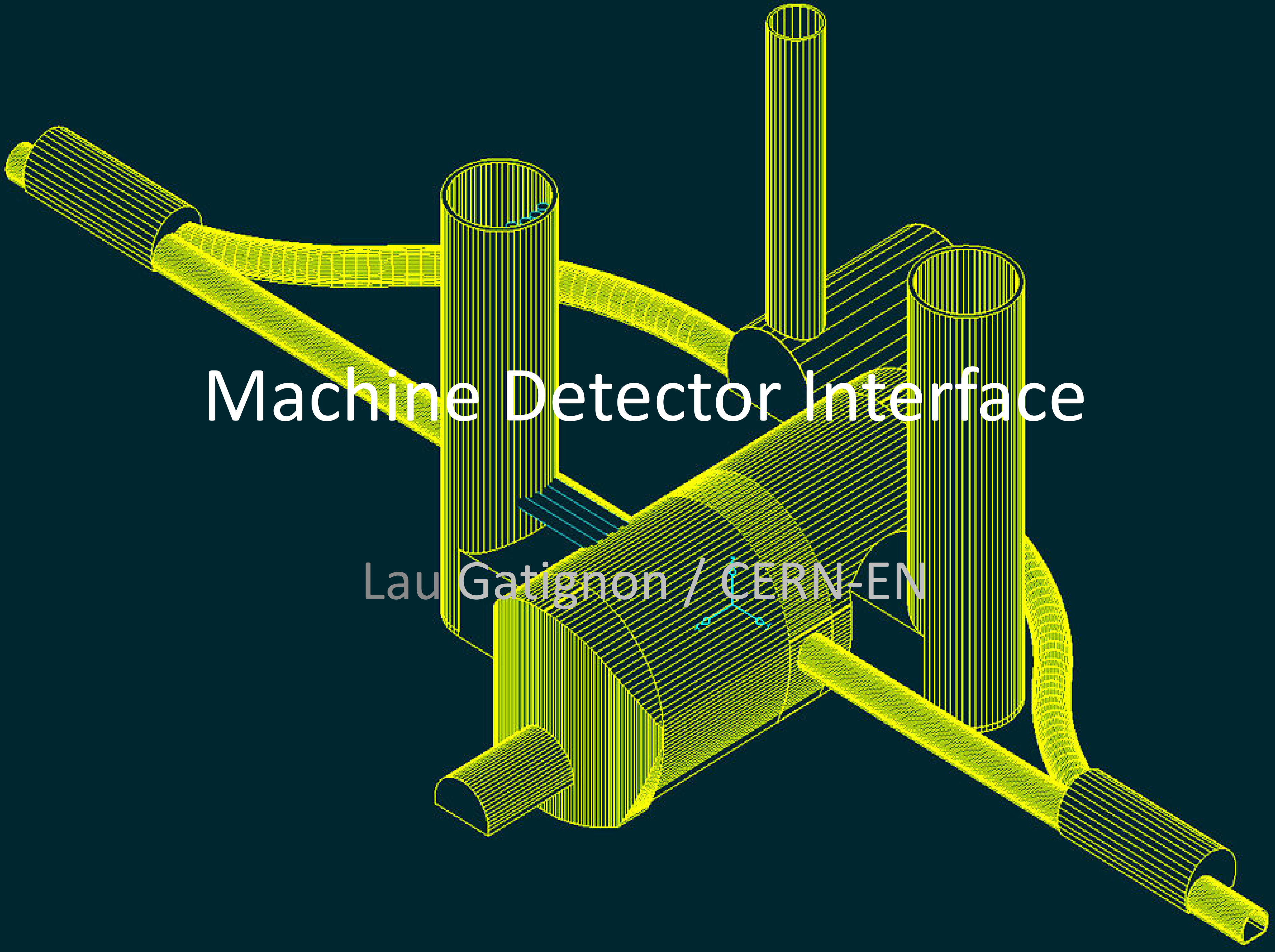
Machine Detector Interface

Lau Gatignon / CERN-EN



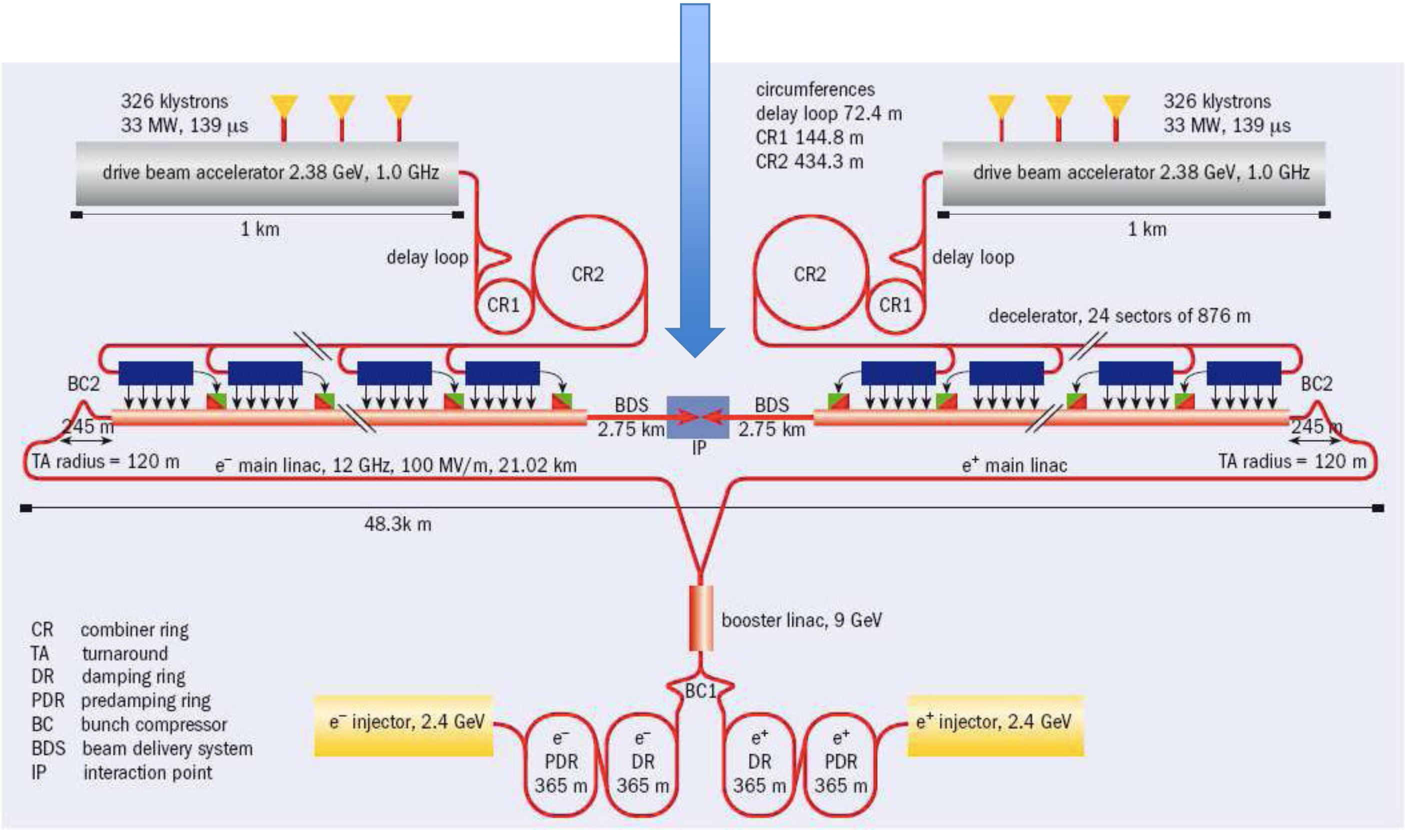
Overview

- Introduction to Machine Detector Interface
- QD0 magnet design
- QD0 stabilisation and integration
- Backgrounds
- Post-collision line
- IP Feedback
- Other items
- Conclusion

What is the MDI

The MDI is the part of the CLIC facility (approximately) inside the detector cavern, i.e. the area in which there is a strong coupling of technical sub-systems of the machine and of the physics detectors.

The lines for the spent beams shall also be considered part of the MDI.



CLIC PARAMETERS

Parameter	ILC	CLIC	Impact on MDI
Max. Center of Mass energy [GeV]	1000	3000	**Detector design, backgrounds**
Luminosity $L_{99\%}$ [cm^{-2} sec^{-1}]	$2\ 10^{34}$	$2\ 10^{34}$	**Instrumentation**
Bunch frequency [Hz]	5	50	
Bunch spacing [ns]	369	0.5	**Background, IP feedback**
# Particles per bunch	$2\ 10^{10}$	$3.7\ 10^{9}$	
# Bunches per pulse	2670	312	
Bunch train length [μs]	985	0.156	
Beam power per beam [MW]	9	14	**Spent beam line**
Bunch length [μm]	300	44	
Crossing angle [mrad]	14	20	
Core beam size at IP horizontal σ_x* [nm]	639	45	
Core beam size at IP vertical σ_y* [nm]	5.7	0.9	**QD0, stabilisation**

MDI Priorities

Highest priority for the work until end 2010 are those subjects linked to the “CLIC critical feasibility items”, nota bene:

- Choice of the **magnet technology for the FF magnets**
- **Integration of these magnets** into the detectors, and their alignment
- Feasibility study of sub-nm active **stabilization** of these magnets
- **Luminosity instrumentation**
- **Spent beam disposal**
- **Beam background backsplash** from the post-collision collimators and dumps into the detector
- **Intrapulse-Beam feedback systems** in the interface region

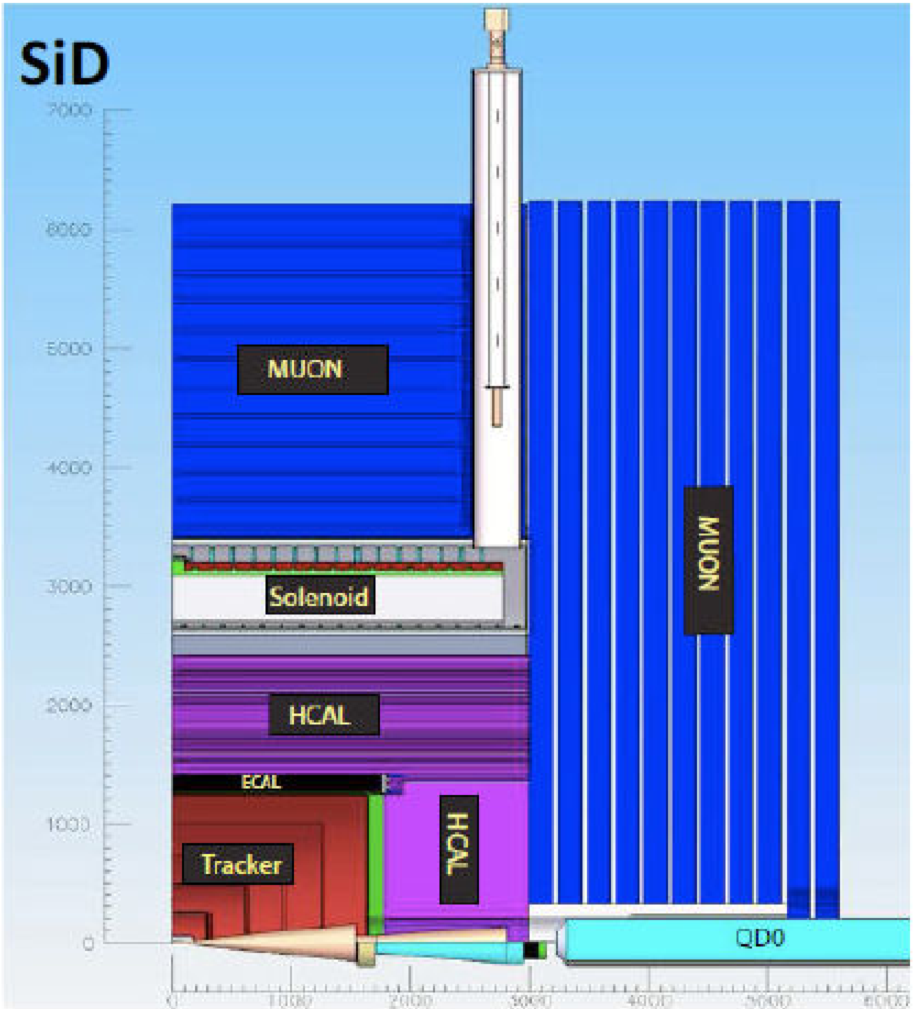
From the CLIC MDI working group mandate

Other items to be addressed in MDI:

