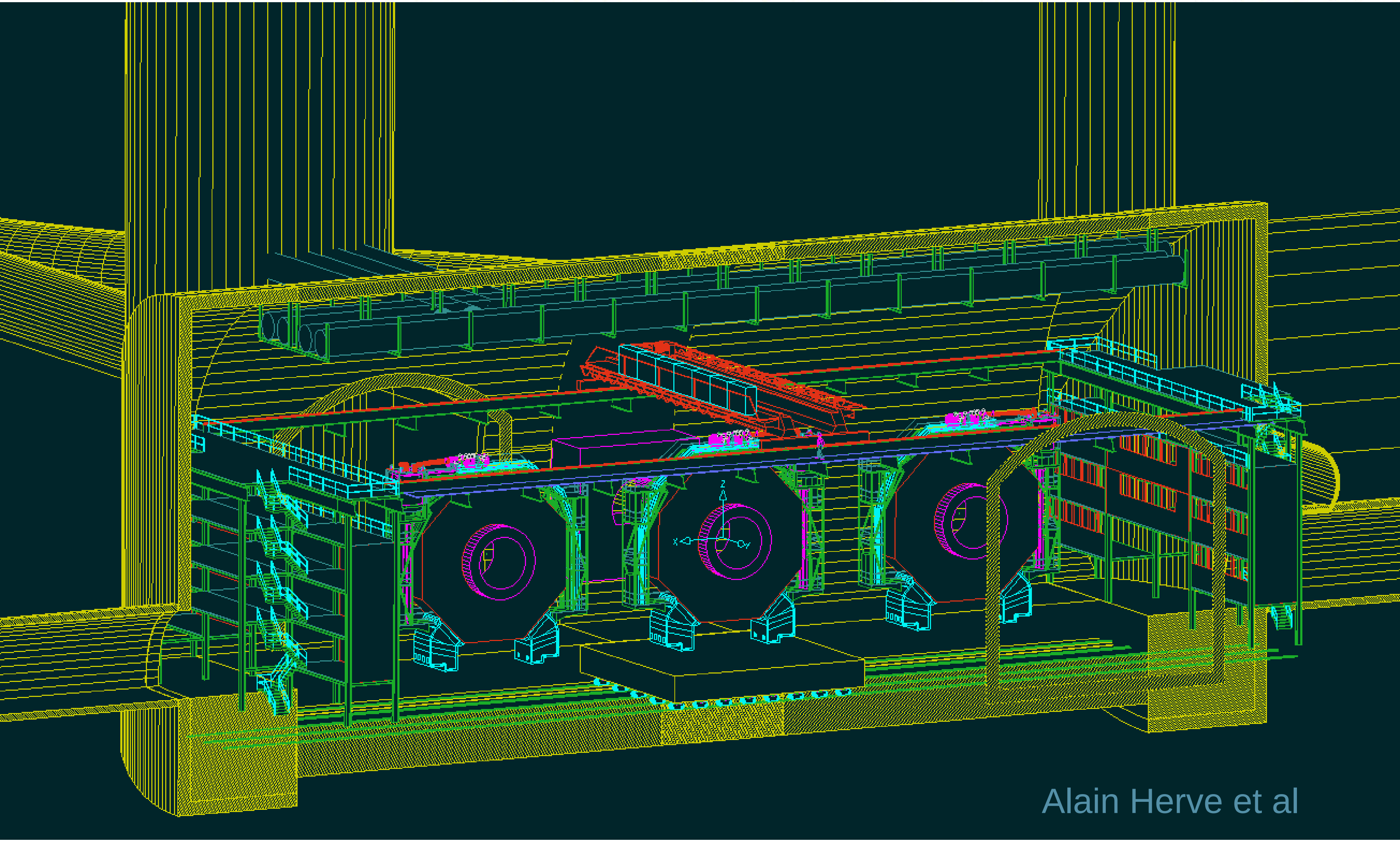
Air-pads at CMS – move 2000k



View from the bottom

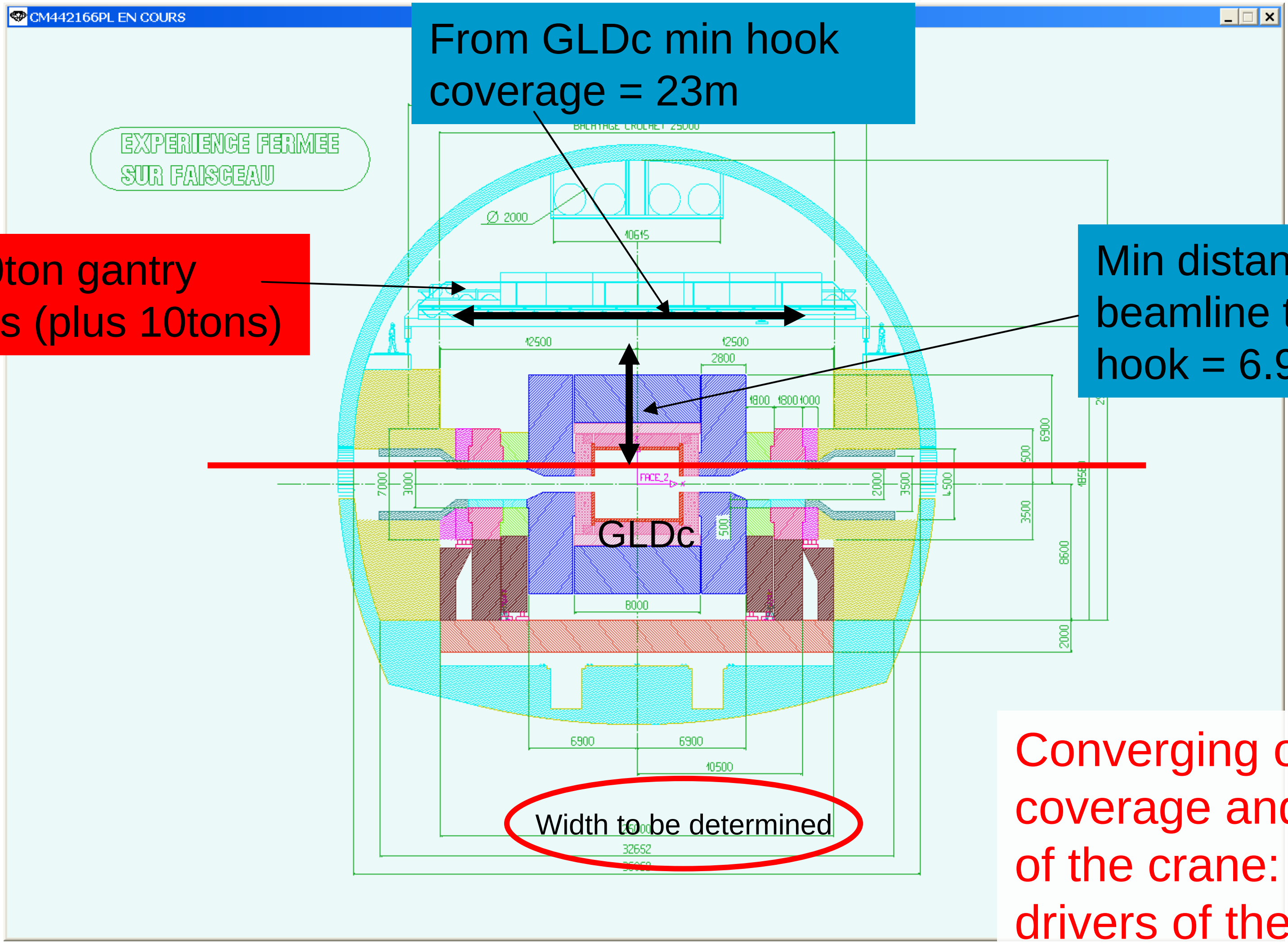
J.Amann

# Details of the Push-Pull configuration and of the platform



Alain Herve et al

# IREN07 : Experimental Cavern Criteria



From GLDc min hook coverage = 23m

