CLIC Machine-Detector Interface (MDI)

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CERN TS/LEA

CLIC Workshop 2008

Introduction

Mandate of MDI Working Group

- The CLIC Machine Detector Interface (MDI) Working Group provides a forum where those technically responsible for issues at the interface between the machine and experiments can meet and discuss matters of mutual interest in preparation for the CLIC Conceptual Design Report.
- The subjects treated cover technical items of common importance to the machine and experiments and include, but not limited to, the specification of the experimental areas, the experimental beampipes and vacuum, the estimation of the machine-induced background at the particle detectors, the radiation shielding and monitoring, the instrumentation in and around the particle detectors required to measure beam parameters, the data exchange and common safety issues.
- The Working Group will also provide a forum to discuss issues of common interest for the machine and detector, such as the machine performance (luminosity and background measurement and monitoring) for the experiments.
- The Working Group acts in close collaboration with other CLIC working groups (Civil Engineering & Services WG, Beam Dynamics & Beam Delivery WG, Physics & Detector WG, and the Stabilisation WG) and reports to the CLIC Technical Committee.

Organization

- Membership
  - Co-Chairpersons : D. Schulte & E. Tsesmelis
  - Beam Delivery System design – R. Tomas Garcia
  - Machine-induced background – H. Burkhardt
  - Collimation system – F. Zimmermann
  - Luminosity performance simulations – J. Resta-Lopez
  - Design and integration of post collision beam line – K. Elsener, V. Ziemann
  - Experimental beam pipe & vacuum – R. Veness
  - Final Focusing Magnets Studies – D. Swoboda
  - Representatives from relevant CTC WGs
    - Civil Engineering & Services WG - J. Osborne
    - Beam Dynamics & Beam Delivery WG - D. Schulte
    - Physics & Detector WG - A. Gaddi
    - Stabilisation WG – C. Hauviller

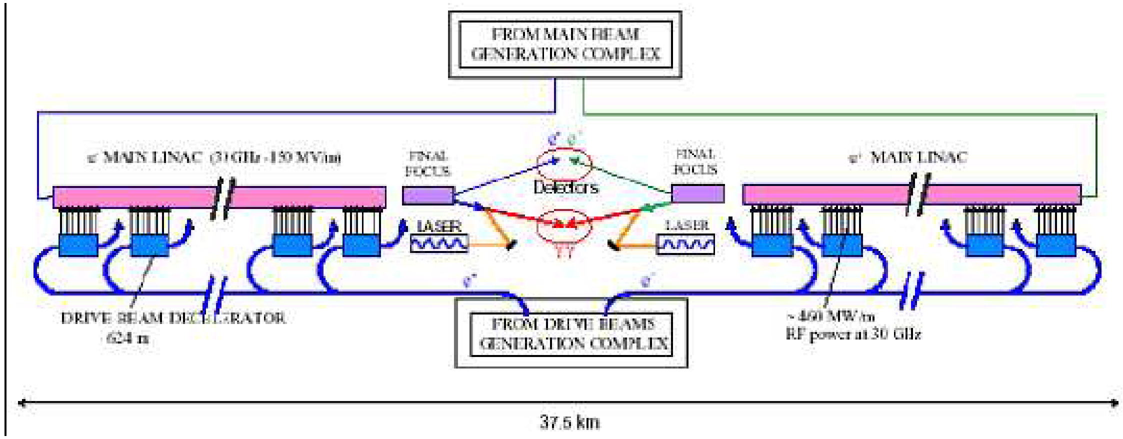
- Regular meetings planned at a monthly frequency.
- Work together with ILC in areas of synergy.
- Working Group Web site - http://cern.ch/CLICMDI

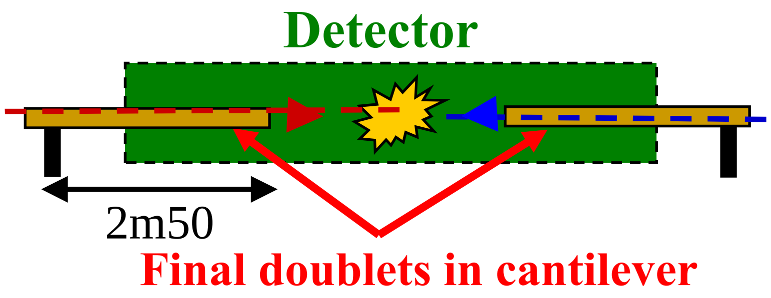
Interaction Region

Final Focusing System (FFS)

- Distance L* between final quadrupole and IP is being evaluated
  - L* < 3.5. m. compromises luminosity
  - 3.5 < L* < 4.3 m. yields similar luminosity
- Design of final focusing doublet is challenging
  - High gradient required.
  - Mechanical supports need to be very stable due to vibrational transmission from detectors.
  - A first concept of a magnet has been done (S. Russenschuck *et al.* CLIC Note 506)
    - Permanent magnet vs. superconducting magnet.
    - Perhaps some hybrid approach should be studied.

Scope of FFS





Vertical beam size σ_y^* at the interaction point: 1nm

Tolerance of vertical relative positioning between the two beams to ensure the collision with only 2% of luminosity loss: 1/10nm

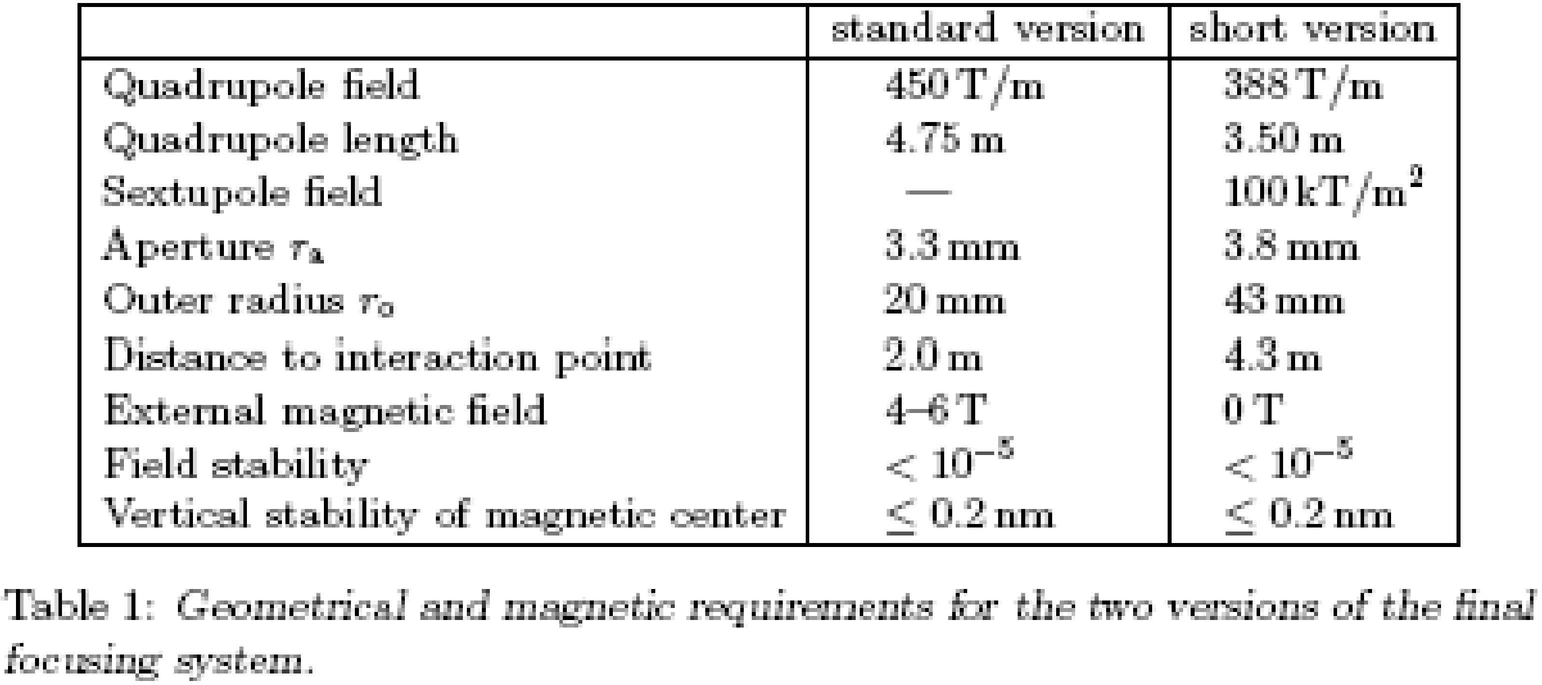
Below 5Hz:

