The Large Hadron electron Collider Detector Design Concept

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(for the LHeC Study Group)

Outline:

- Experiment requirements and accelerator boundaries (Physics, Machine, Interaction Region and Detector)
- Present Detector Design
- Future and Outlook

The LHeC at Poetic 2013

Mon 12:00 - Paul Laycock
“An Overview of the LHeC”

Tue 17:40 - Voica Radescu
“PDFs from the LHeC and the LHC search program”

Thu 10:00 – Vladimir Litvinenko:
“Energy Recovery Linac based LHeC”

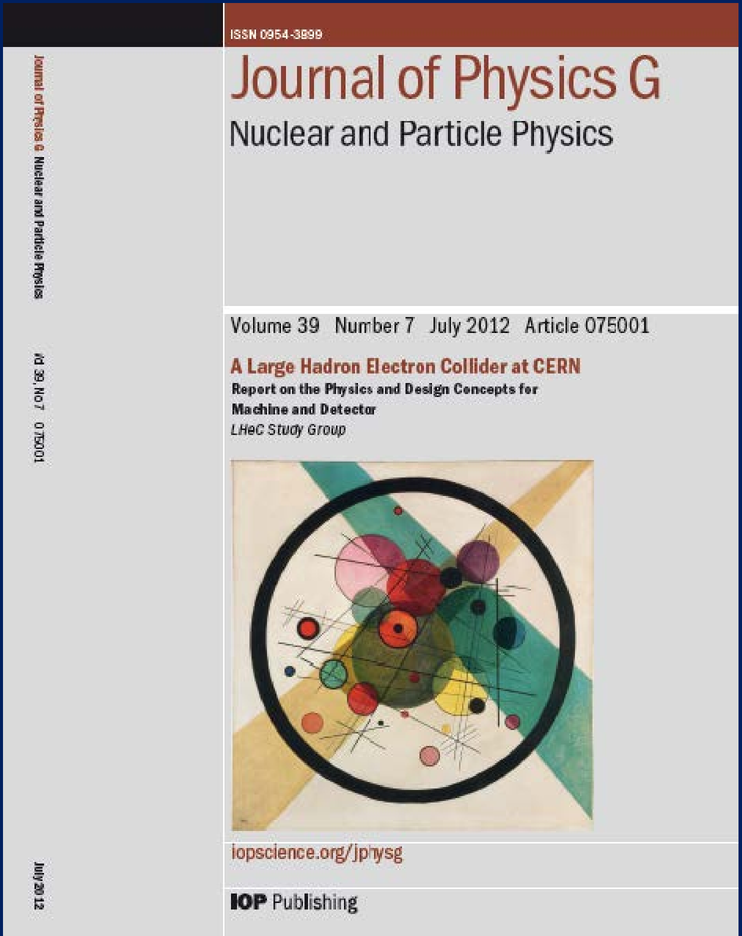
Thu 13:20 - Alessandro Polini:
“The LHeC Detector Design Concept”

Fri 10:50 - Anna Stasto
“eA Physics with the LHeC”

Fri 13:15 - Pierre Van Mechelen
“Diffraction and forward Physics in ep collisions
at the LHeC”

http://cern.ch/lhec

CDR: “A Large Hadron Electron Collider at CERN”
LHeC Study Group, arXiv:1206.2913
J. Phys. G: Nucl. Part. Phys. 39 (2012) 075001