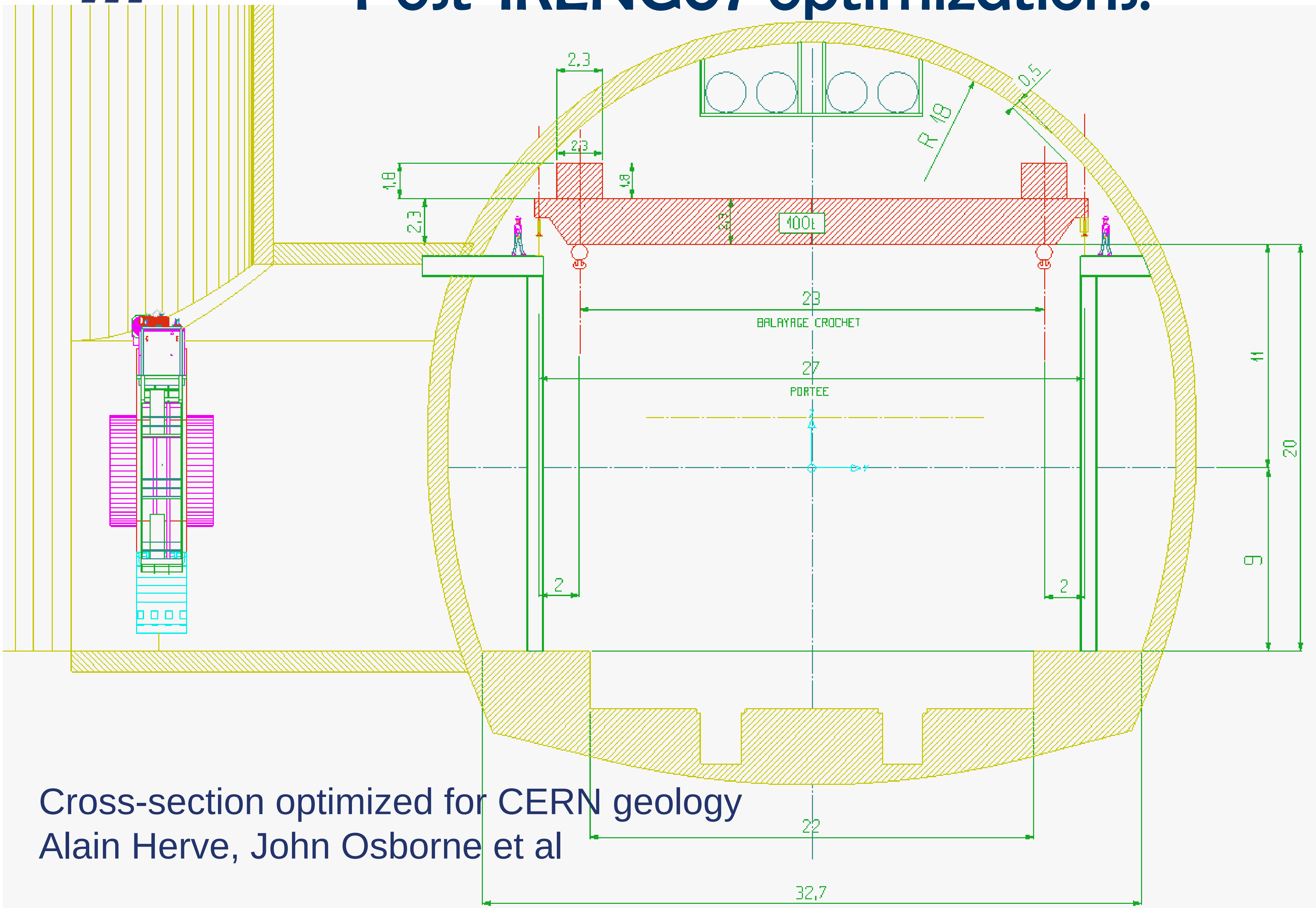
2*100ton gantry cranes (plus 10tons)

Min distance from beamline to underside of hook = 6.9m+4m = 11m

Width to be determined

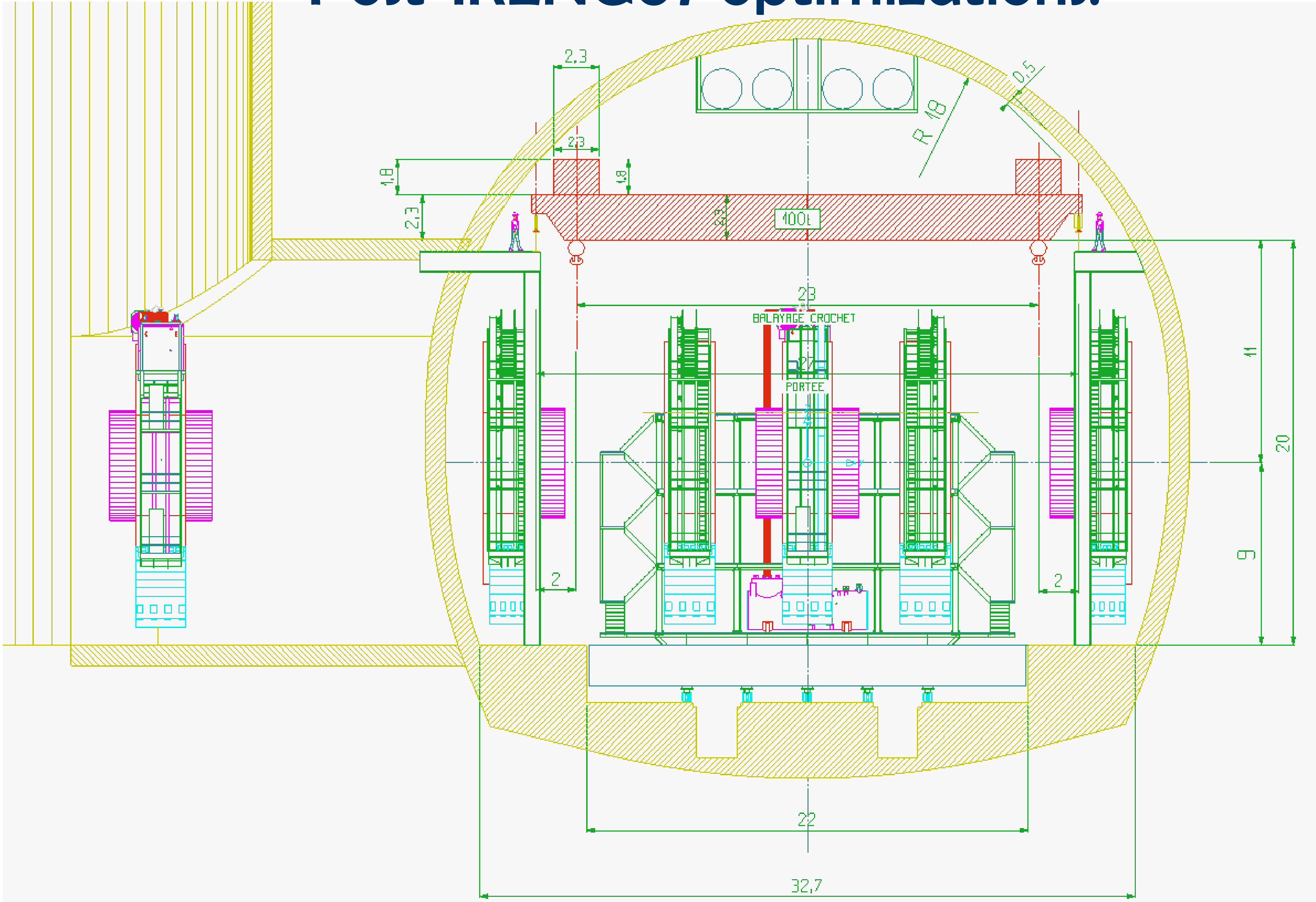
Converging on required coverage and capacity of the crane: one of the drivers of the hall size