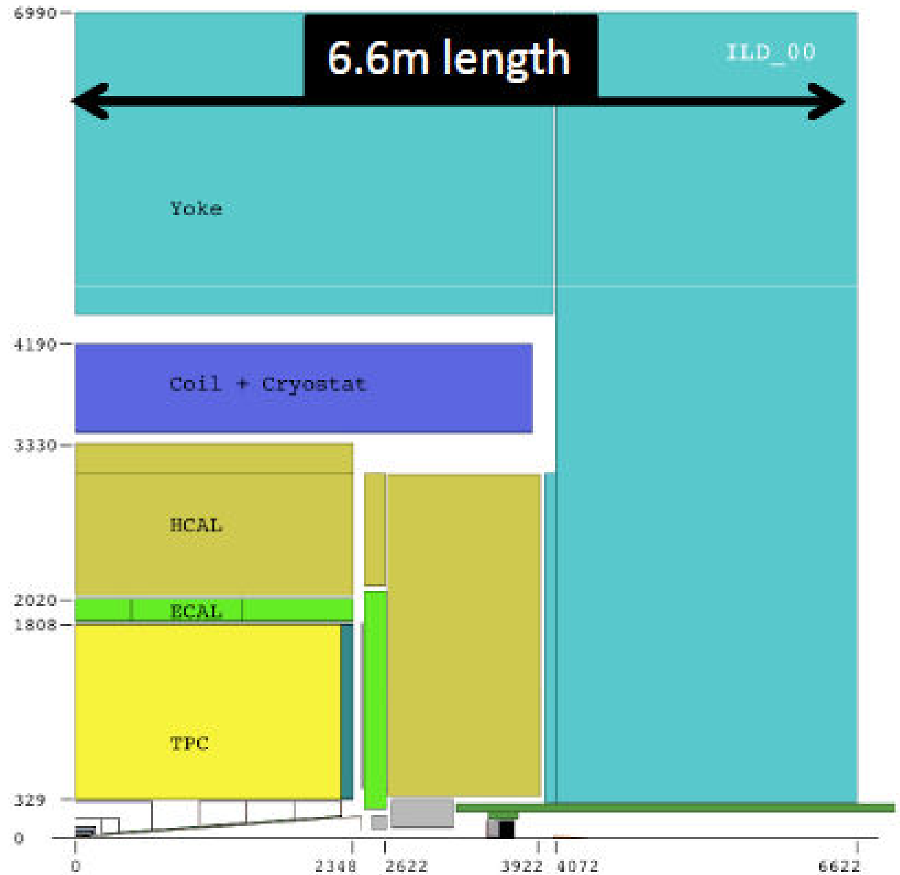
- Issues where the beam delivery system (BDS) influences the beam/**background** conditions for the detector
- Issues where the BDS physically impacts on the detector
- Beam **background** and its impact on the forward (det.+accel.) elements, including backsplash of **background** particles from one hardware element to the surrounding elements
- Beam pipe, beam vacuum and vacuum infrastructure in the interface region
- Radiation environment and radiation shielding in the interface region
- Cryogenic operational safety issues in the interface region
- Magnetic environment in the interface region (shielding of FF quadrupole, correction coils, anti(-DID), stray fields from the detector, etc.)
- Overall mechanical integration (including the routing of services) in the interface region
- Pull-push elements and scenarios (detector-to-detector interface)
- Cavern layout and services (handled principally under CES WG)

From the CLIC MDI working group mandate

ILC Detector Concepts



ILD



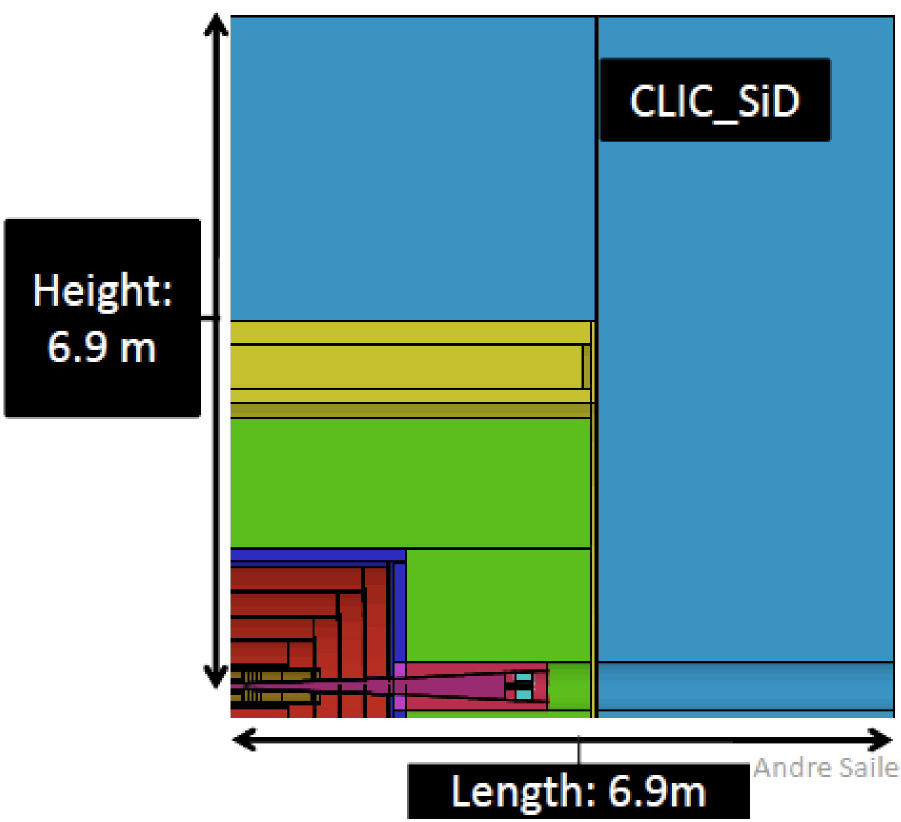
Andre Sailer - LCD Layout - MDI 2

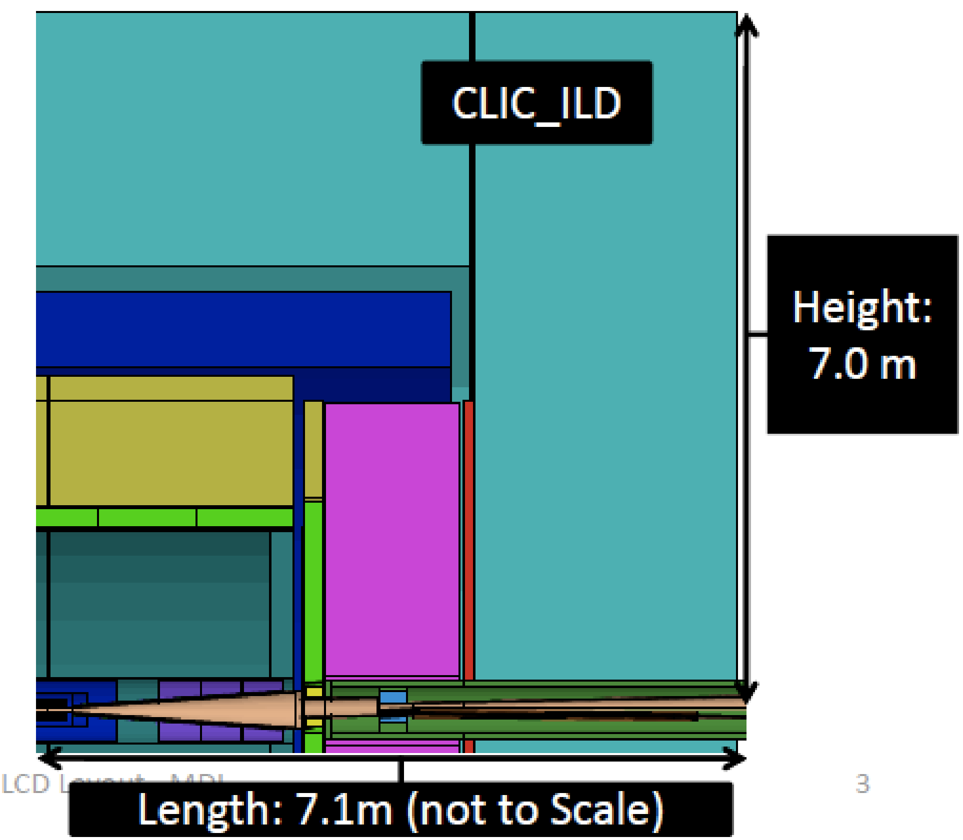
From ILC to CLIC Detectors

- Detectors for CLIC (3 TeV) are based on the two Detectors for ILC (500GeV)

Changes:

- 20 mrad crossing angle (instead of 14 mrad)
- Vertex Detector, due to Beam-Beam Background
- Hadron Calorimeter (due to higher energetic Jets)
- For CLIC_SiD: Moved Coil to 2.9m (CMS Like)



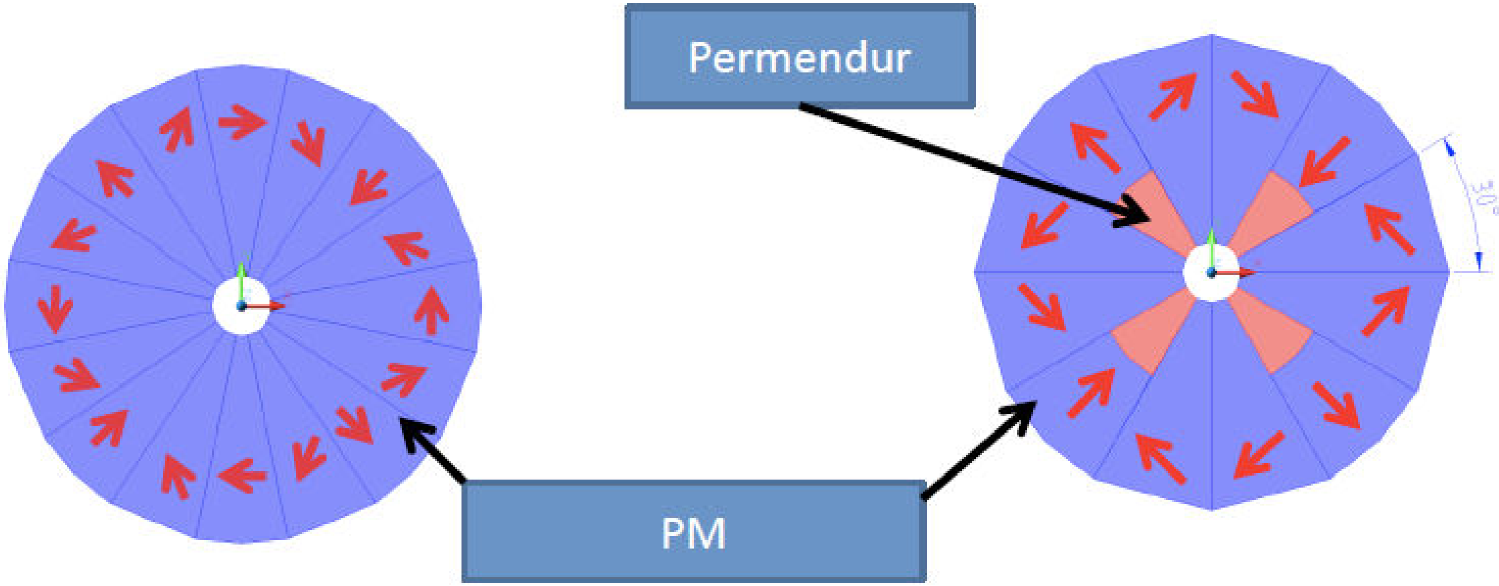


Final Focus Quadrupole (QD0): Parameters

Parameter	Value
Gradient [T/m]	575
Length [m]	2.73
Aperture radius [mm]	3.83
Outer radius [mm] *– for spent beam*	< 50
Peak field [T]	2.20
Tunability of gradient from nominal	[-10%, 0%]

A conceptual design has recently been proposed by TE-MSC
see presentation by M.Modena tomorrow

"Halbach" vs. "Super Strong" performances:



	R=3.8 [mm] (no chamber)		R=4.125 [mm]	
Material	Sm_2Co_{17}	$Nd_2Fe_{14}B$	Sm_2Co_{17}	$Nd_2Fe_{14}B$
Grad [T/m] "Halbach"	450	593	409	540
Grad [T/m] "Super Strong"	564	678	512	615