Beam position control with deflector magnets efficient

Above 5Hz:

Need to control relative motion between final doublets

FFS - Specifications



	standard version	short version
Quadrupole field	$450\,\mathrm{T/m}$	$388\,\mathrm{T/m}$
Quadrupole length	$4.75\,\mathrm{m}$	$3.50\,\mathrm{m}$
Sextupole field	—	$100\,\mathrm{kT/m^2}$
Aperture r_a	$3.3\,\mathrm{mm}$	$3.8\,\mathrm{mm}$
Outer radius r_o	$20\,\mathrm{mm}$	$43\,\mathrm{mm}$
Distance to interaction point	$2.0\,\mathrm{m}$	$4.3\,\mathrm{m}$
External magnetic field	4–6 T	0 T
Field stability	$< 10^{-5}$	$< 10^{-5}$
Vertical stability of magnetic center	$\leq 0.2\,\mathrm{nm}$	$\leq 0.2\,\mathrm{nm}$

Table 1: *Geometrical and magnetic requirements for the two versions of the final focusing system.*

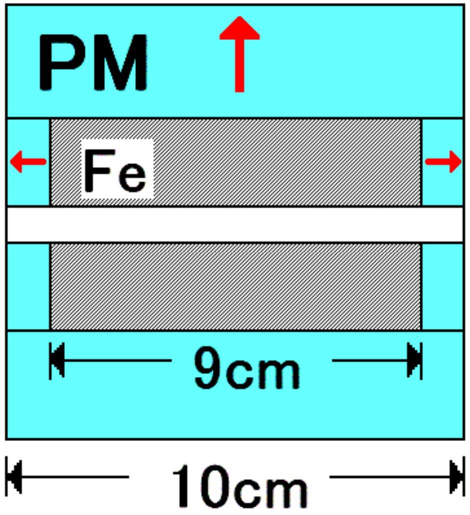
FFS - Permanent Magnets

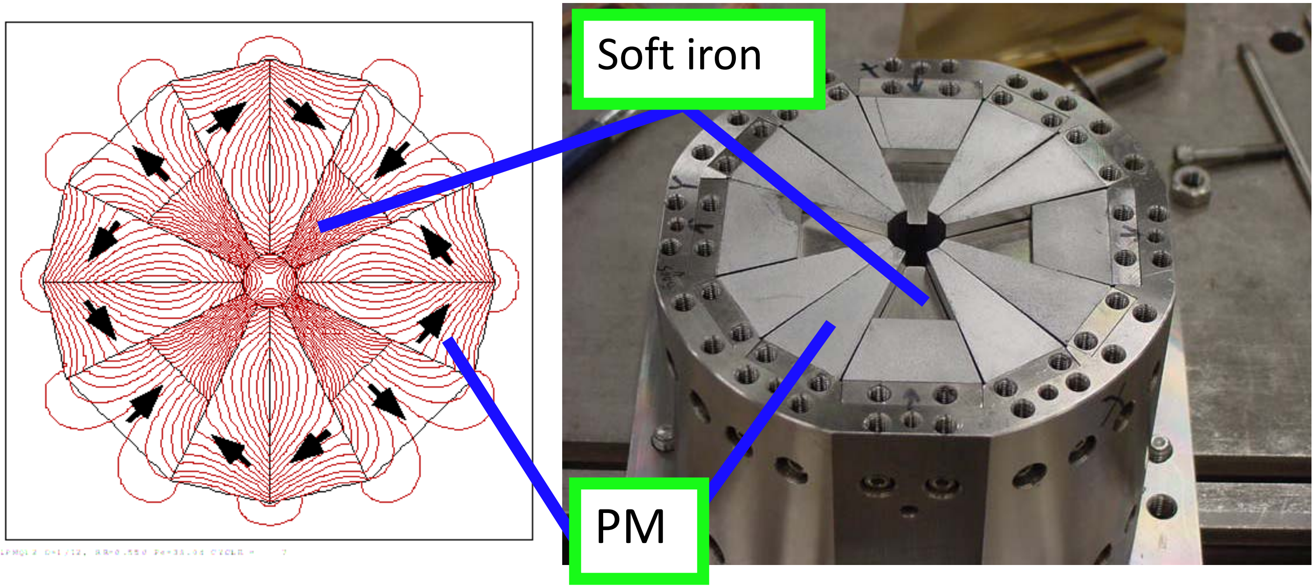
Material	Characteristics
samarium cobalt (Sm2Co17)	brittle
neodymium iron boron (NdFeB)	can lose strength under irradiation ultrahigh coercivity grades show very small remanence losses, <0.4%±0.1%, for absorbed doses up to 3 Mgy from 17 MeV electrons Ductile
	irradiation by 200 MeV protons does reduce the remanence considerably
Samarium erbium cobalt ($Sm_xEr_{l-x}Co$)	Stability ~ 10^{-6}/hr

Pros	Cons
No pwr cables	Adjust. Range limitation
No cryo	Demagnetization
No vibration	Temperature gradient
High coercitivity	Radiation tolerance

Permanent Magnet Quadrupole Prototype

Cut plane view





Axial view

Integrated strength GL=28.5T (29.7T by calc.)