# Post-IRENG07 optimizations:

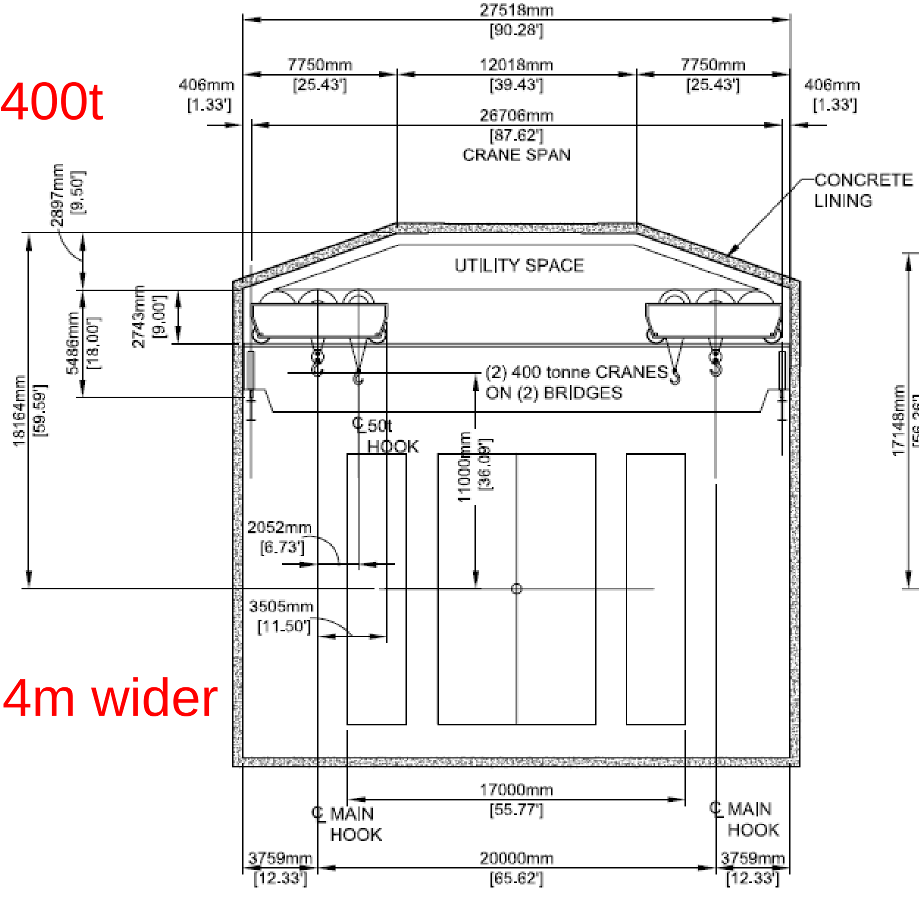


Cross-section optimized for CERN geology
Alain Herve, John Osborne et al

# Post-IRENG07 optimizations:



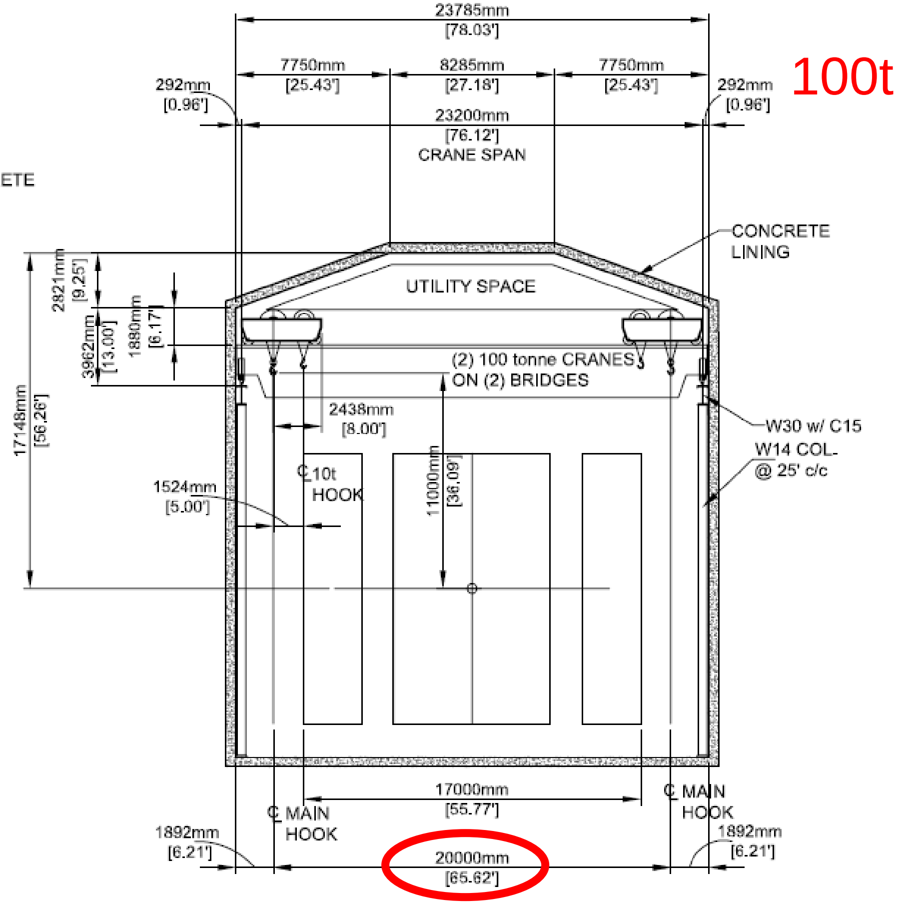
# Post-IRENG07 optimizations:



400t

~4m wider

SECTION @ IR HALL - 400t CRANE



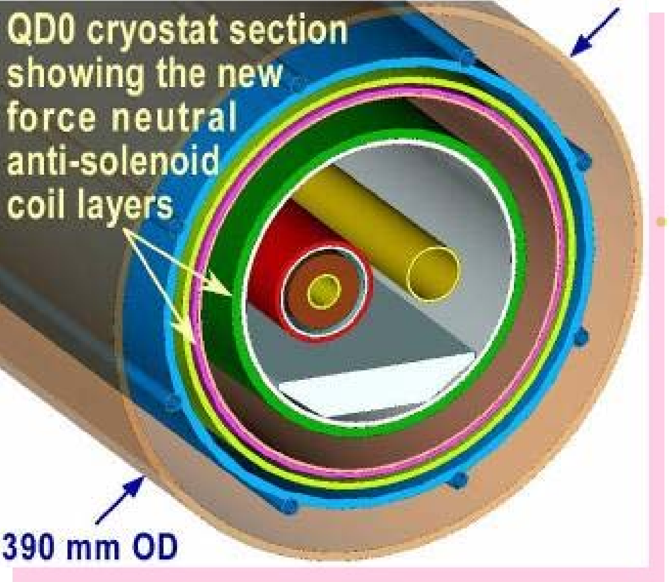
100t

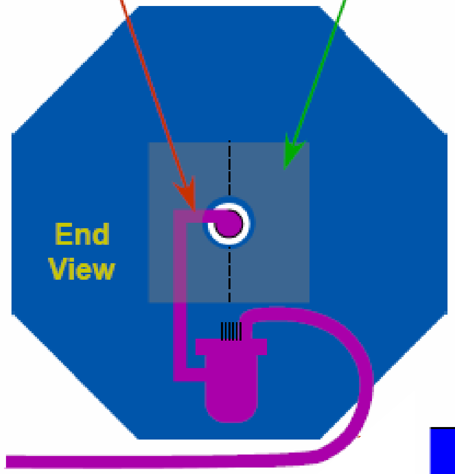
SECTION @ IR HALL - 100t CRANE

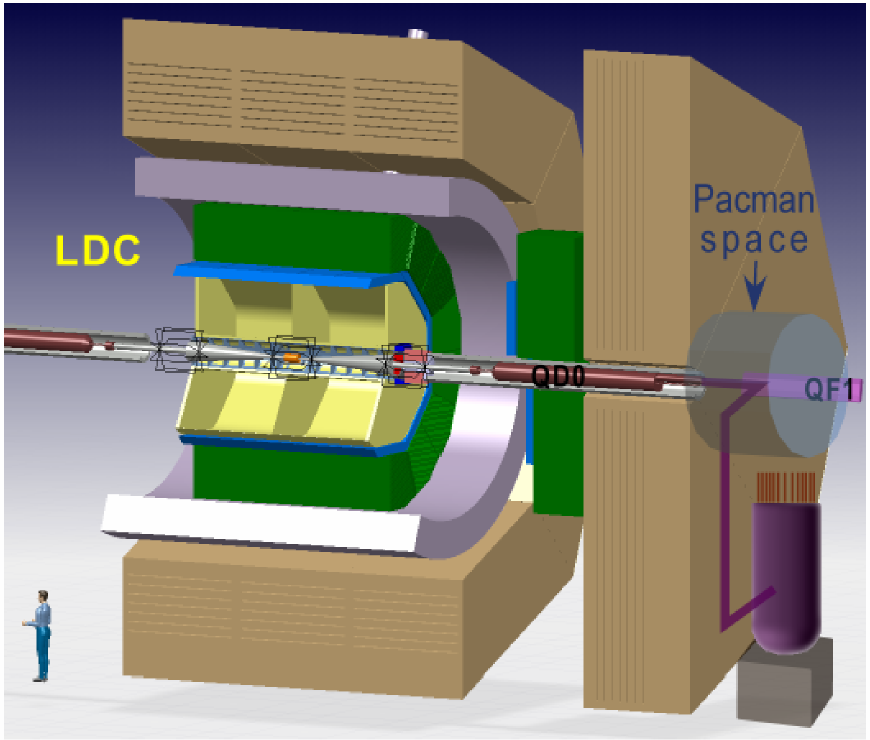
Cross-section being optimized for FNAL geology, Tom Lackowski et al

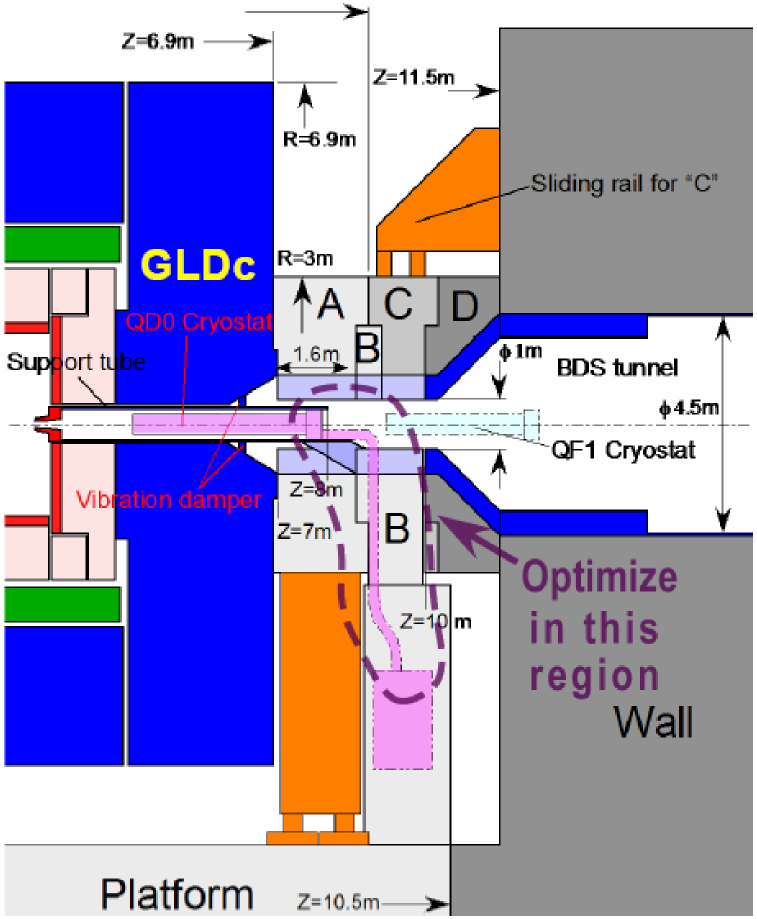
The RDR 400t crane configuration is planned to be replaced by ~100t version