CLIC MDI Meeting" on 27 August 2009, M. Modena – CERN TE/MSC

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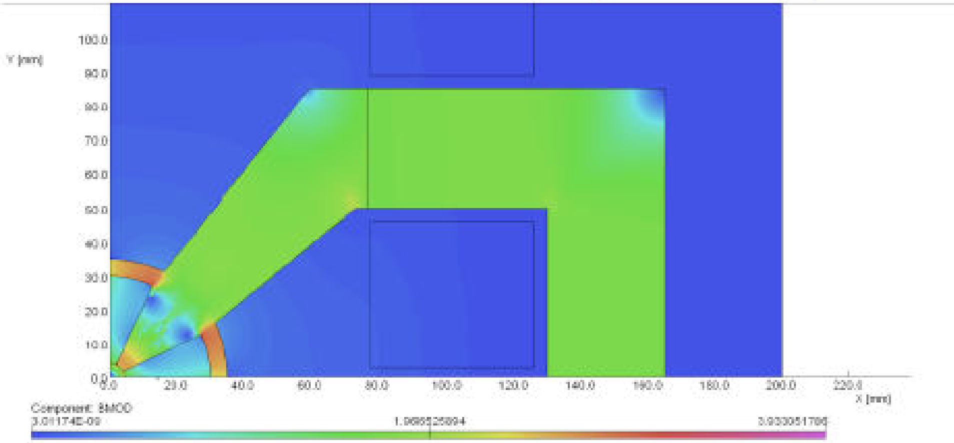
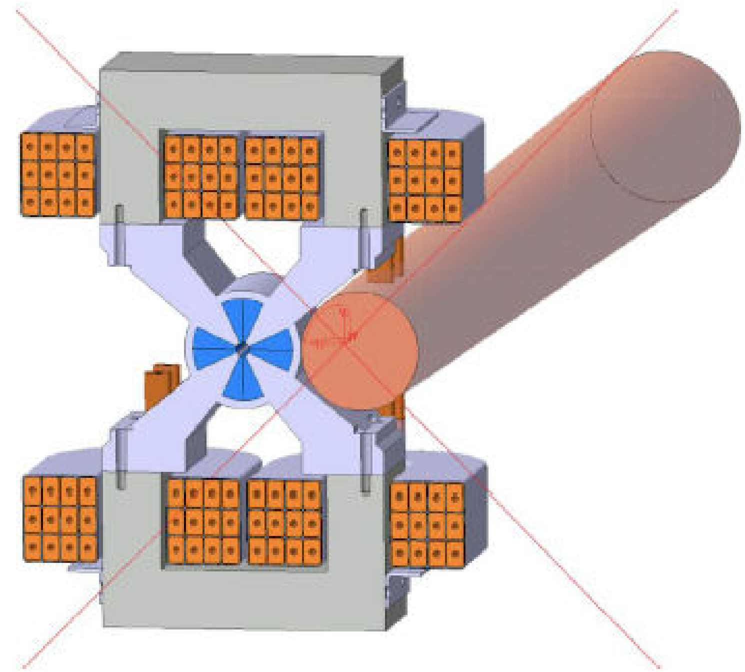
"Hybrid" approach, Version 2:





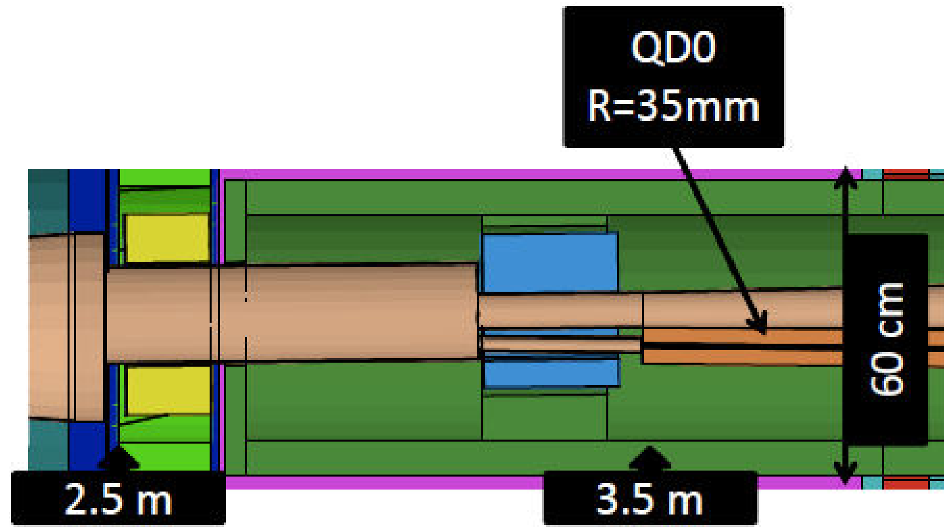
	Iw=5000 [A]
Grad [T/m] Sm_2Co_{17}	531
Grad [T/m] $Nd_2Fe_{14}B$	599

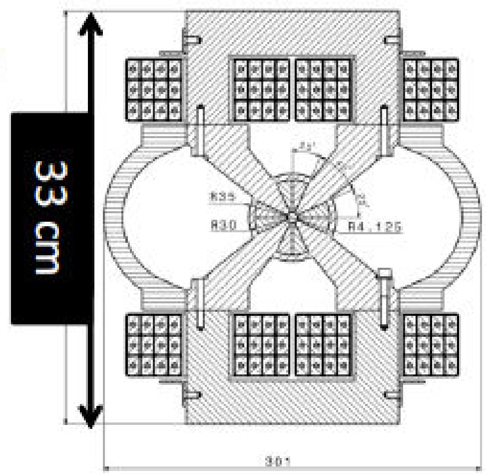
- The presence of the "ring" decrease slightly the Gradient (by 15-20 T/m) but will assure a more precise and stiff assembly

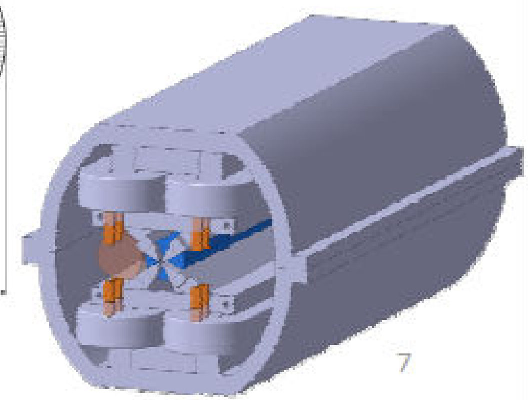
- EM Coils design will permit wide operation conditions (with or without water cooling) that can be critical for performances (ex. stabilization)

QD0

- Inner radius for Endcaps
  - CLIC_ILD: 35 cm
  - CLIC_SiD: 26 cm
  - Add ~10 cm masking
    - Protect Calorimeter
  - Anti-Solenoid?
- QD0 Prototype
  - 33cm height
  - Should fit into forward region
  - Easier for CLIC_ILD than for CLIC_SiD
  - How is the Magnet attached to support structure?
  - How far do the coils extend beyond 3.5 m?







QD0 Stabilisation

- Any movement (vibration) of the QD0 quadrupole would lead to a deplacement of the beam at the IP comparable to the movement of the magnet
- As the vertical spot size is about 1 nm, the quadrupole position must be stabilised to 0.15 nm in the vertical plane and 5 nm in the horizontal plane for frequencies > 4 Hz.
- Beam-beam feedback will help.
- A R&D program is under way for the stabilisation, based on passive and active stabilisation and cantilever based stabilisation.
- The integration in the experiment (push-pull) is still an open issue. Studies are under way.
- A review of stabilisation options is planned around the end of the year.
- In case the L^*=3.5 m (present baseline) option seems unrealistic, larger L^* values may have to be considered for the CDR

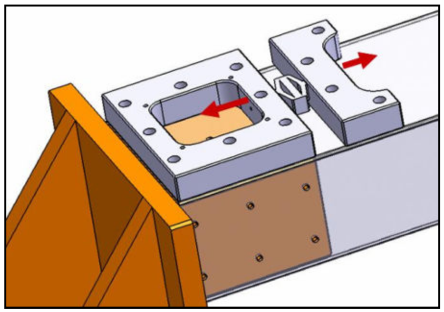
See presentation by A.Jeremie in the parallel session tomorrow

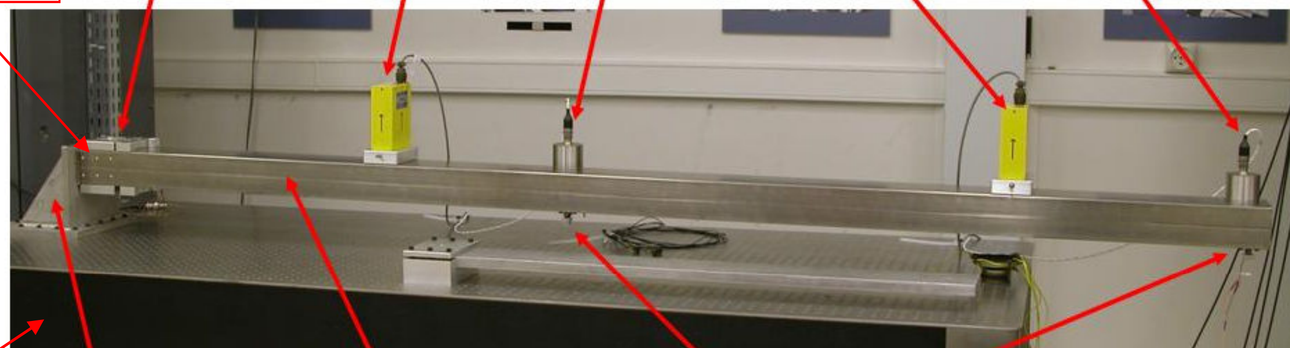
Achieved performance

LAPP active system for resonance rejection

Actuator in flexion

Seismic sensor (accelerometer and velocity sensor)

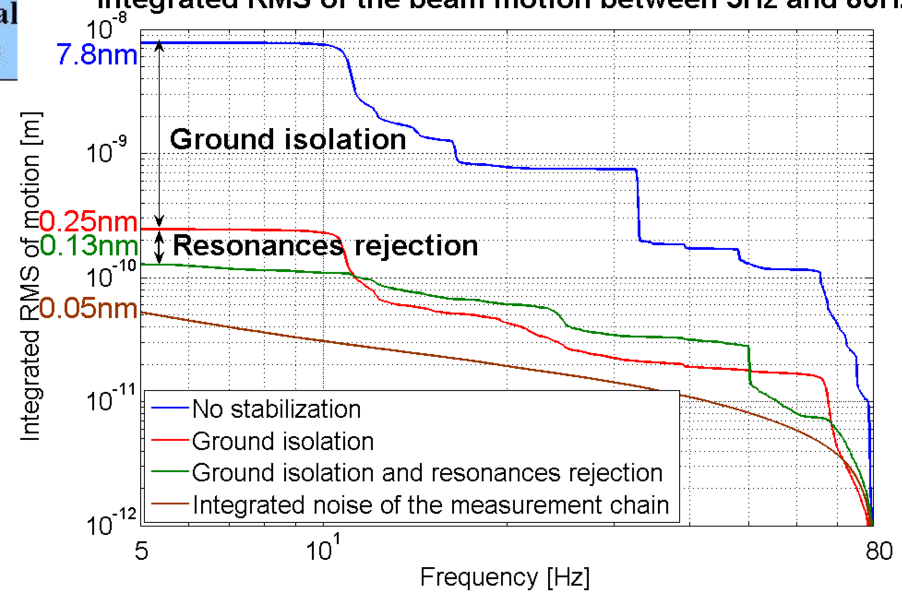




Clamping

Mechanical structure

CERN TMC active table for isolation

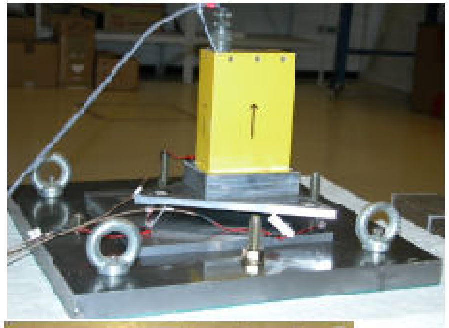


- **The two first resonances entirely rejected**
- **Achieved integrated rms of 0.13nm at 5Hz**

Courtesy A.Jeremie

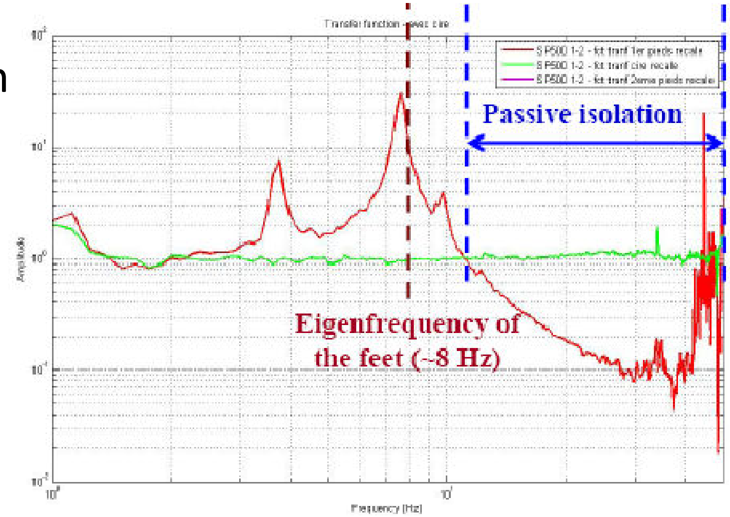
Current work

Replace big stabilisation table by a compact passive+active stabilisation system



Active system

Passive system



Instrumentation study (sensors and actuators)