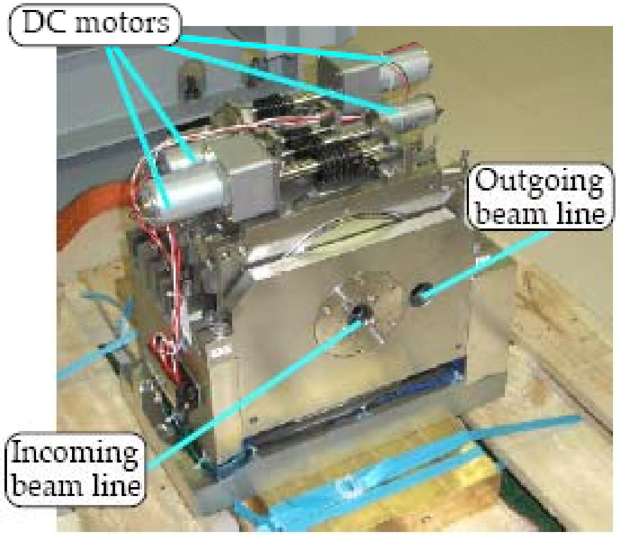
magnet size. ϕ10cm

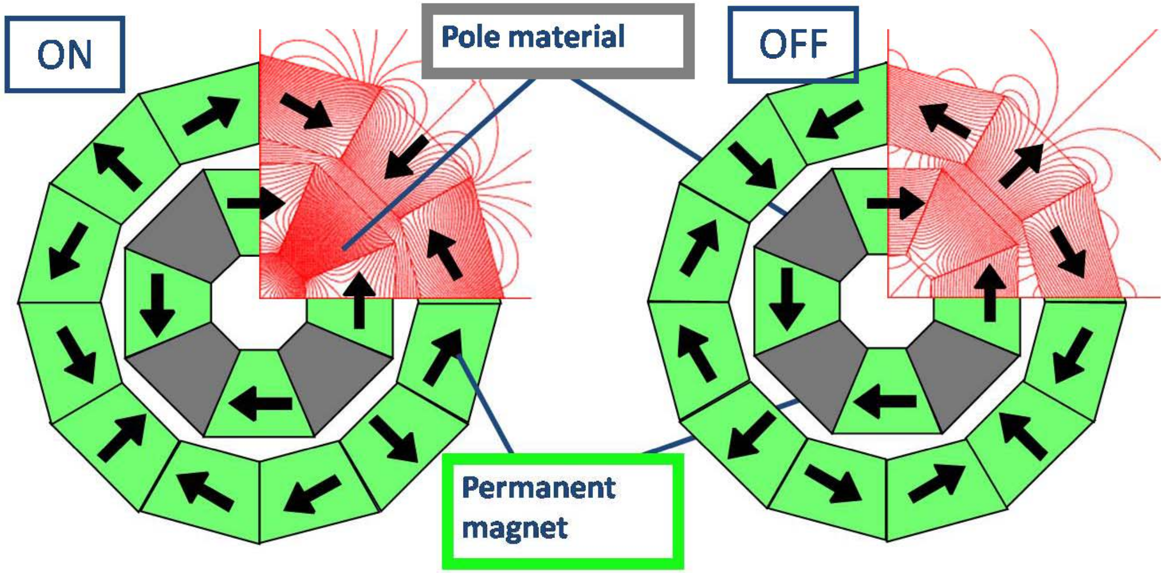
Bore ϕ1.4cm

Field gradient is about **300T/m**

$$GL = \int \frac{dB}{dr} dz$$

Double Ring Structure – Adjustable PMQ





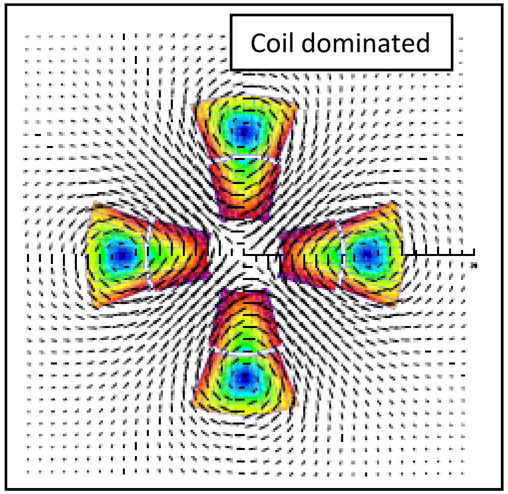
•High gradient → heat load

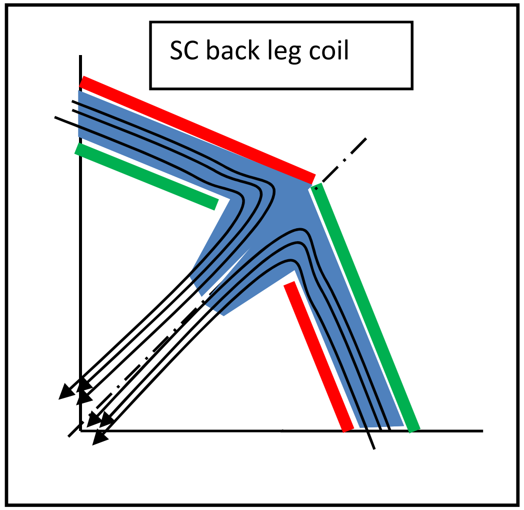
The double ring structure

PMQ is split into inner ring and outer ring. Only the outer ring is rotated 90° around the beam axis to vary the focal strength.

FFS - Superconducting Magnets

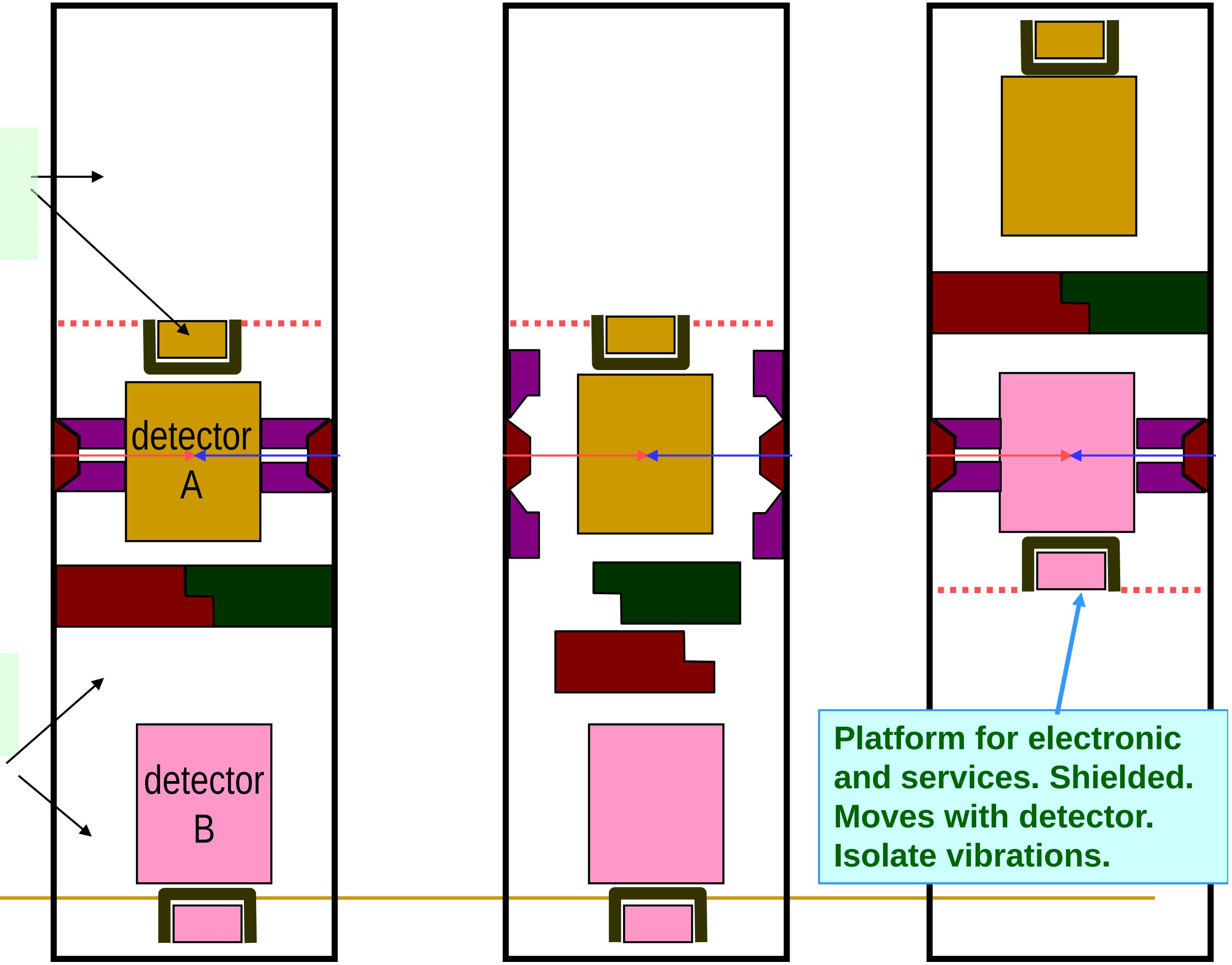
Pros	Cons
Ramping, adjust setting	Services
Low sensitivity to external fields	Quench
Temperature stability	Vibrations
	Cryostat Cross-section, inner radius
	High gradient