# Cryo, shielding & QD0 design



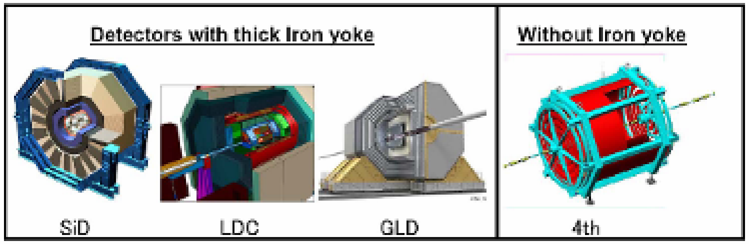


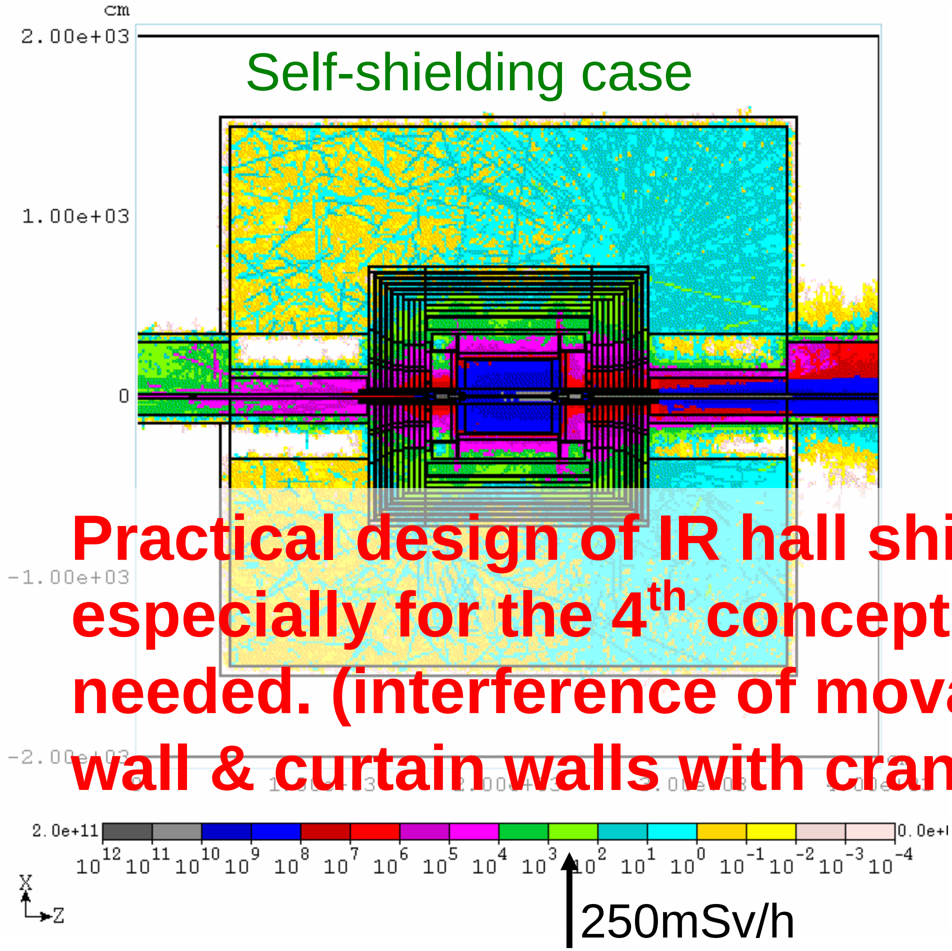




→ practical design of integr. cryo system is needed

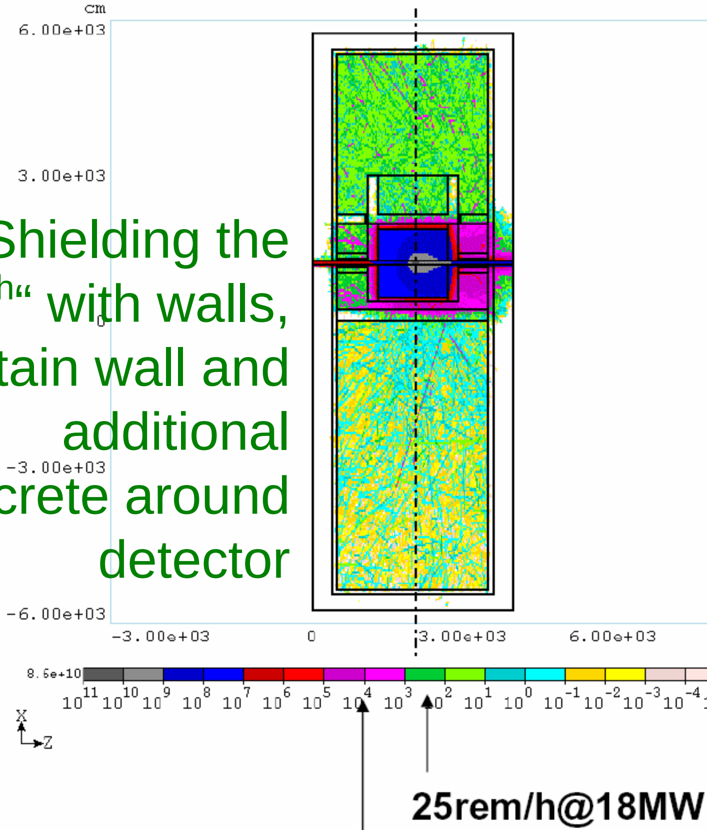
# Shielding the IR hall



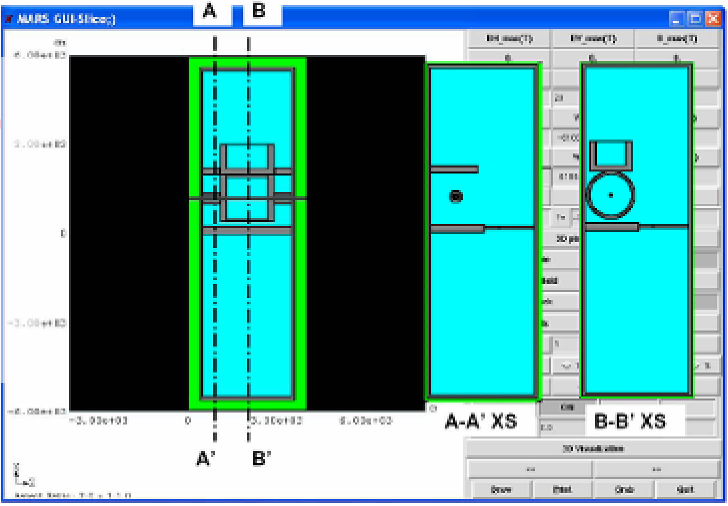

Self-shielding case

250mSv/h

Shielding the "4th" with walls, curtain wall and additional concrete around detector