- **Seismometers** (geophones) — Velocity
- **Accelerometers** (seismic - piezo) — Acceleration

electrochemical

Streckeisen STS2

Guralp CMG 3T

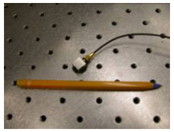
Guralp CMG 40T

Eentec SP500

PCB 393B31

Endevco 86

PCB 393B12

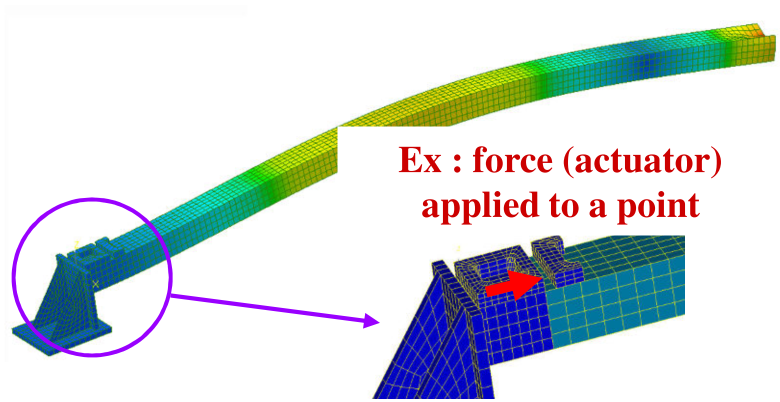


B&K 450B3

Courtesy A.Jeremie

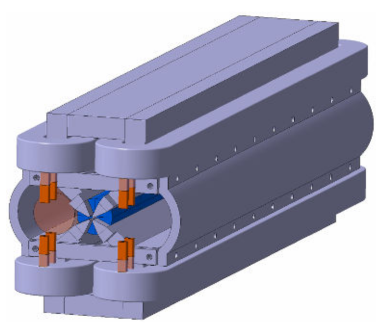
Current work

Simulations



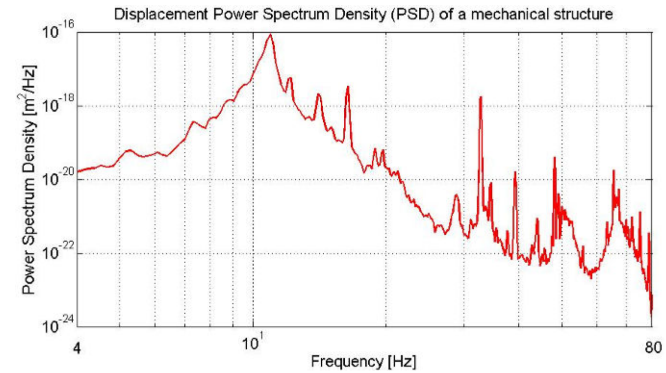
SAMCEF	MATLAB	Simulink
FE Model Creation →	State-Space Model Creation →	State-Space Model Use

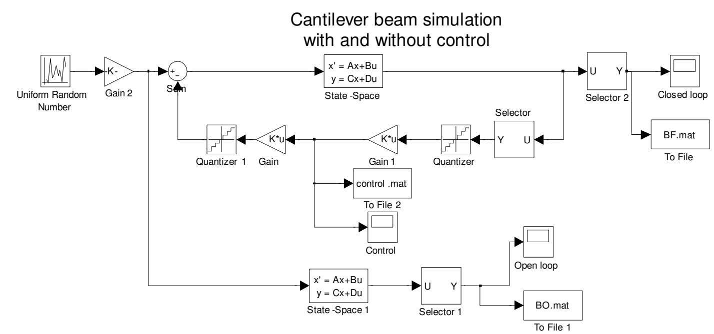
FF magnet design



Evgeny Solodko

Feedback development



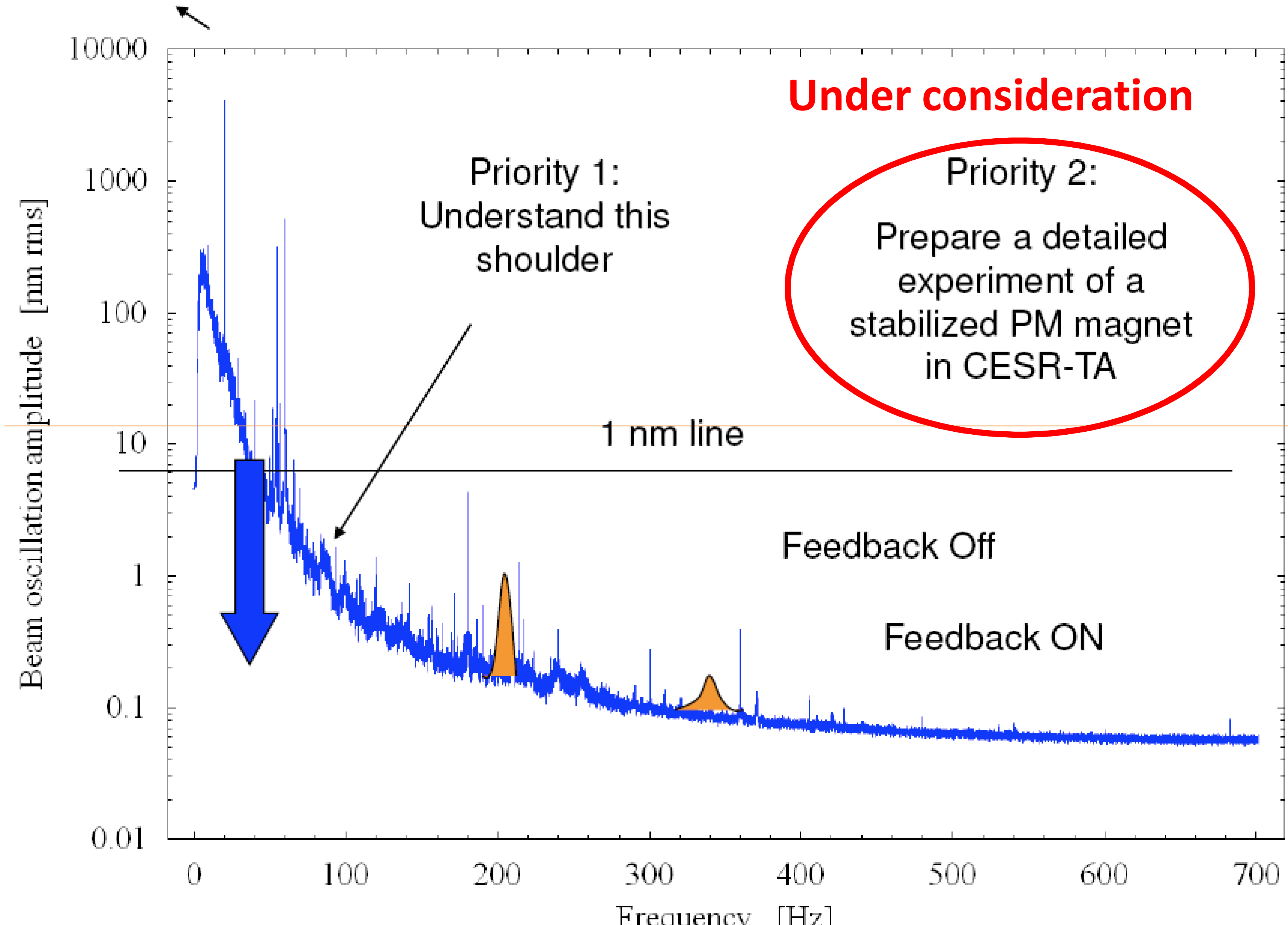


Different strategies studied:

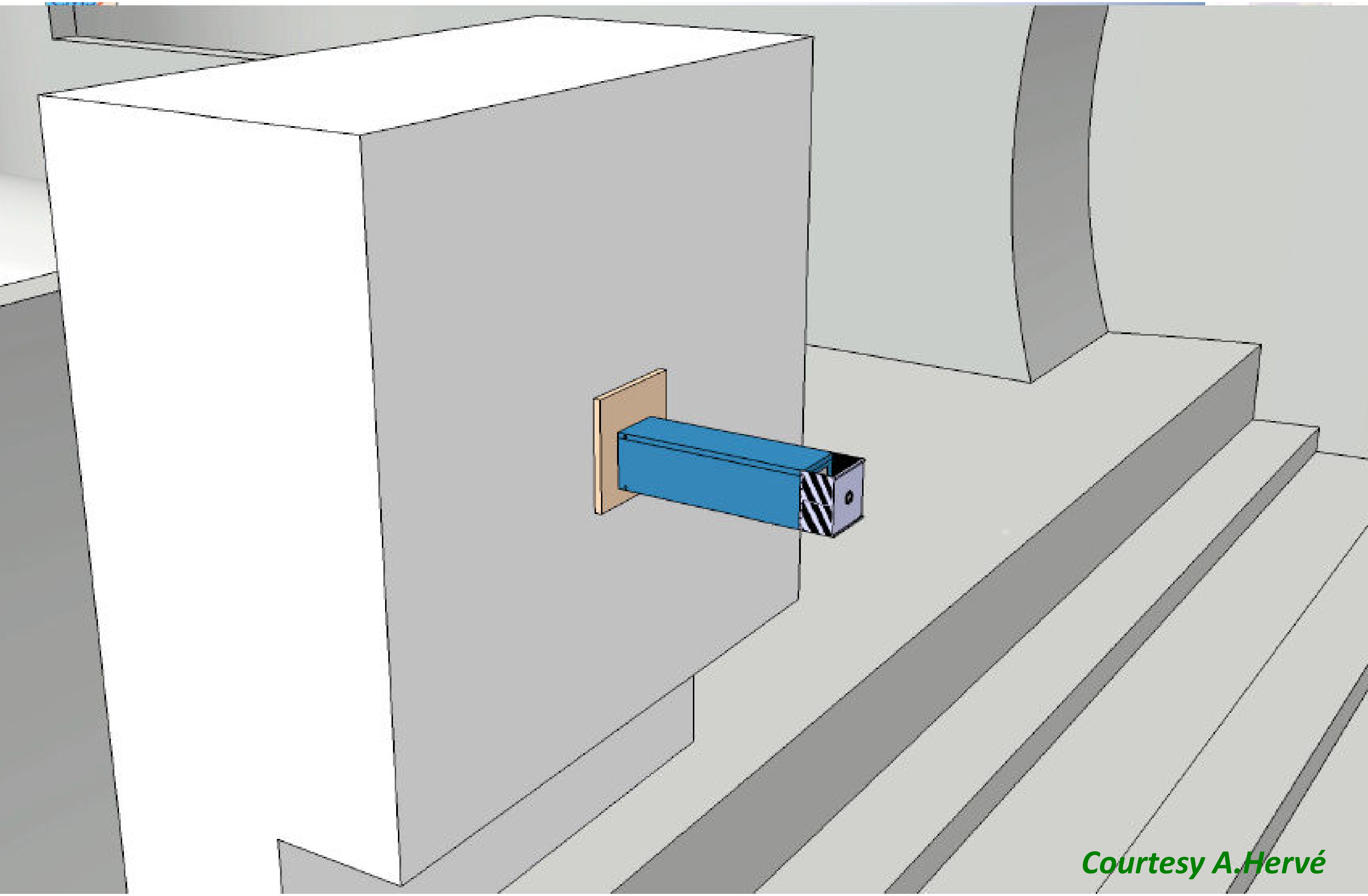
- A knowledge only at strategic points
- A local model for the disturbances amplified by eigenfrequencies.
- A complete model

From H.Schmickler

Perspectives for the future



QD0 Integration concept: first ideas



Vibration measurements (e.g. recently in CMS cavern, with cooling off by Artoos, Guinchard) suggest once more that:

- The QD0 quadrupole shall NOT be suspended from the detector
- However, it must penetrate in the experiment to maintain peak luminosity
- The QD0 supporting system must be strengthened (and shortened?)

Solutions may exist if opening the experiment on the IP is abandoned.

This implies that special efforts must be made in the machine and experiment, insulating e.g. rotating machines and water pipes mechanically

See presentation by A.Hervé tomorrow

BDS/MDI IMPACT ON DETECTOR, BACKGROUNDS

Various effects occurring in the Beam Delivery System and Interaction Region impact significantly on luminosity, backgrounds and detector performance.