Push-Pull Scenario

- Baseline scenario assumes two particle detectors that share occupancy of the interaction point in push-pull mode.
  - Keep a two-beam delivery system under conceptual investigation while detailed engineering study of push-pull mode is on-going.
- The two particle detectors and associated infrastructure/services should be arranged in such a way as to facilitate a rapid change-over.
- Engineer the mechanical particle detector concept for push-pull capability.
  - Access to the inner components of the particle detector (e.g. vertex detector).
  - Maintenance of internal alignment of the particle detector and need to avoid recalibration after a move.
  - Ability to service the various superconducting elements of the particle detector during and after a move.
- Design of underground experiment cavern should be such that one particle detector can be serviced while the other one is running.

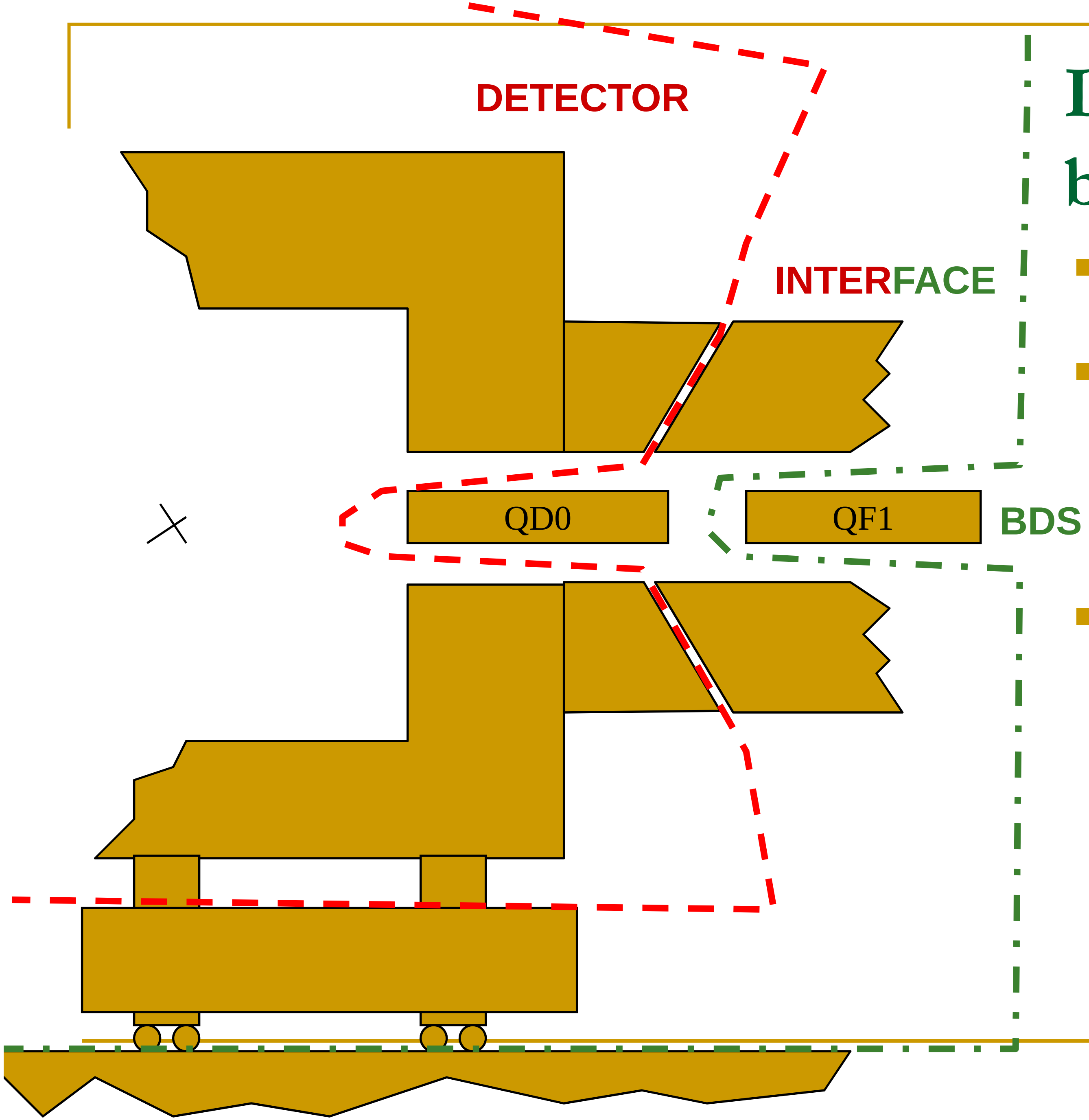


may be accessible during run

accessible during run

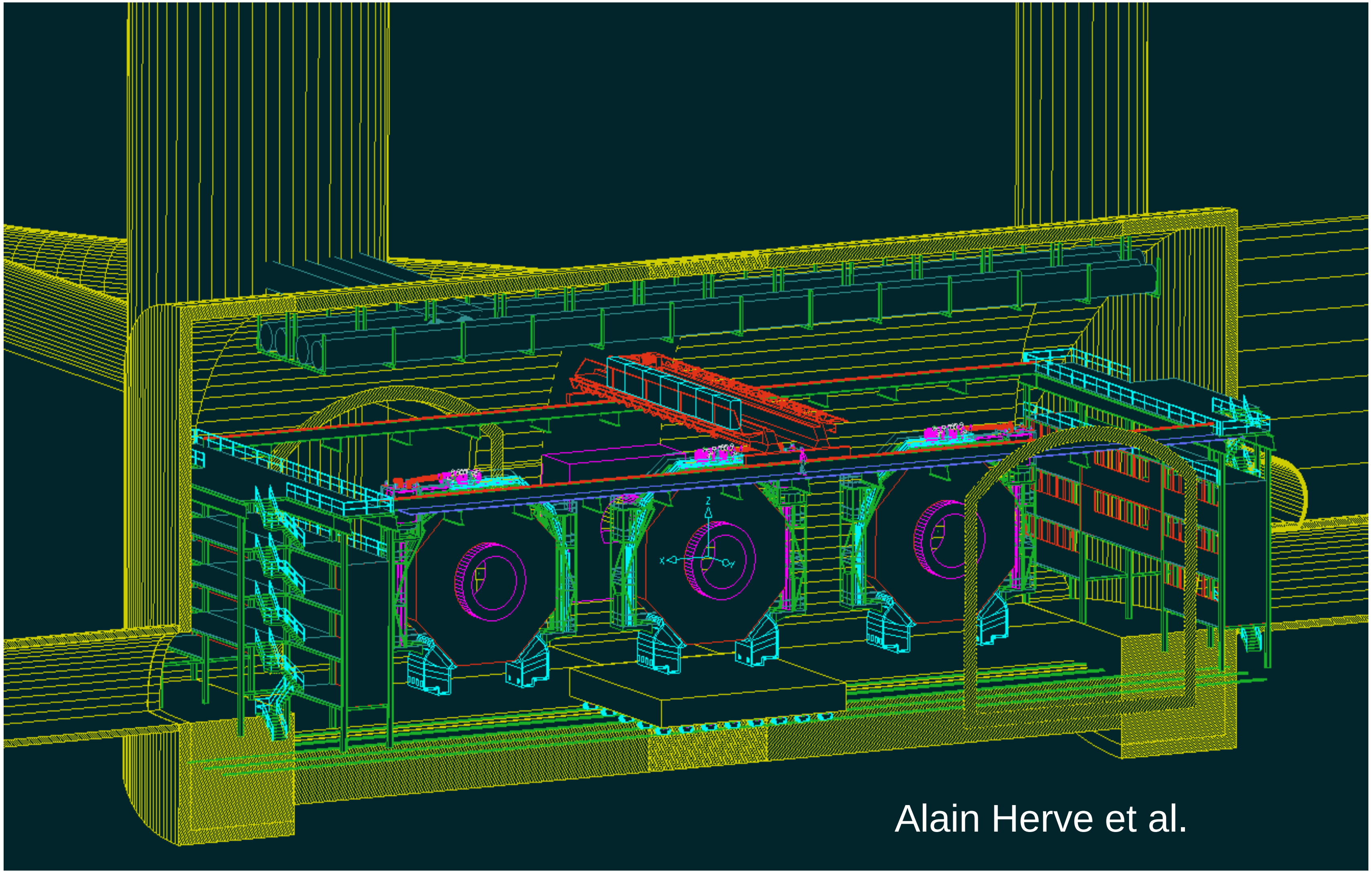
Platform for electronic and services. Shielded. Moves with detector. Isolate vibrations.

IR Interface boundaries



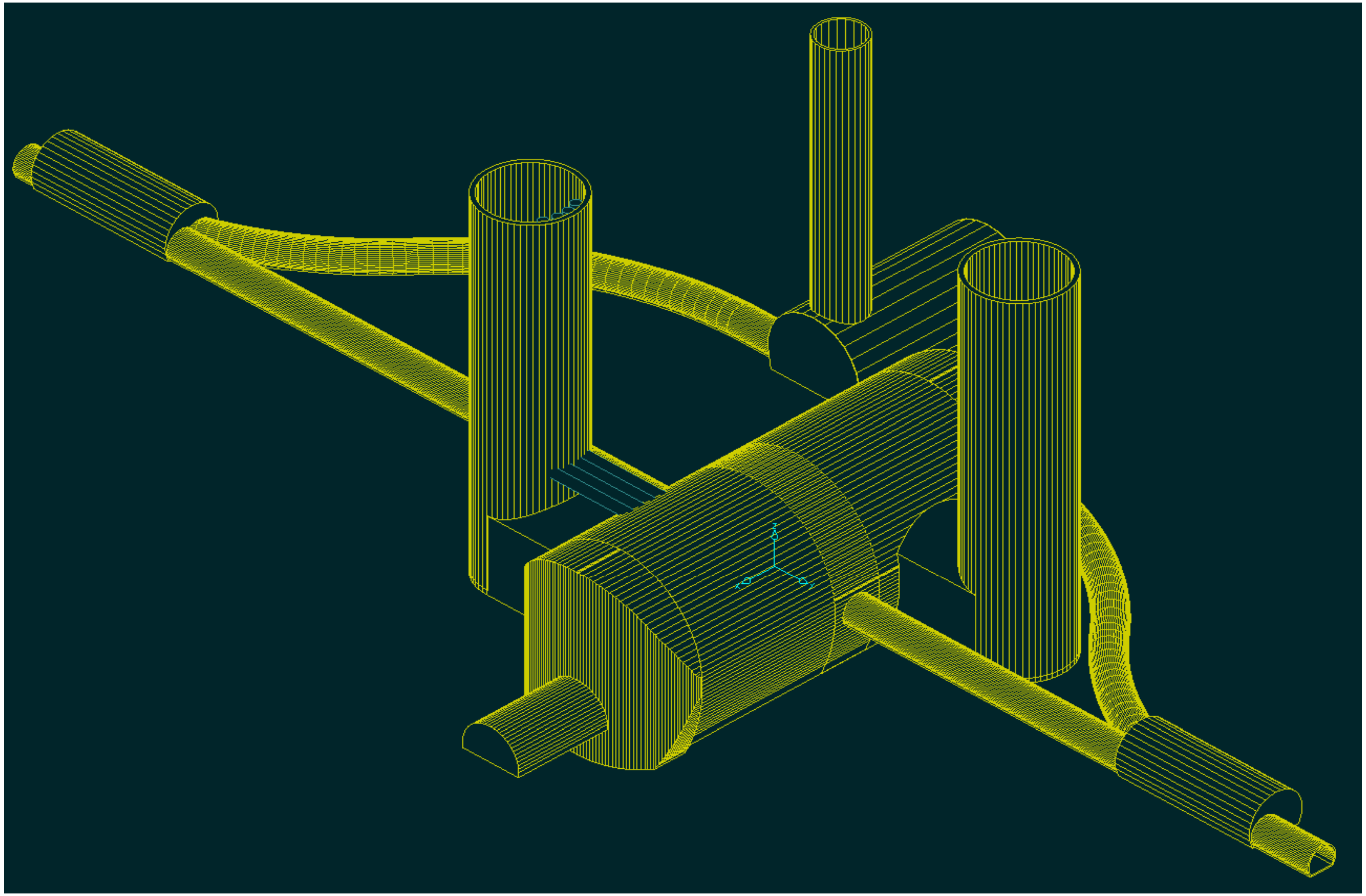
- This picture is over simplified.
- But it shows that interface and boundaries of responsibilities will be complicated.
- A question can be asked if a simpler interface would be possible and what impact on performance it would make.

Push-pull Study for Two Detectors



Alain Herve et al.