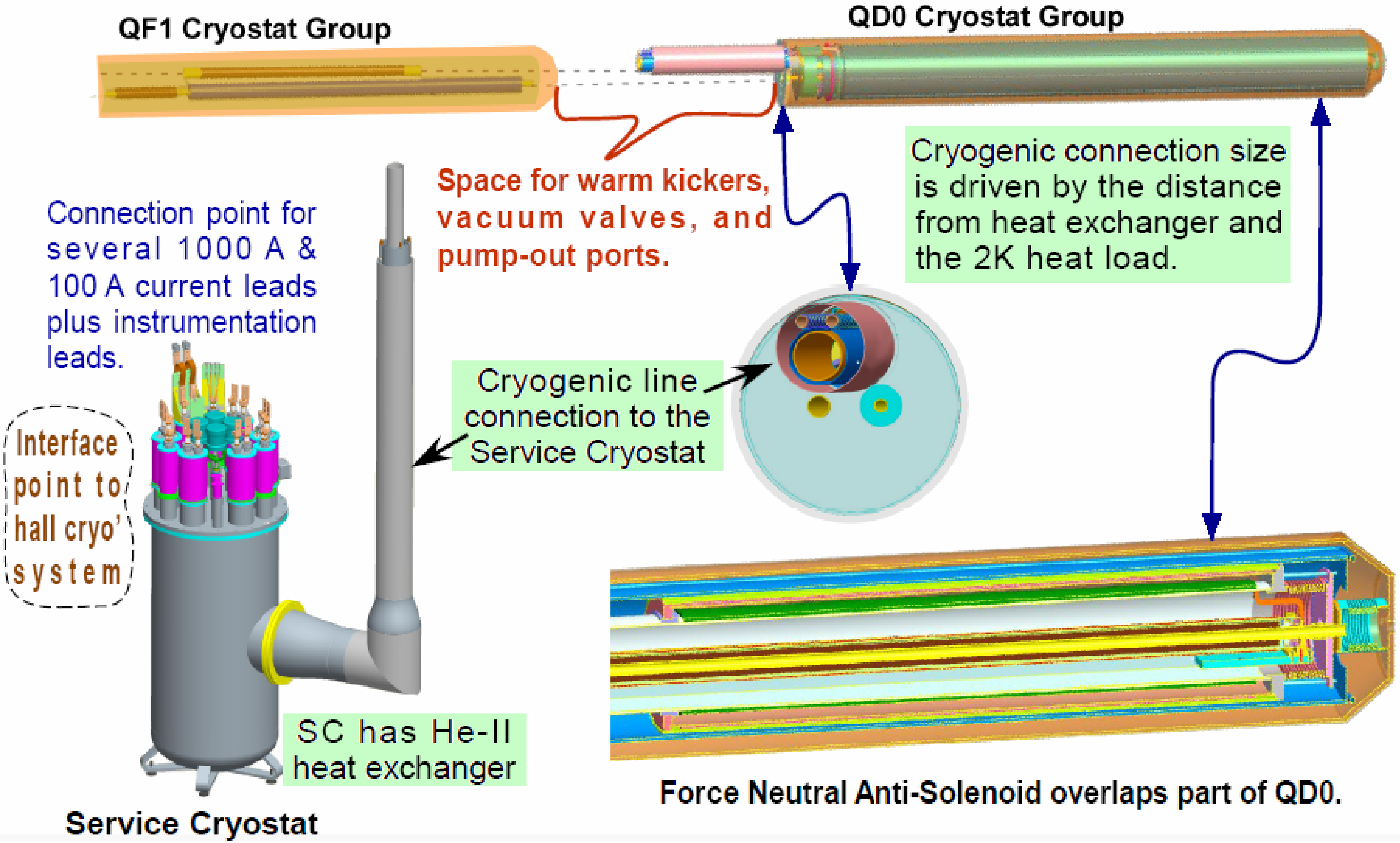


25rem/h@18MW



**Practical design of IR hall shielding, especially for the 4th concept is needed. (interference of movable wall & curtain walls with cranes)**

# IR magnets and cryo connections



**QF1 Cryostat Group**

**QD0 Cryostat Group**

Space for warm kickers, vacuum valves, and pump-out ports.

Cryogenic connection size is driven by the distance from heat exchanger and the 2K heat load.

Connection point for several 1000 A & 100 A current leads plus instrumentation leads.