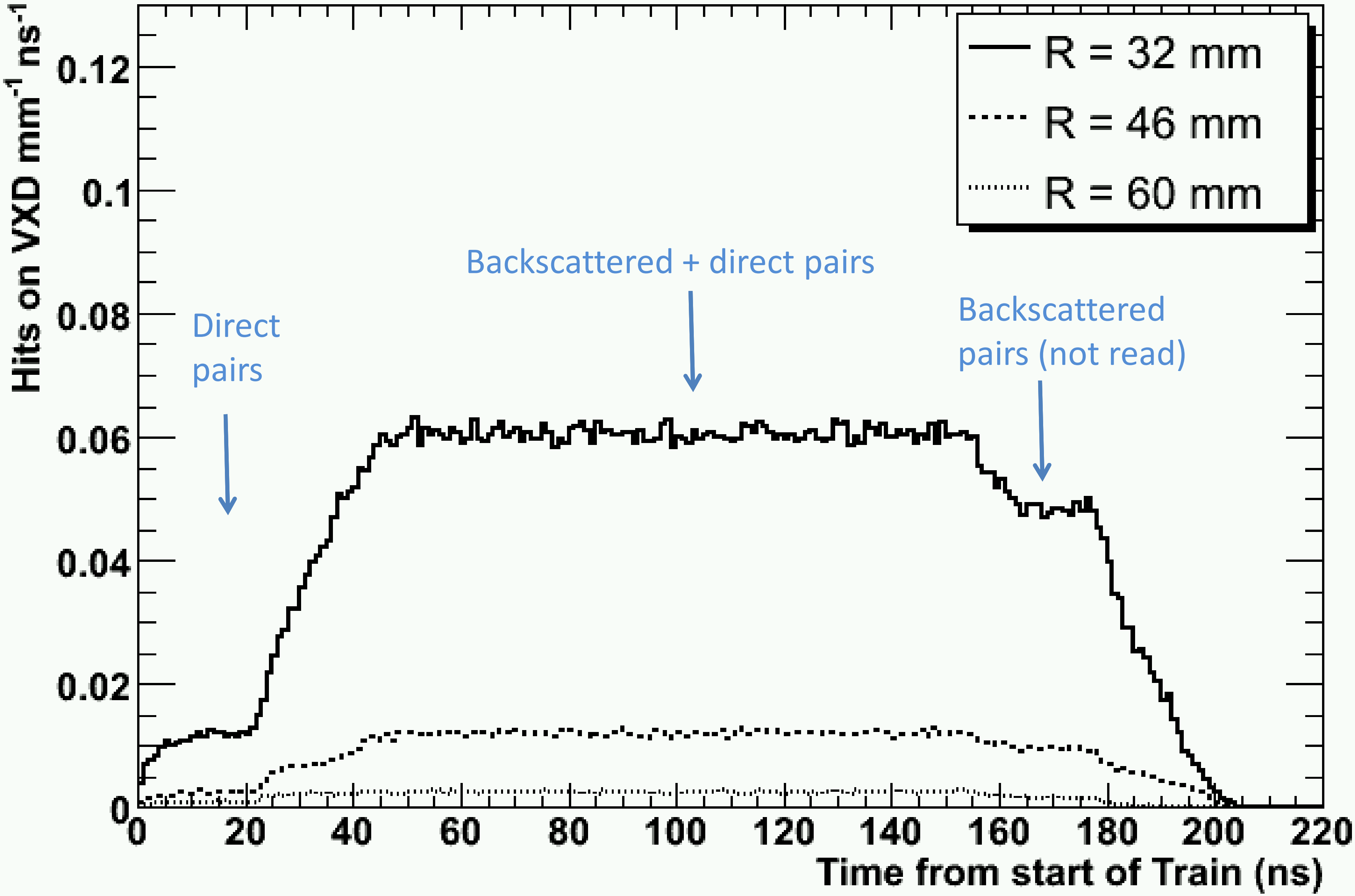
Effect	Consequences	How to deal with
Coherent pairs	Main background. Tails in CM energy Blow-up, e^+e^+, e^-e^-	Spent beam Crossing angle Detector design
Incoherent pairs	Backgrounds, e^+e^+, e^-e^-	Detector
$\gamma\gamma \rightarrow$ hadrons	Backgrounds, radiation	Horiz. beam size at IP
Neutrons from dumps	Background via backscattering through spent beam aperture	Masks? Dump design and location
Muons from collimation	Backgrounds, e.g. catastrophic Bremsstrahlung	Magnetic shielding
Solenoid field + crossing angle	Couples to beam, luminosity reduction	Anti-solenoid *Crab cavities*

Pair production - Spent beam line

- Beam-beam interaction blows up & disrupts particles of opposite sign of main beam
- Pair production limits the minimum radius of the vertex detector
- Backscattering would cause serious background and radiation problems for the detector
- Therefore particles leaving the IP at up to 10 mrad must be transported away cleanly
- The energy contained in the outgoing beam is huge (14 MW) and must be dumped properly. A dump baseline design exists (ILC) but remains to be validated.
- The spent beam lines also houses instrumentation for luminosity monitoring, the background conditions for these detectors must be optimised
- Neutrons in the spent beam line and from the dumps remain to be simulated

See presentations in the parallel sessions

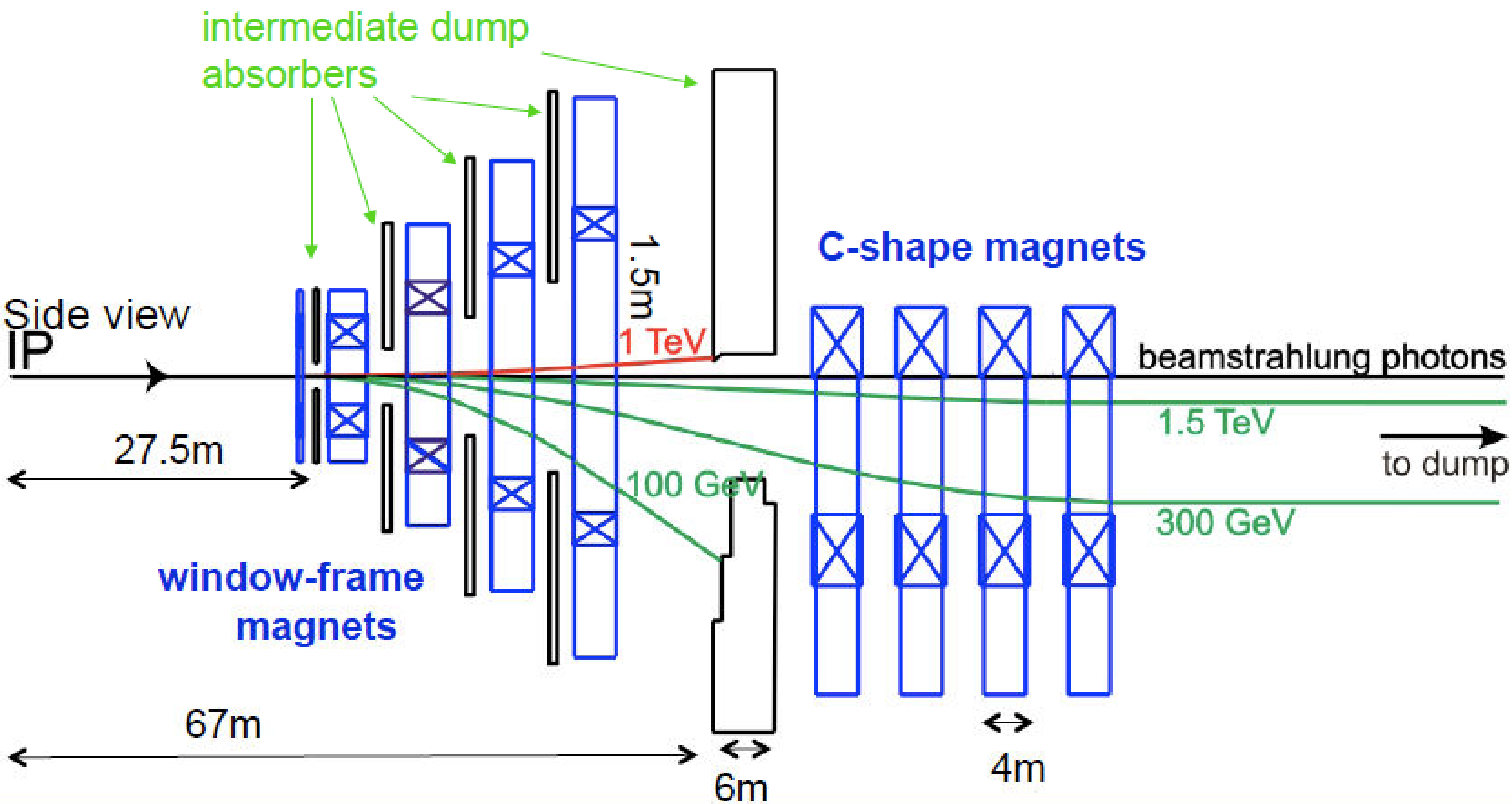
Courtesy M.Battaglia and A.Sailer



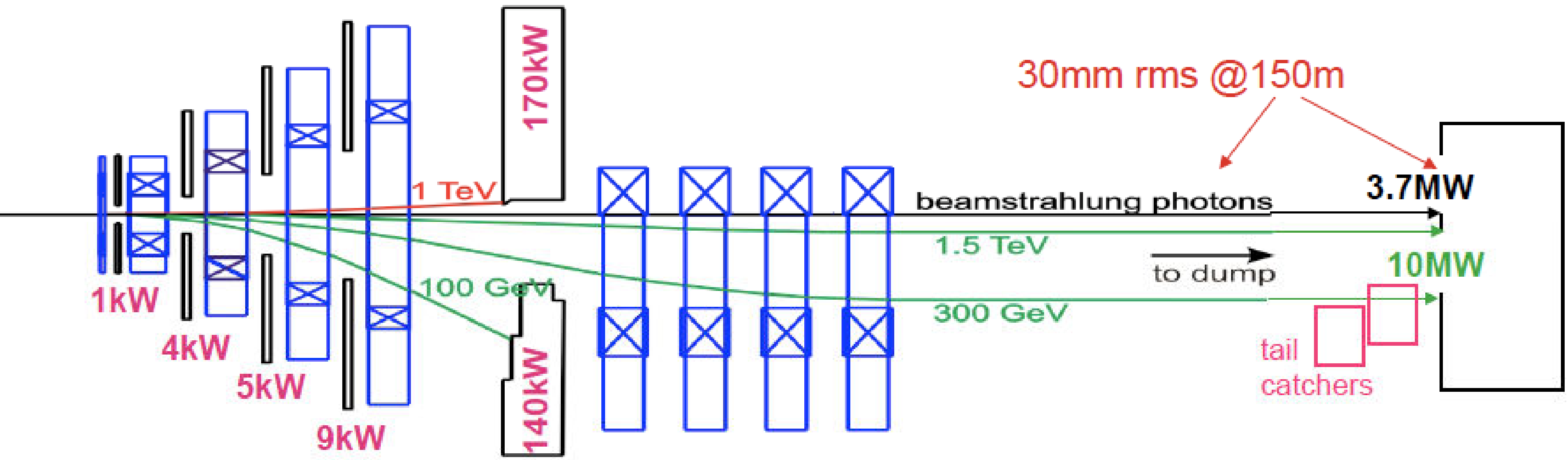
Present Conceptual Design (A. Ferrari, M. Salt et al)

Baseline: vertical chicane with dipole magnets to separate

1. particles from the e+,e- pairs with the wrong-sign charge and low energy tail
2. disrupted beam, beamstrahlung photon



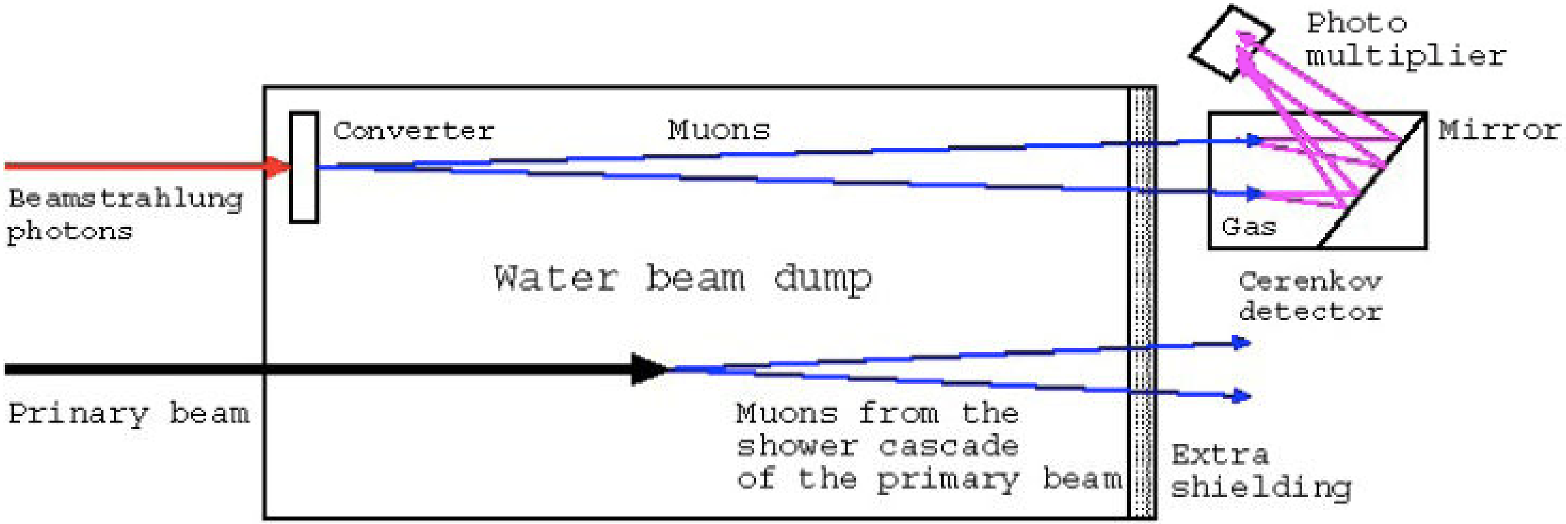
Power Deposition in Main Dump



Luminosity Monitoring: $\mu^+\mu^-$ pair production

- Converter in main dump → muons
- Cherenkov detector
  - ~4 E5 photons/bunch

EUROTeV-Report-2008- 016 .



→ To be studied in more detail: background, converter, detector, etc..