Configuration of IR Underground Area



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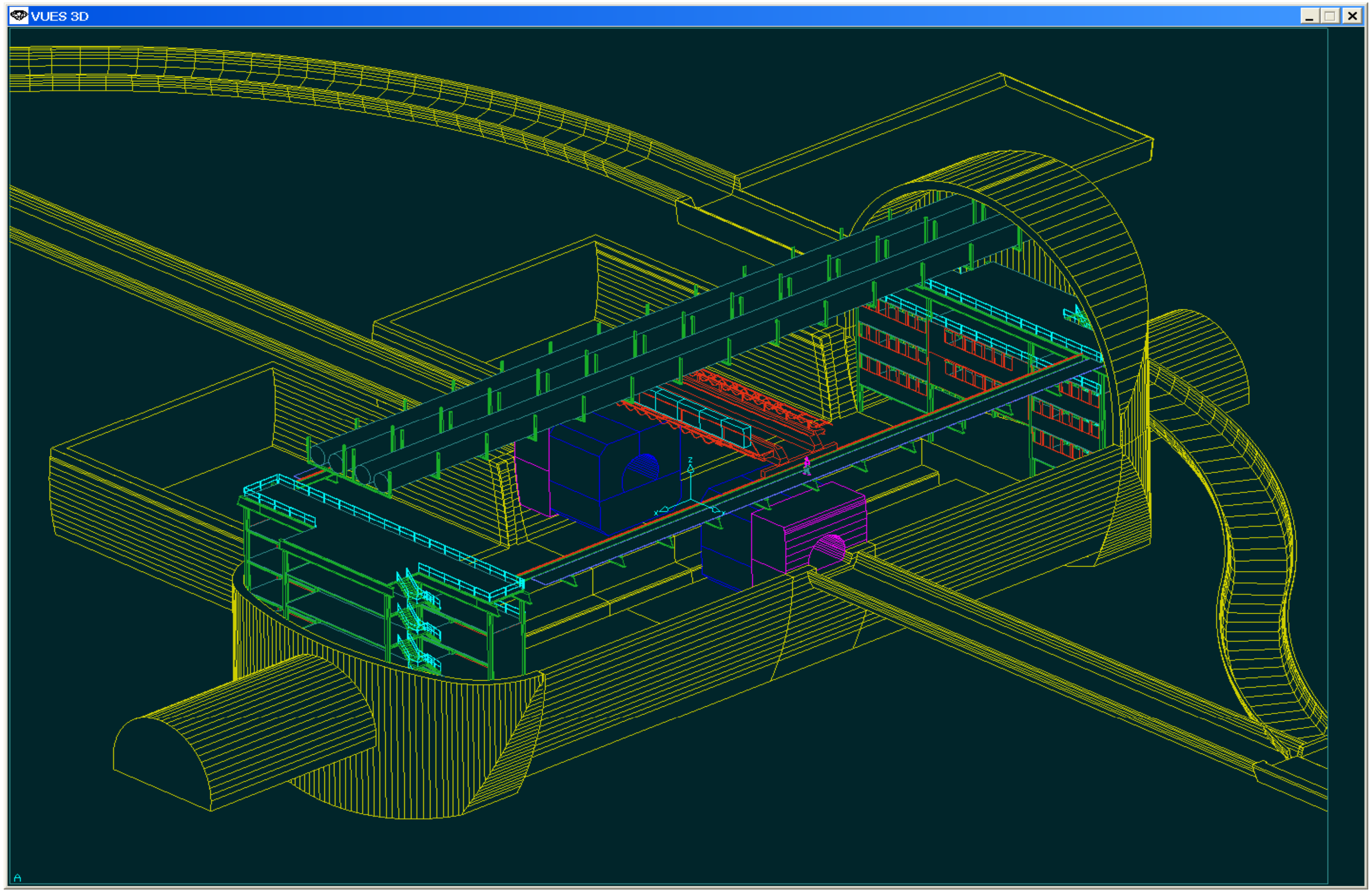


Spectrometer Magnetic Fields

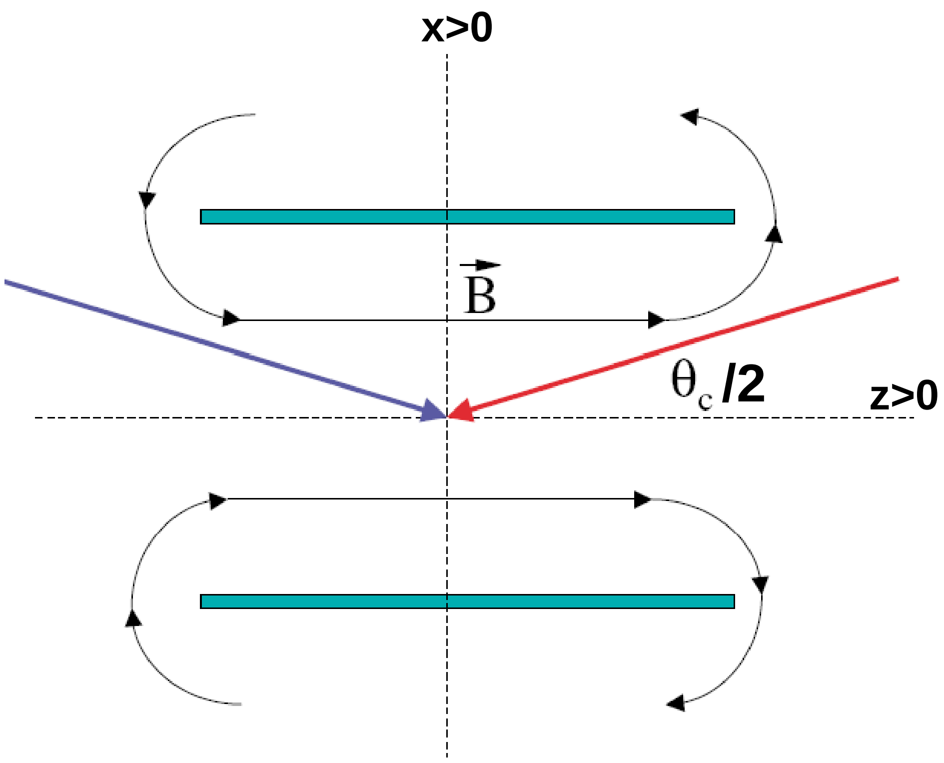
- Main issue is coupling of the beams to the spectrometer solenoid field.
  - Beam coupling to the detector field affects the beam size at IP.
  - This fixes an upper limit to the beam crossing angle.
- Previous studies showed that 4 T are the acceptable limit for 20 mrad.
- Currently including the detector solenoid field into the main beam tracking code PLACET.
  - End fringe fields are of particular importance.
  - The as-measured CMS solenoid magnetic field is being used.

Effect of Spectrometer Solenoid

- Due to the crossing angle the beam encounter a nonzero vertical bending (y) as it travels in the solenoid detector.

- Particles at lower energies experience a larger deflection than those at higher energies ⇒ vertical dispersion