Cryogenic line connection to the Service Cryostat

Interface point to hall cryo' system

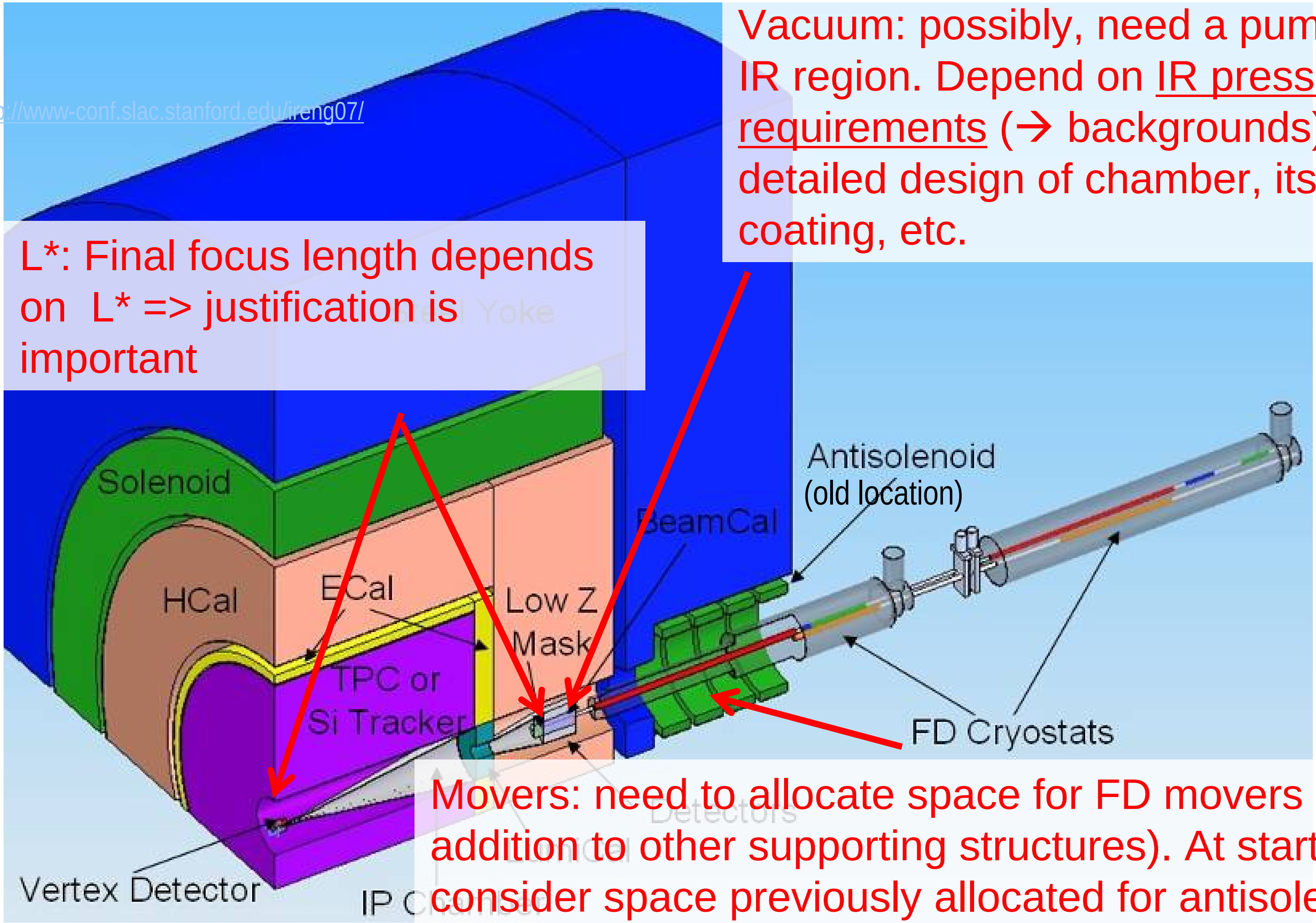
SC has He-II heat exchanger

Force Neutral Anti-Solenoid overlaps part of QD0.

**Service Cryostat**

# Vacuum, FD movers, L*...

http://www-conf.slac.stanford.edu/ireng07/



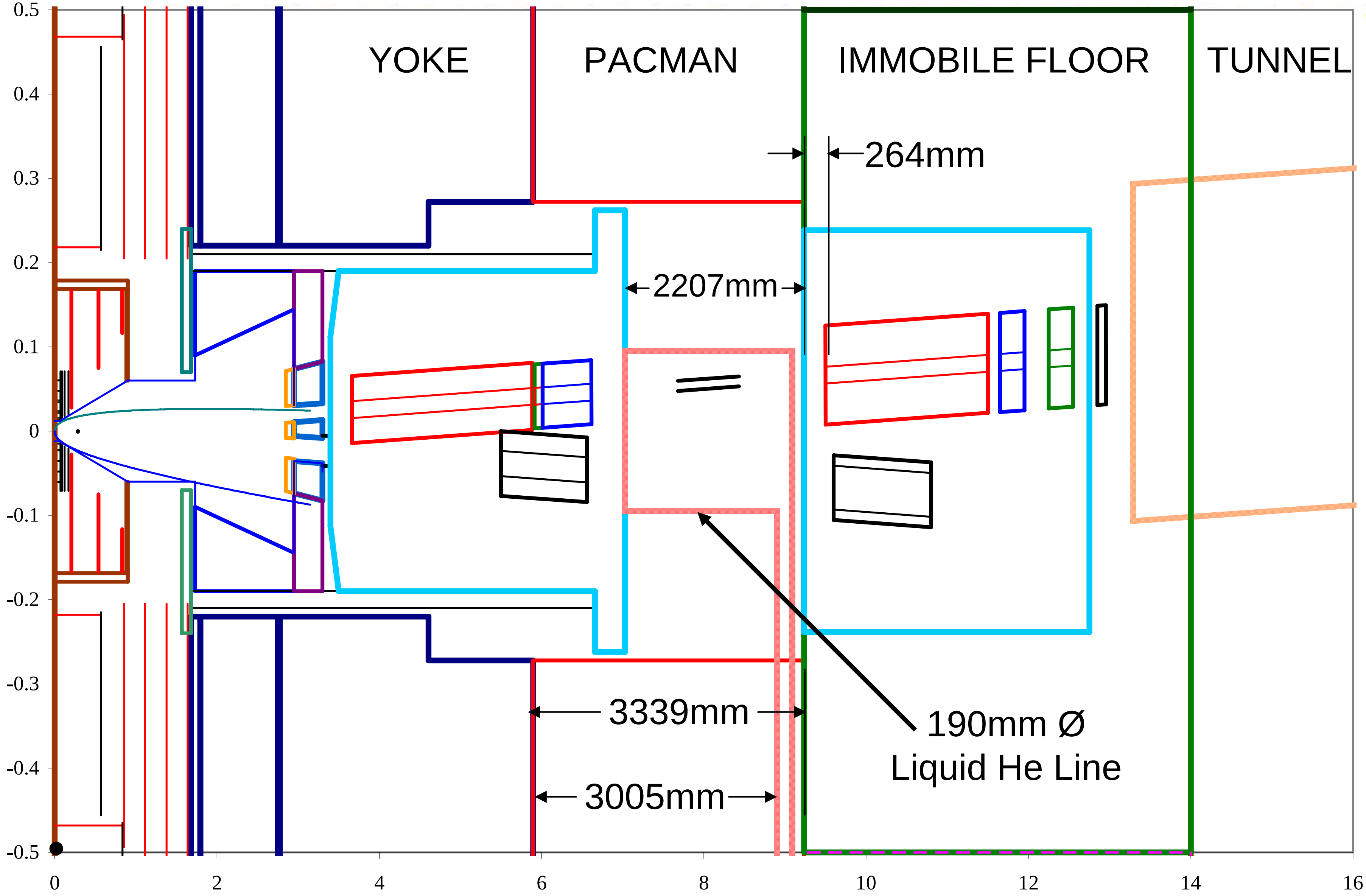
Vacuum: possibly, need a pump in IR region. Depend on <u>IR pressure requirements</u> (→ backgrounds) and detailed design of chamber, its coating, etc.

L*: Final focus length depends on L* => justification is important

Movers: need to allocate space for FD movers (in addition to other supporting structures). At start, consider space previously allocated for antisolenoid