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E. Gschwendtner, EN/MEF

The water-based dump

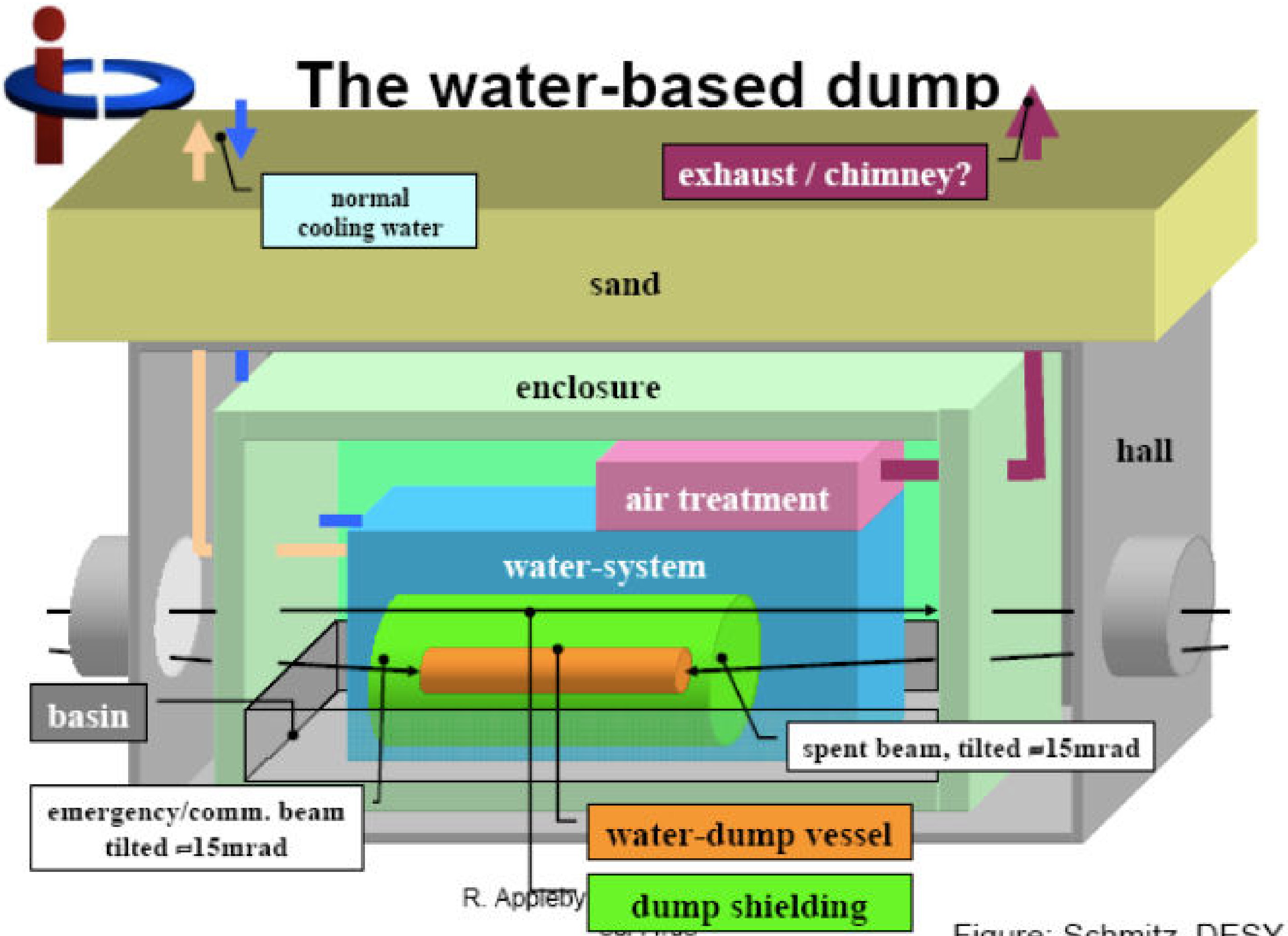
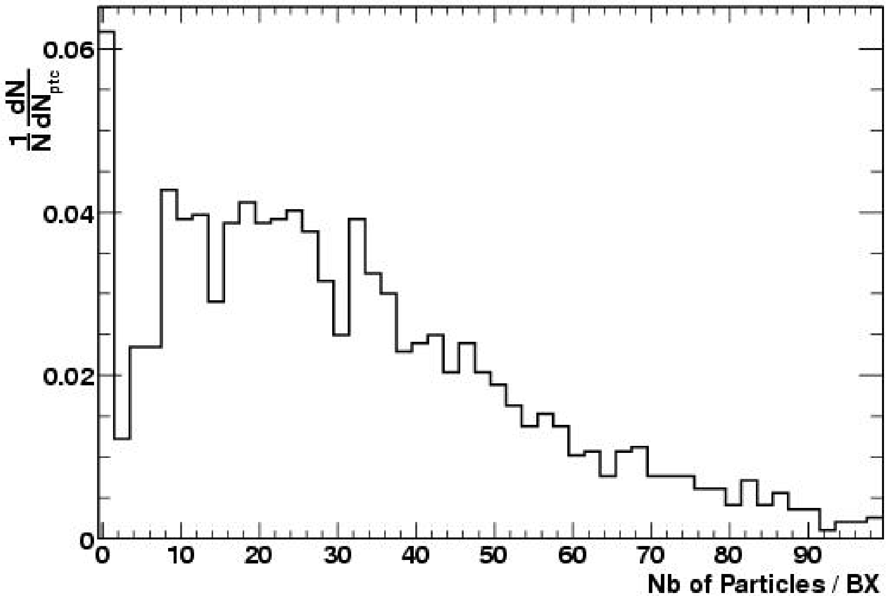
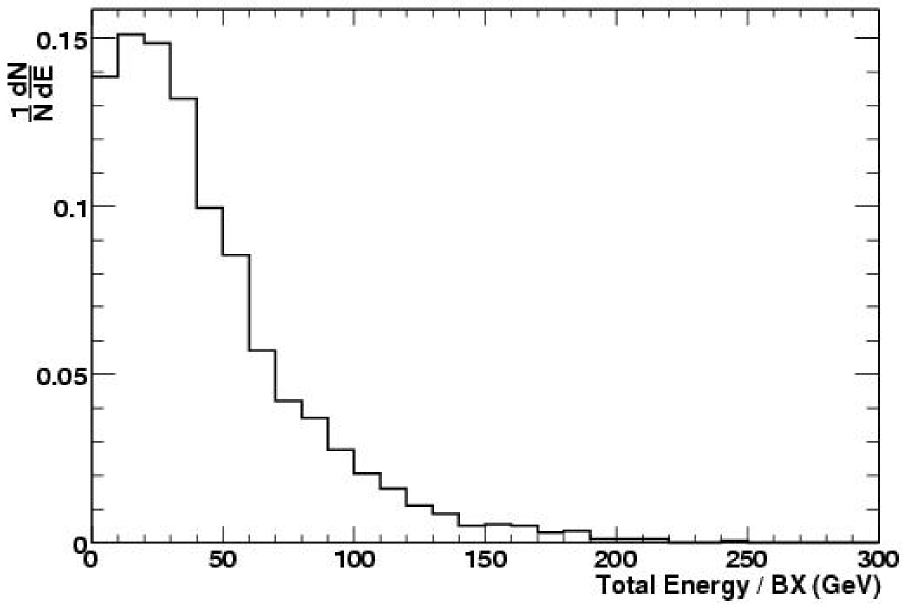


Figure: Schmitz, DESY

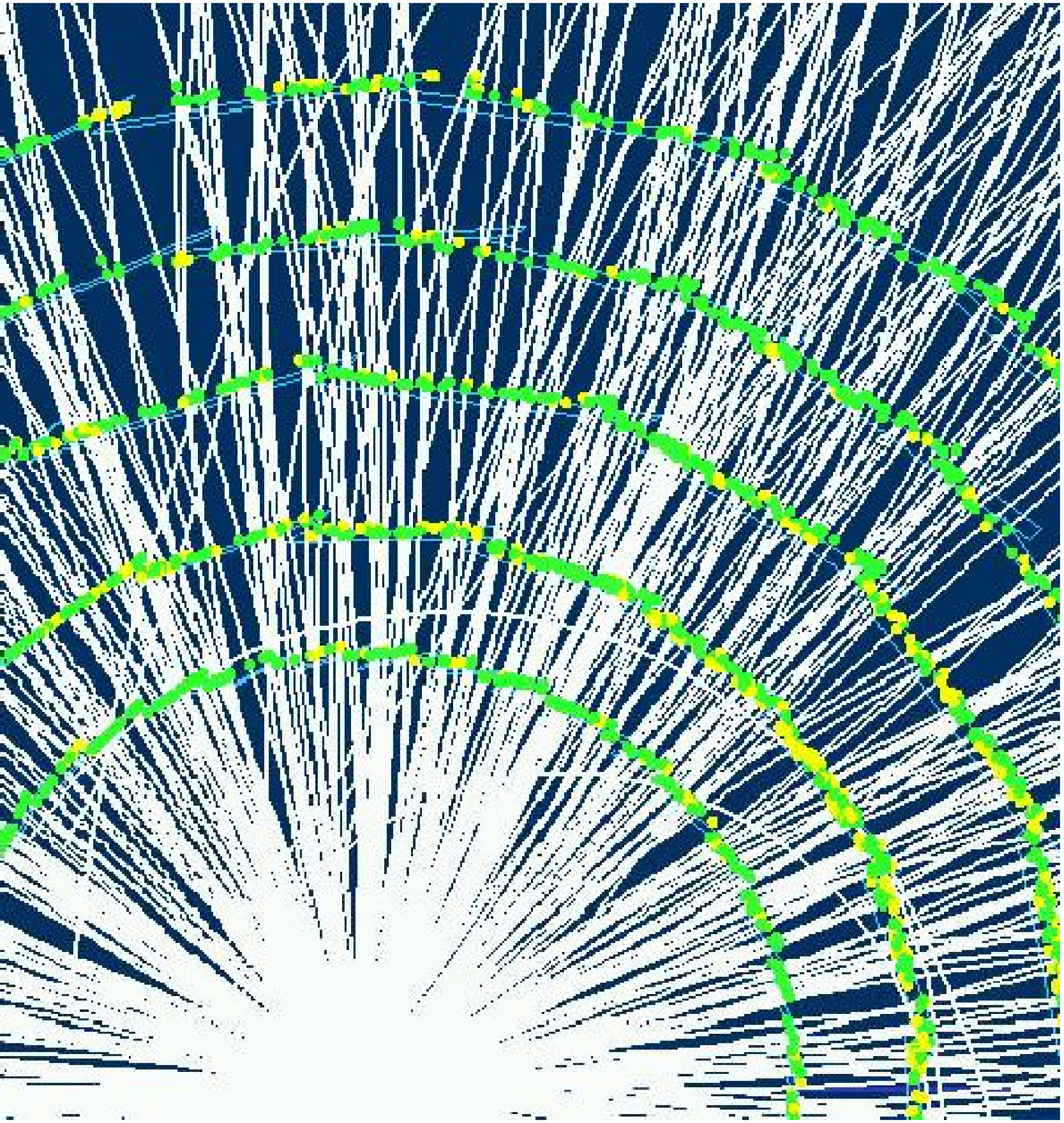
$\gamma\gamma \rightarrow$ Hadrons

This process gives a particle density in the vertex detector which is only about a factor of 4 lower than the background from incoherent pairs:





Courtesy M.Battaglia and D.Schulte

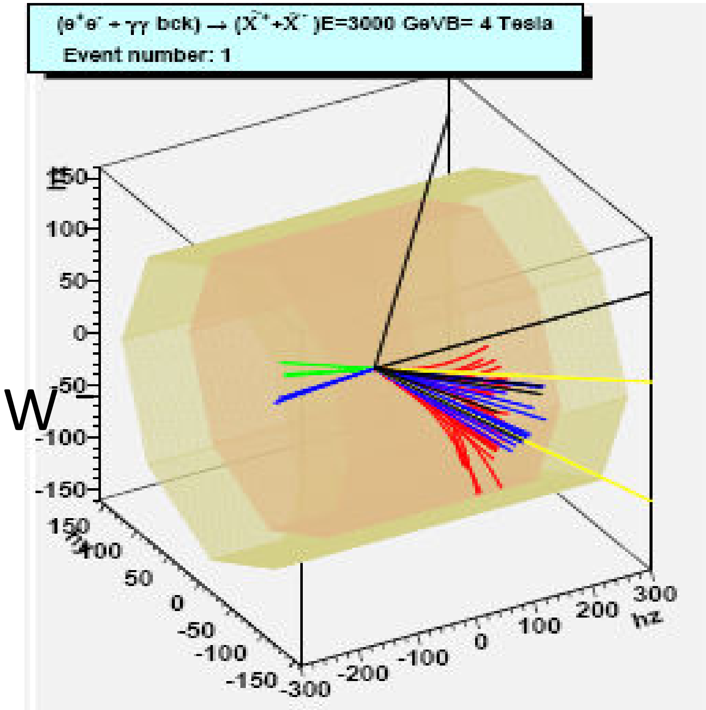


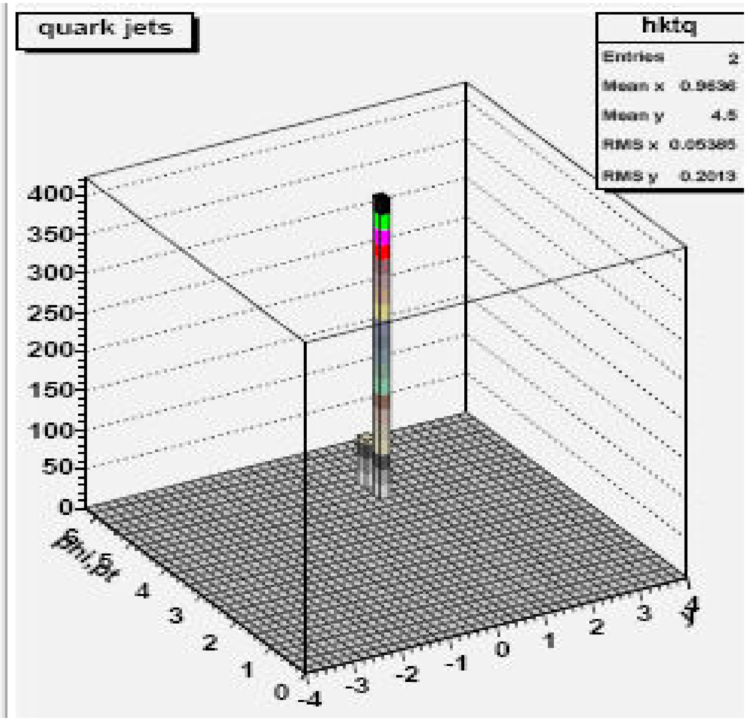
50 Bunch crossings of
$\gamma\gamma \rightarrow$ hadrons background
in the vertex detector