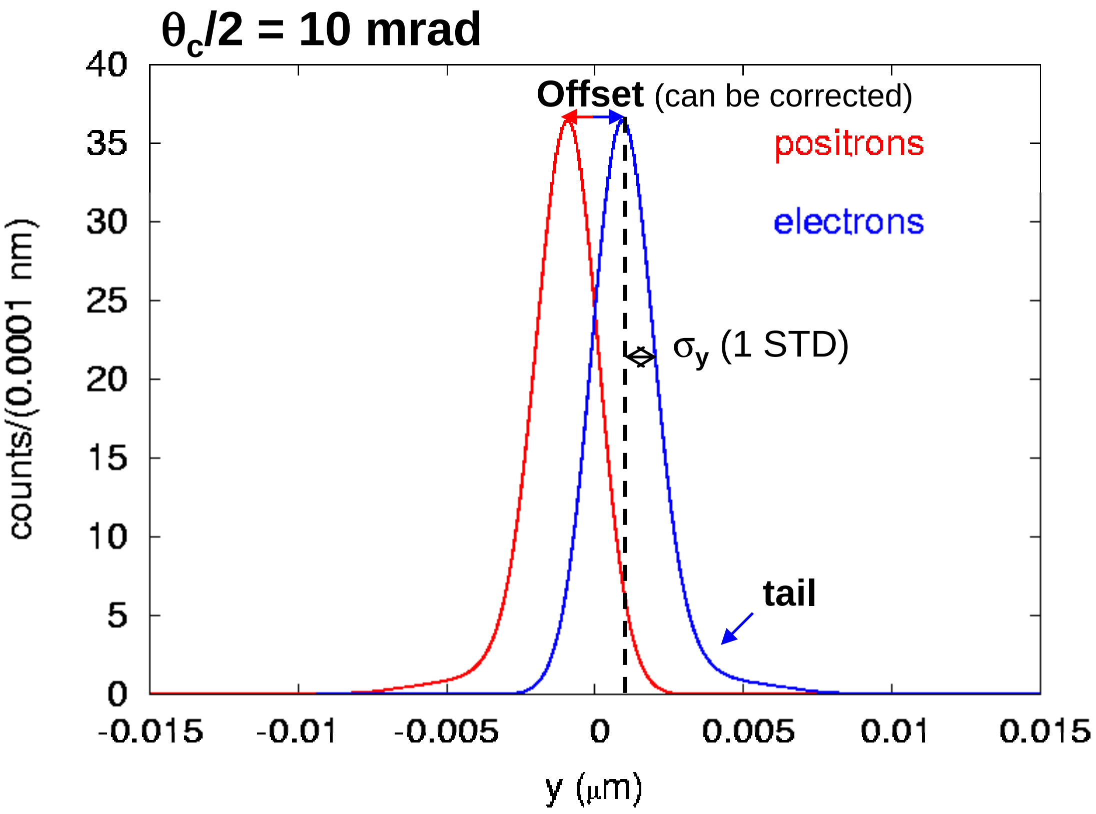
- The beam emits synchrotron radiation as it is deflected ⇒ growth in the vertical direction of the IP spot size.



Schematic view of the two beam colliding with a crossing angle in the detector solenoid.
P. Tenenbaum et al., PR ST- AB, vol. 6, 061001 (2003)

Synchrotron Radiation Effects

- Constant field in central solenoid region 0< z < 3.5 m (distance between the final quadrupole and IP). Tracked back ~ 1000 particle with synchrotron radiation.
- The convolution of the simulated spectrum with a Gaussian (beam size σ_{y0} = 1 nm) result in an offset of the gaussian + a tail on opposite side for e^+e^-.
- The vertical increase of the beam spot size is evaluated at 1 STD.

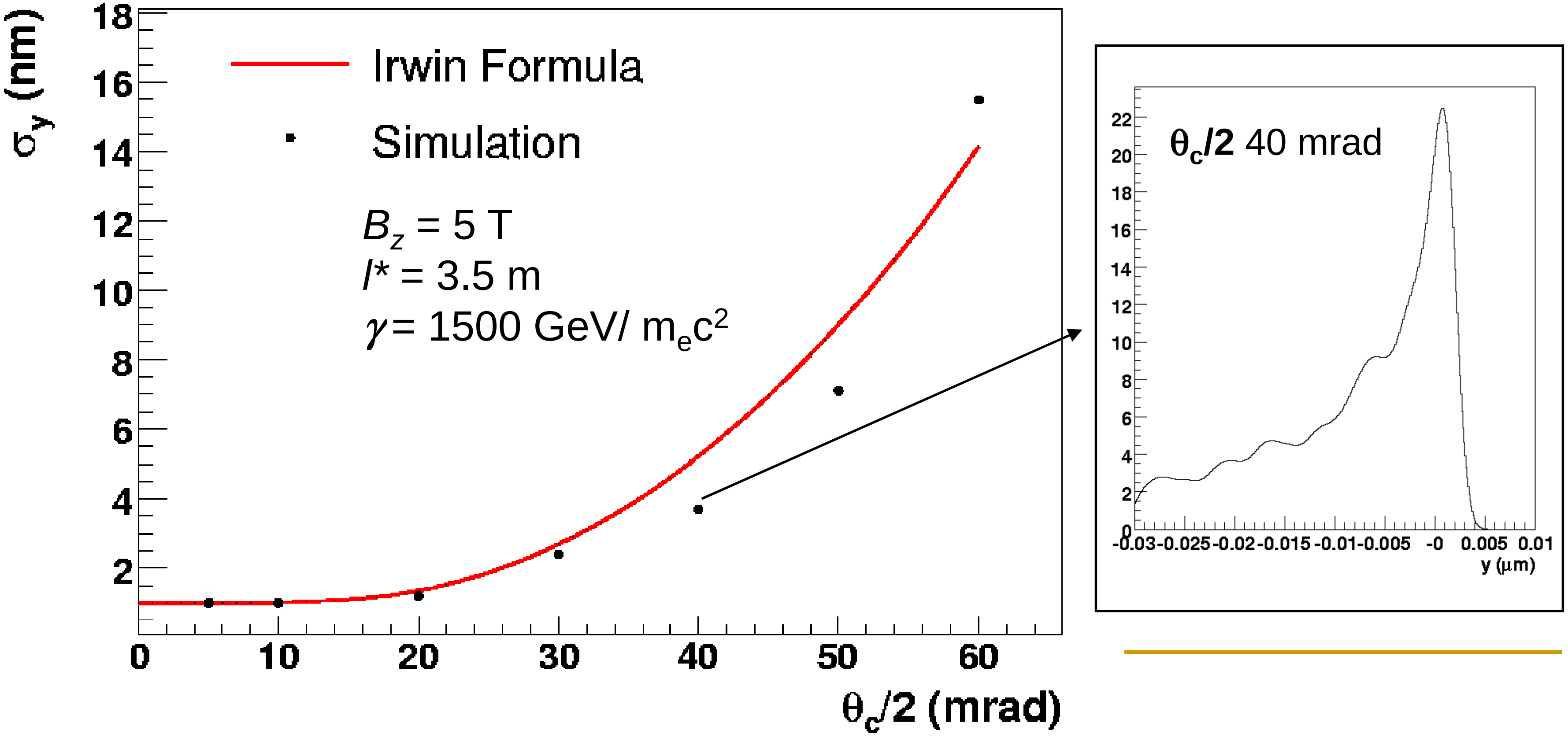


Irwin Formula

- Vertical spot size increase due to synchrotron radiation in the solenoid constant field as a function of the crossing angle.

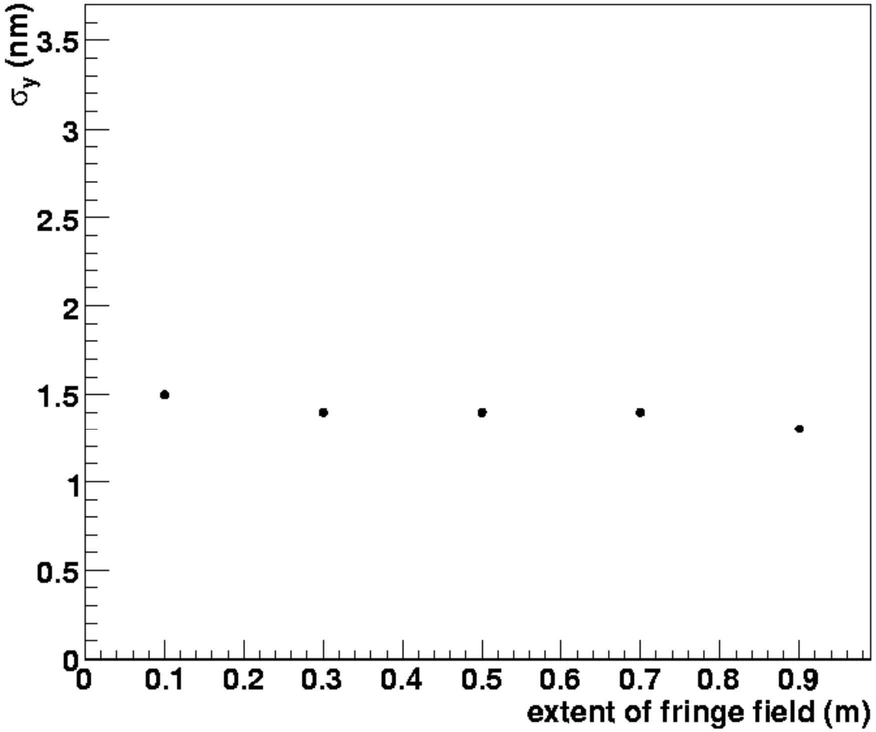
$$\frac{\Delta\sigma_y^2}{\sigma_{y0}^2} = \frac{1}{20}\,\frac{c_u r_e \bar{\lambda}_e}{\sigma_{y0}^2}\left(\frac{B_z\theta_c l^*\gamma}{2(B\rho)}\right)^5 \longrightarrow$$