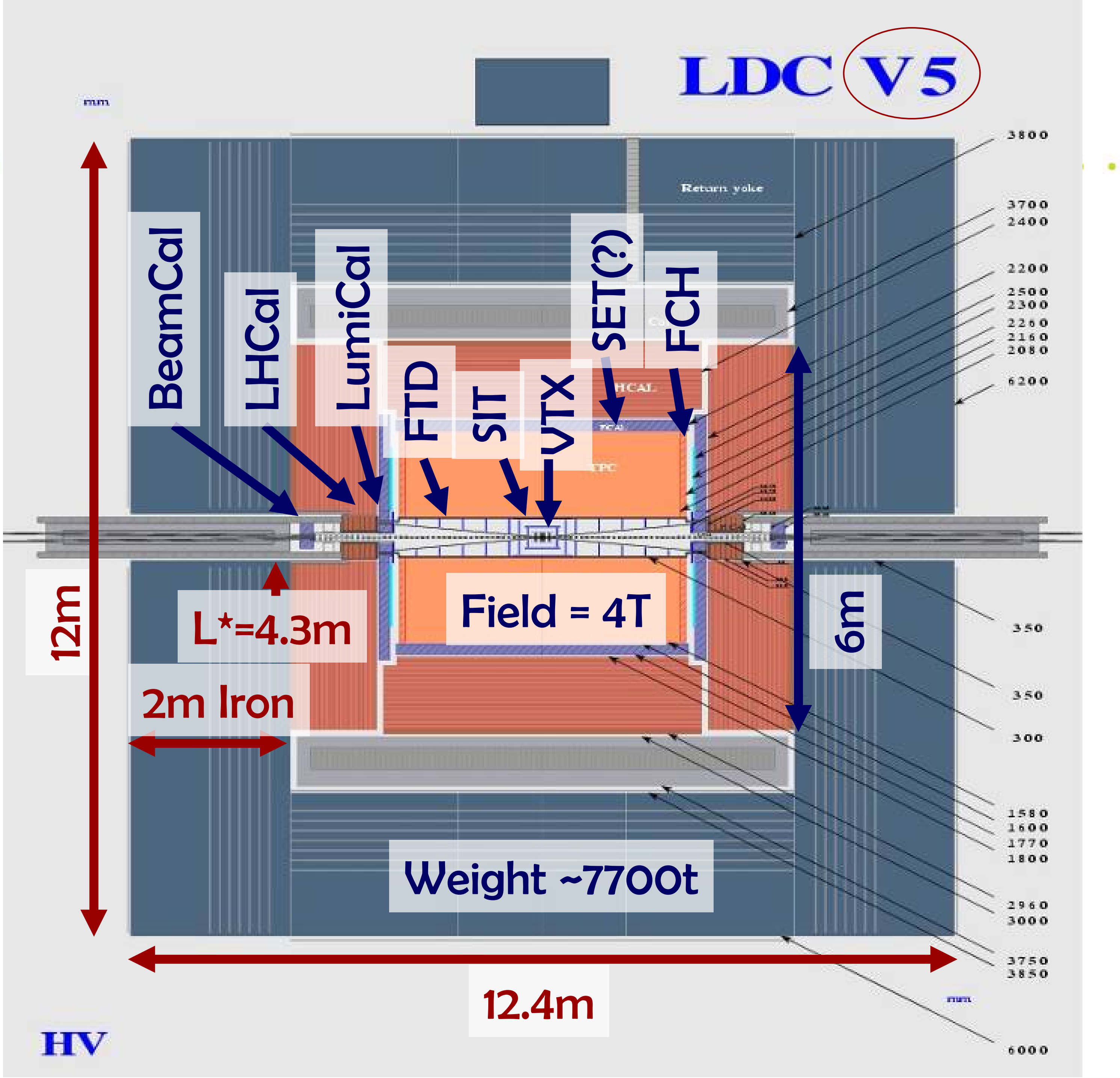
# Thank you for attention!

# SiD r<50cm, L*=3.664m, 14mrad, Push-Pull, QF@9.5m, Door Closed



# LDC

Norbert Meyners

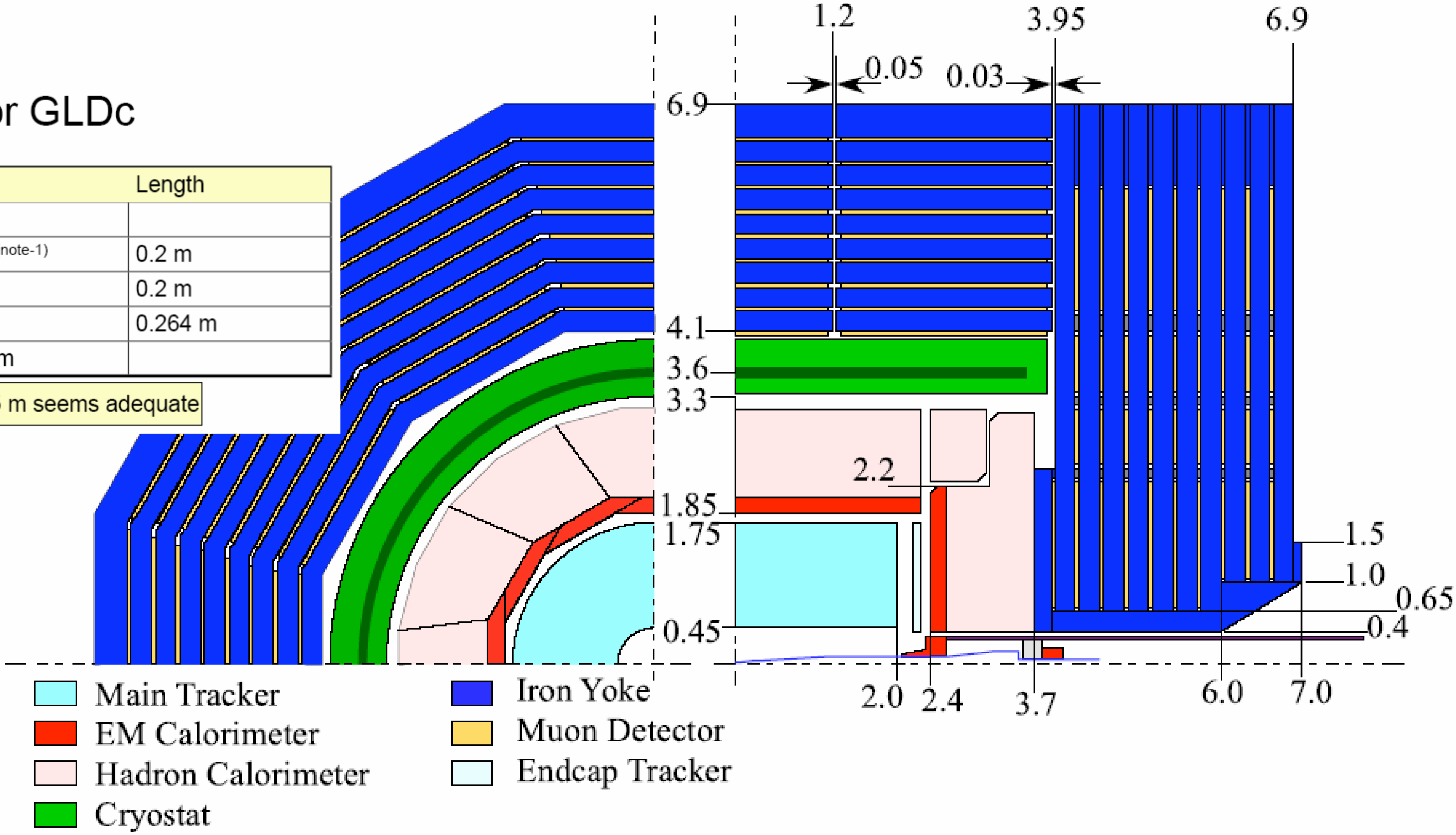


# Compact GLD ( GLDc )

## L* for GLDc

| Component | Start | Length |
|---|---|---|
| End cap yoke | 3.7 m | |
| BCAL | 3.8 m (note-1) | 0.2 m |
| BPM | 4.0 m | 0.2 m |
| QD0 cryostat | 4.2 m | 0.264 m |
| QD0 coil (L*) | 4.464 m | |

L* of ~4.5 m seems adequate



**T.Tauchi, Y.Sugimoto**