850 tracks reconstructed by local pattern recognition

Courtesy M.Battaglia

$e^+ + e^- \rightarrow \chi^+ + \chi^-$
$\rightarrow \chi^0 + \chi^0 + W^+ W^-$

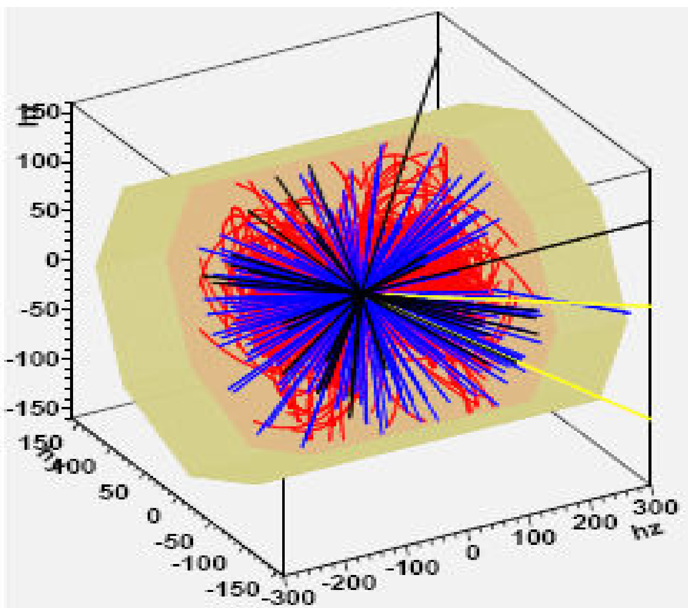


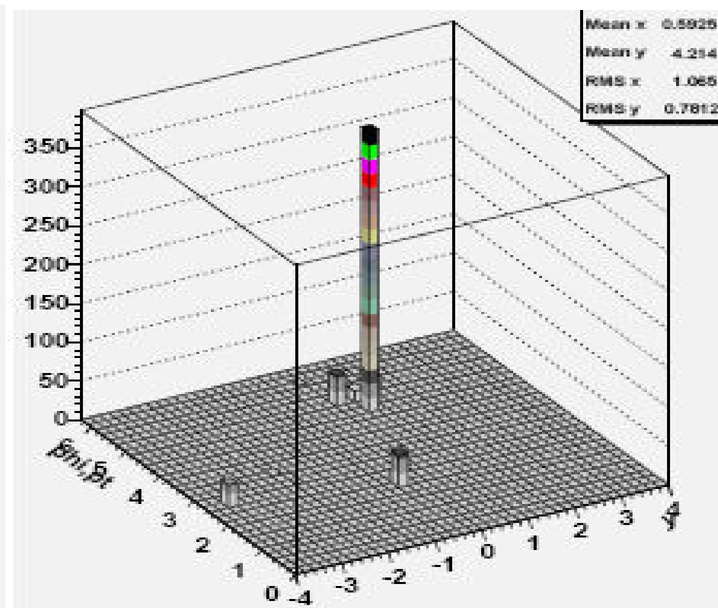


Without γ γ

Idem with 20 Bx
γ γ → hadrons
pile up.

The background may spoil the jet energy resolution and affect discrimination variables e.g missing energy, Θ ,....
But low E, P_t particles.



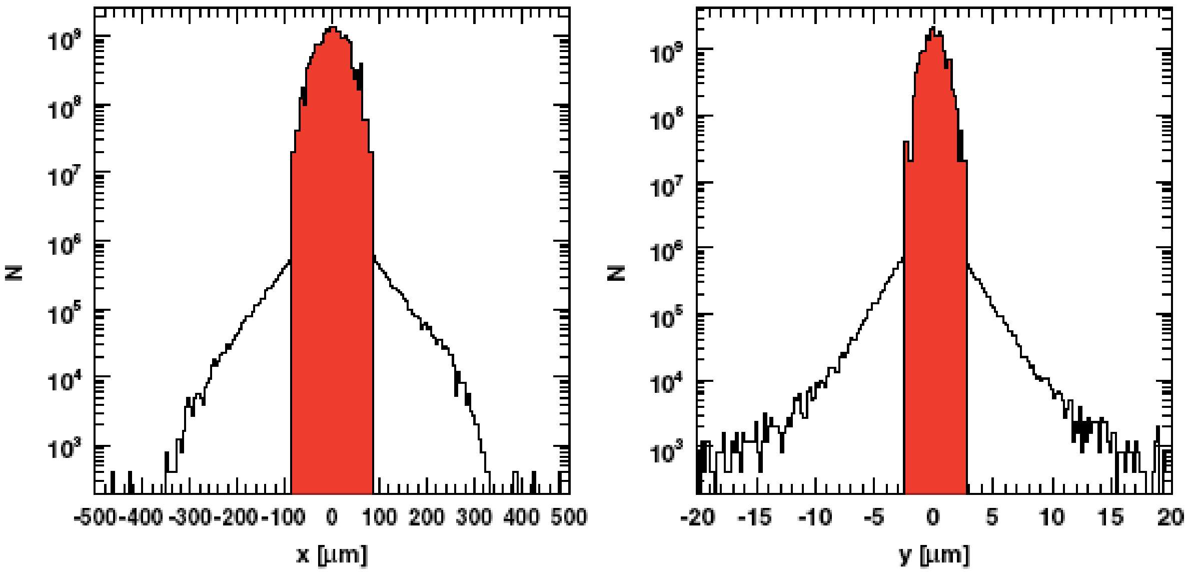


Courtesy JJ.Blaising

Muons from beam halo

Beam tails are scraped away by a collimation system in the BDS.
Below we show simulated profiles of the beam at the BDS entrance (core of beam in red)

From I.Agapov et al, 2009, to be published



From these simulations one estimates that a fraction 2 10^{-4} hit the collimators, i.e. about 2.4 10^{8} particles per train assuming a total flux of 1.24 10^{12} per train. Preliminary estimates indicate that out of those ~ 2 10^{5} would reach the detectors.

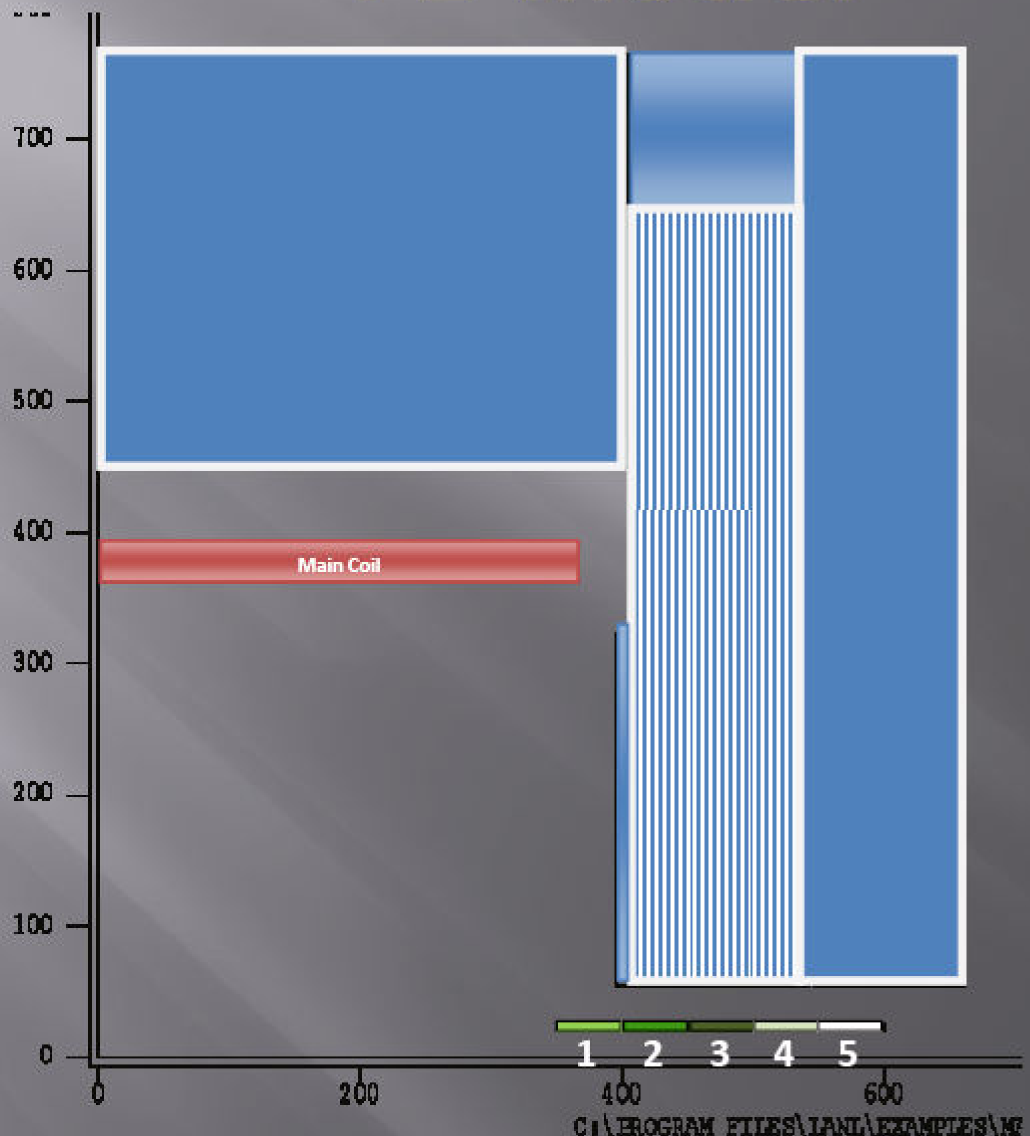
The final rates remain to be studied with BDSIM using the final and detailed geometry

See presentation by H.Burkhardt in BDS parallel session

ANTI-SOLENOID, ANTI-DID

- In the presence of a crossing angle, the beam couples to the longitudinal field of the main detector solenoid.
- The solenoid field would also affect the long-term stability of the permanent magnets in the QD0 quadrupole.
- A proposal has been made for a compensating solenoid around the QD0 quadrupole
  See presentation tomorrow by B.Dalena
- Its mechanical design, integration in the detector and impact on the QD0 stabilisation remains to be studied
- The anti-DID effect has been simulated, in particular its impact on the luminosity
  See presentation tomorrow by B.Dalena

FE model


700
600
500
400
300
200
100
0
Main Coil
1 2 3 4 5
0
200
400
600
C:\PROGRAM FILES\LANL\EXAMPLES\M

Intra-Pulse Feedback

Summary of latency times of different FONT tests:

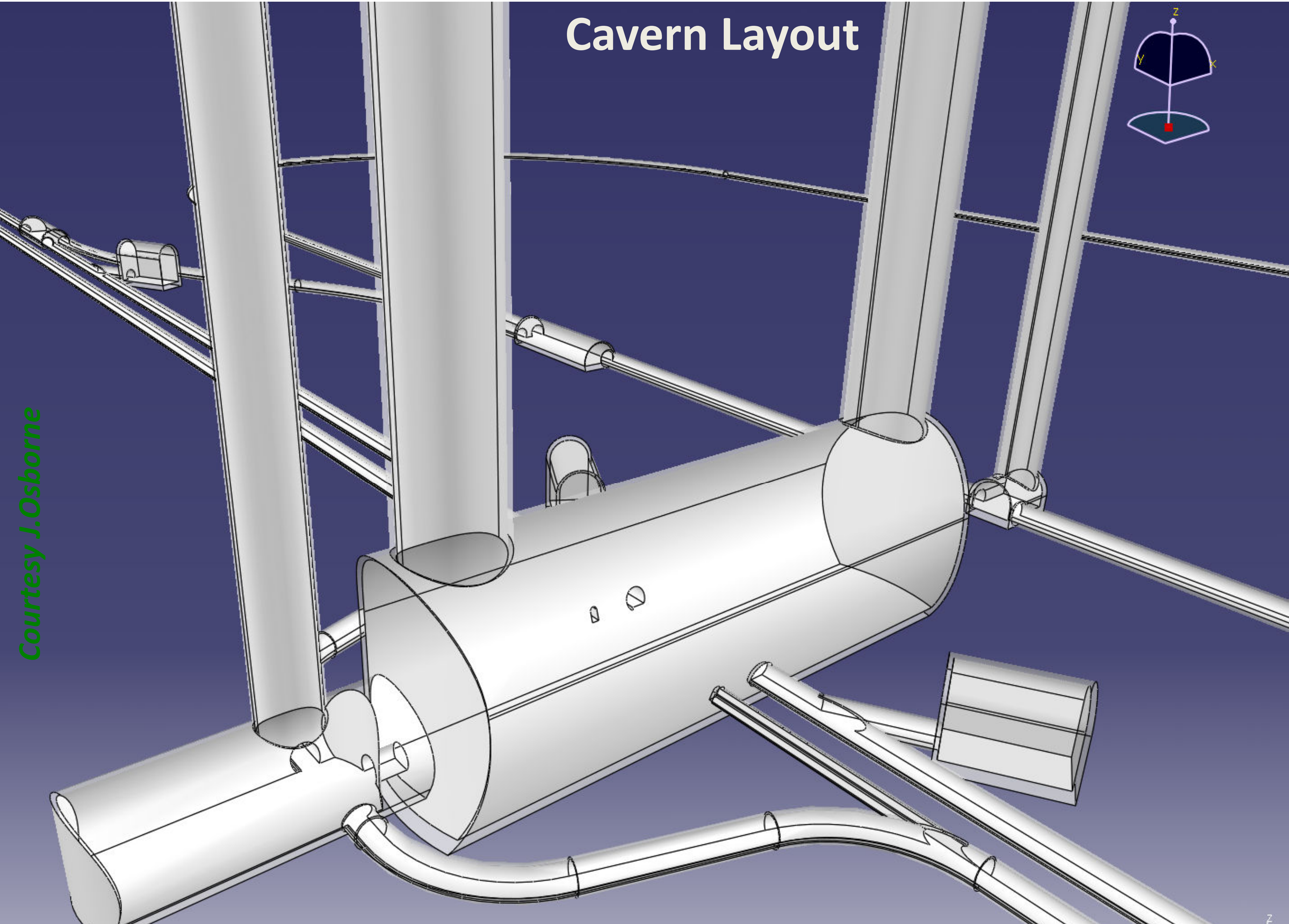
Test	Facility	Train length [ns]	Bunch spacing [ns]	Latency [ns]
FONT1 (2001-2)	NLCTA (SLAC)	170	0.087	67
FONT2 (2003-4)	NLCTA (SLAC)	170	0.087	54
FONT3 (2004-5)	ATF (KEK)	56	2.8	23
FONT4 (2006-7)	ATF (KEK)	420	140	132

Note: 23 ns is the **TOTAL** latency time: 10 ns (tof + signal return time) *Scales with distance*

plus 13 ns (electronics) *(Almost) invariant*

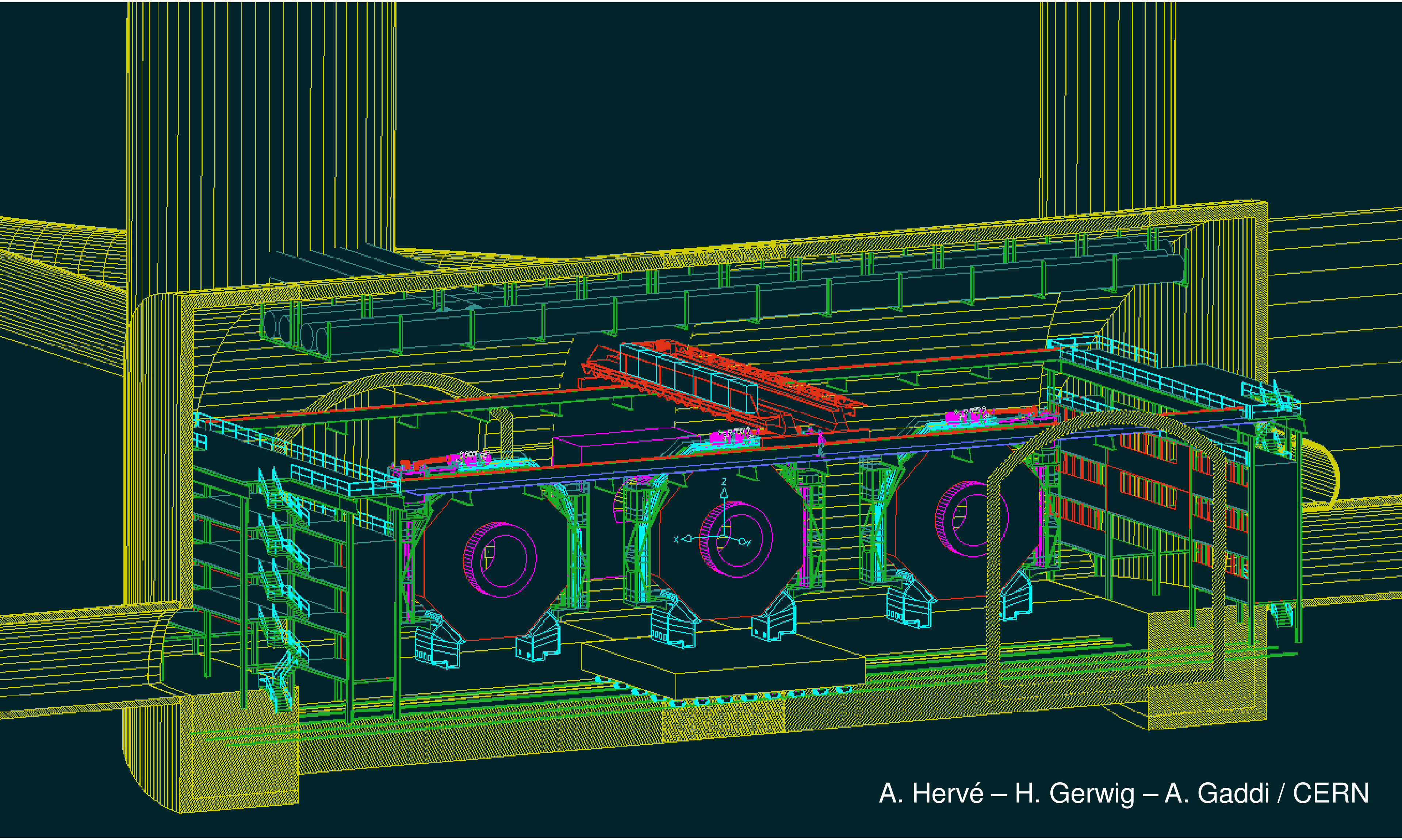
Latest status will be reported by J.Resta Lopez

Cavern Layout

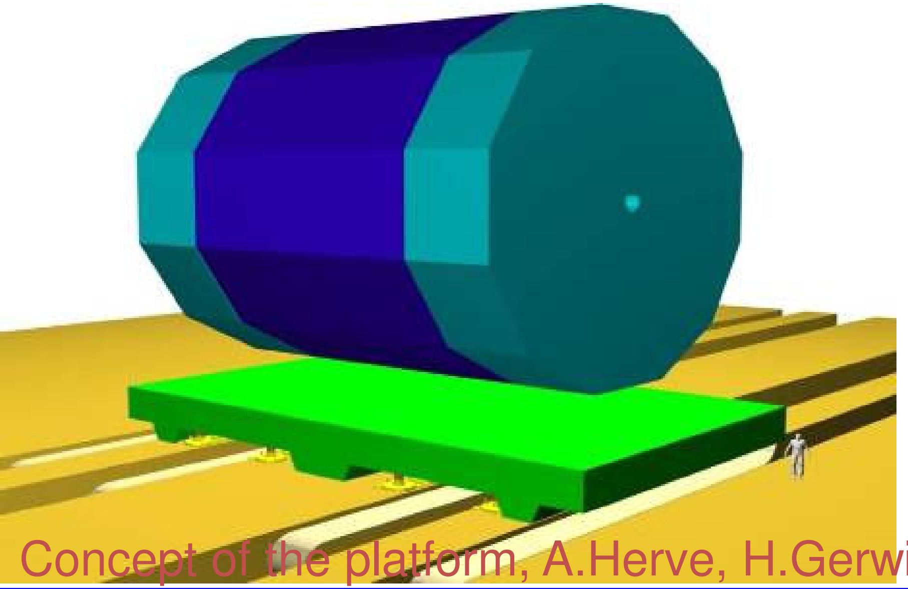


Based on ILC design

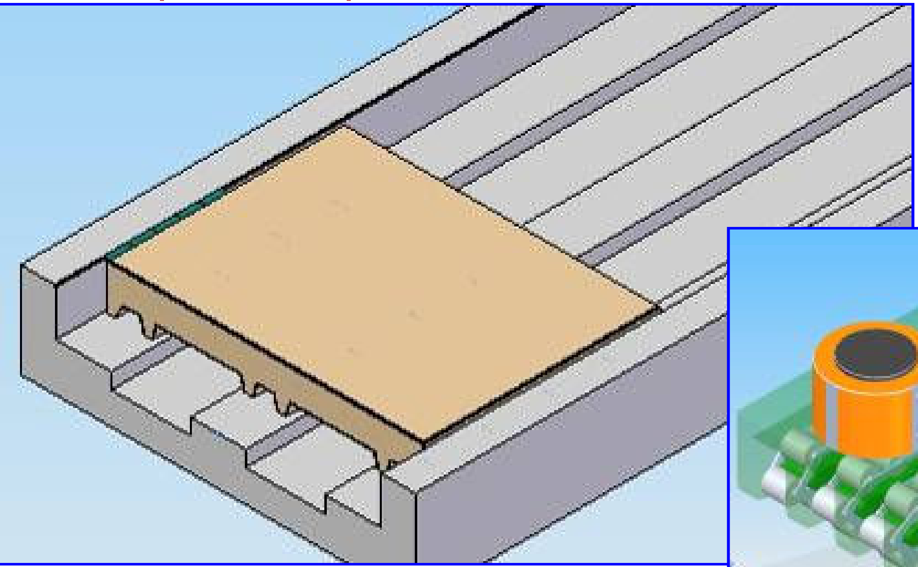
Cavern layout

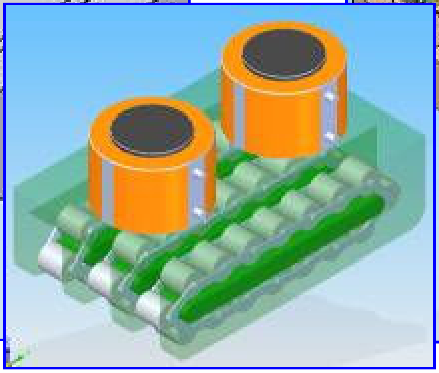


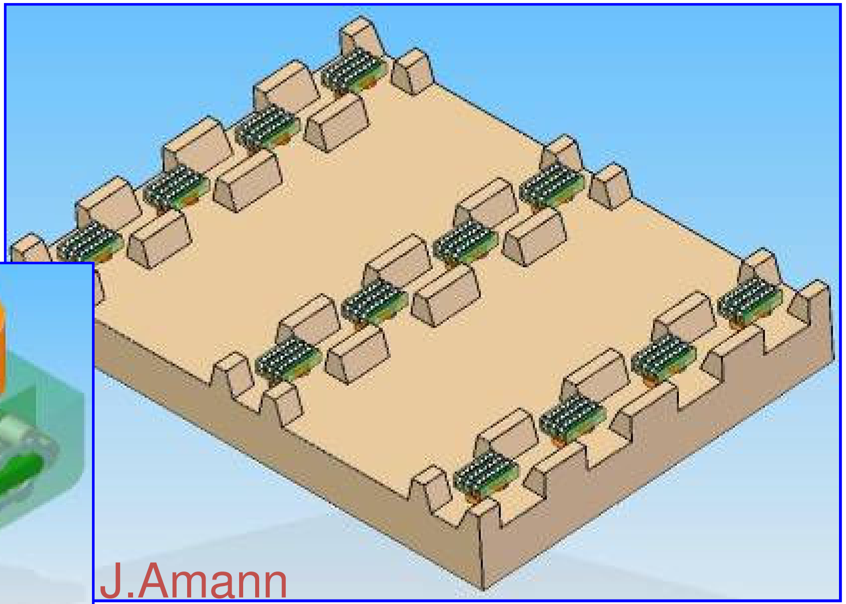
Detector moving



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







J.Amann

Summary and Conclusions

- The Machine Detector Interface region is full of challenges:
  - QD0 quadrupole
  - Its stabilisation and integration
  - Intra-pulse feedback system
  - Backgrounds
  - Handle the beam power of the spent beam
  - Vacuum
  - Civil engineering and services
  - ……..
- Work is going on enthusiastically to cope with these challenges towards a plausible solution for the CDR
- More details in the parallel sessions
- Thanks to the colleagues in the MDI group for their input