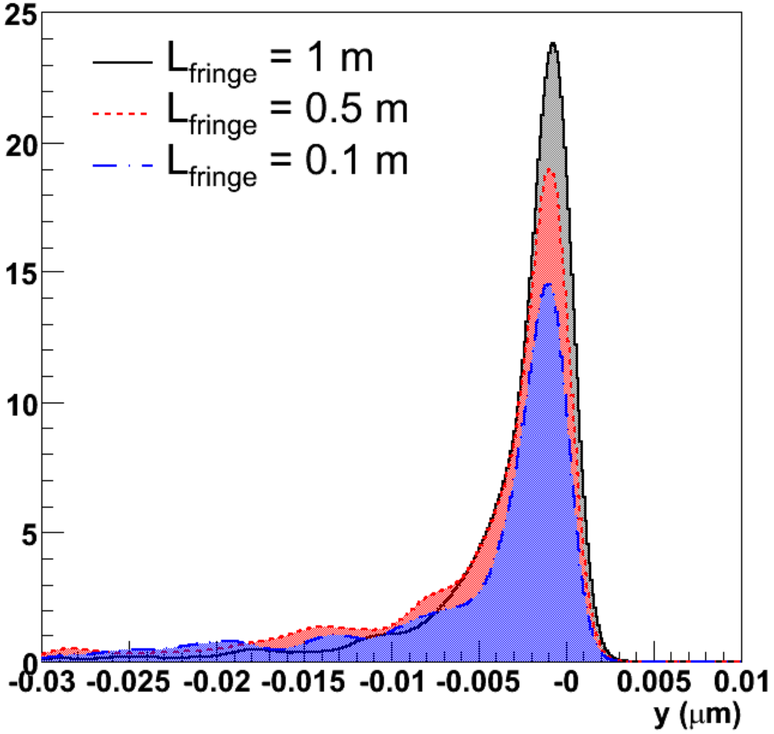
D.Schulte and F.Zimmermann,
Proc. Part.Acc.Conf. (2001) Chicago



Extension of the Fringe Field

- Vertical spot size increase due to synchrotron radiation in the fringe + central solenoid field as a function of the fringe field extent (θ_c = 20 mrad).

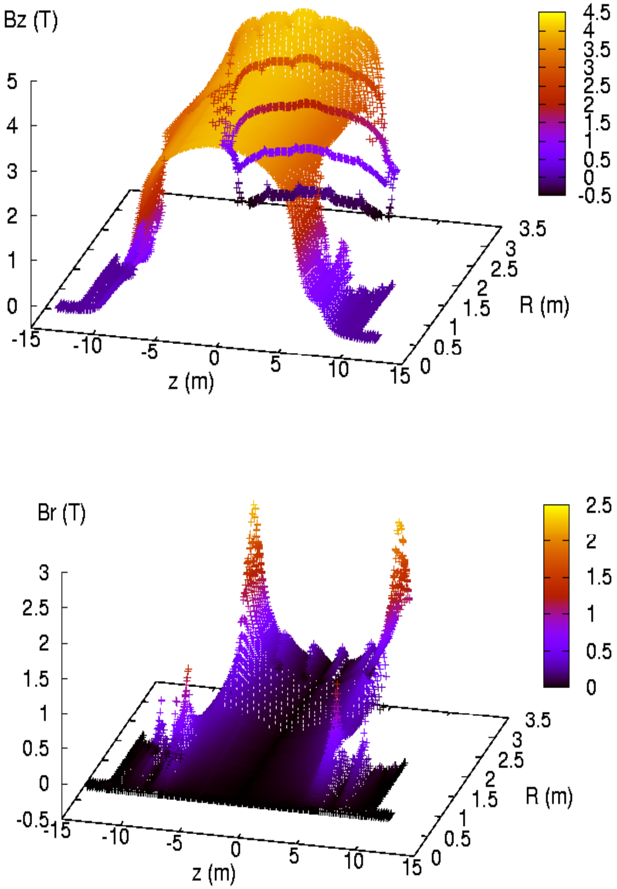




The effect of the fringe field extent is to remove particle from the peak and fill the tails.

CMS Magnetic Field Map

- It is a non *equally-spaced* 3D map ***B****(r,ϕ, z)*
- We need to extrapolate / interpolate in 3D to produce B_z *vs z* and B_x,B_y (Br2=Bx2+By2) *vs z* maps along the beam trajectory (like the SiD map) at various crossing angles.



CLIC-ILC MDI Collaboration

Terms of Reference

- Within the overall framework of strengthening the collaboration and synergy between CLIC and ILC, the Beam Delivery Systems and Machine Detector Interface Working Group provides a forum where those technically responsible for the beam delivery systems and for the issues at the interface between the machines and experiments from the ILC and CLIC projects can meet and discuss issues of mutual interest.
- The subjects treated cover everything of common importance to the machines and experiments and includes, but not limited to, the machine performance for the experiments, the design and integration of the beam delivery system and the corresponding interaction regions and experimental areas, the experimental beampipes and vacuum, the radiation shielding and monitoring, the collimation system, the beam instrumentation, the luminosity and background measurement and monitoring, the mechanical supports and stabilisation, the design of the near-beam forward detectors, the data exchange and common safety issues.
- The Working Group will endeavour to develop and use common standards and codes and undertake common studies.
- The Working Group reports to both the CLIC and ILC Project Managements.

Topics of Common Interest

- Experimental area lay-out and design.
  - Infrastructure/services, push-pull mode, crossing angle.
- Experimental beam pipe and vacuum system.
- Final focusing magnets.
- Background and luminosity studies.
  - Common simulation tools.
  - Studies of machine-induced backgrounds and mitigation strategies.
  - Study of beam-beam background and luminosity spectrum.
- Masking system.
- Spectrometer magnet design and field.
- Forward calorimetry.
- Support, stabilisation and alignment of machine elements inside particle detector.

Summary and Future Work

- Machine-detector interface considerations/studies are central to CLIC.
    - An MDI WG has thus been set up to co-ordinate such studies.
- Work on the MDI is on-going in the following areas:
    - Lay-out of the interaction region, including services
    - Integration of BDS (final focusing, collimation, post collision line, beam instrumentation) and particle detectors
    - Push-pull detector scheme
    - Experimental beam pipe and vacuum
    - Study of backgrounds
    - Luminosity spectrum