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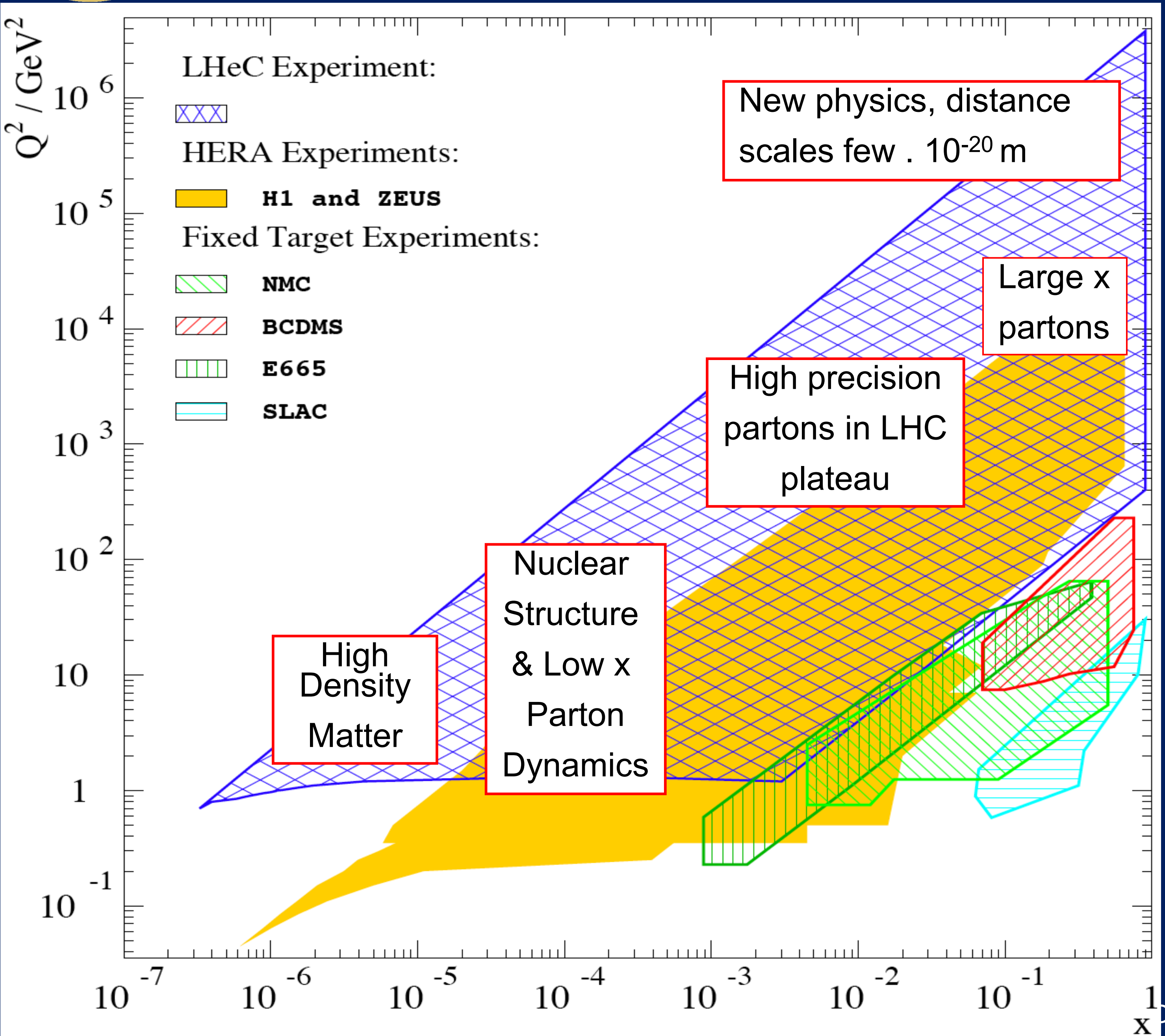
A Large Hadron Electron Collider at CERN
Report on the Physics and Design Concepts for
Machine and Detector
LHeC Study Group

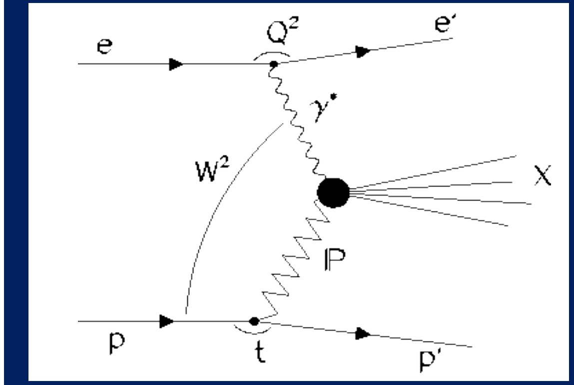
iopscience.org/jphysg

IOP Publishing

Kinematics & Motivation (60 GeV x 7 TeV *ep*)



$\sqrt{s}$= 1.4 TeV



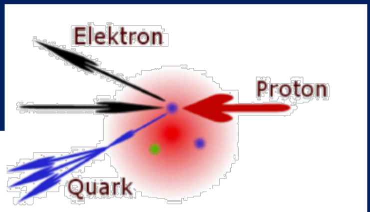
- High mass (M_{eq},Q^2) frontier

- EW & Higgs
- Q^2 lever-arm at moderate & high x → PDFs

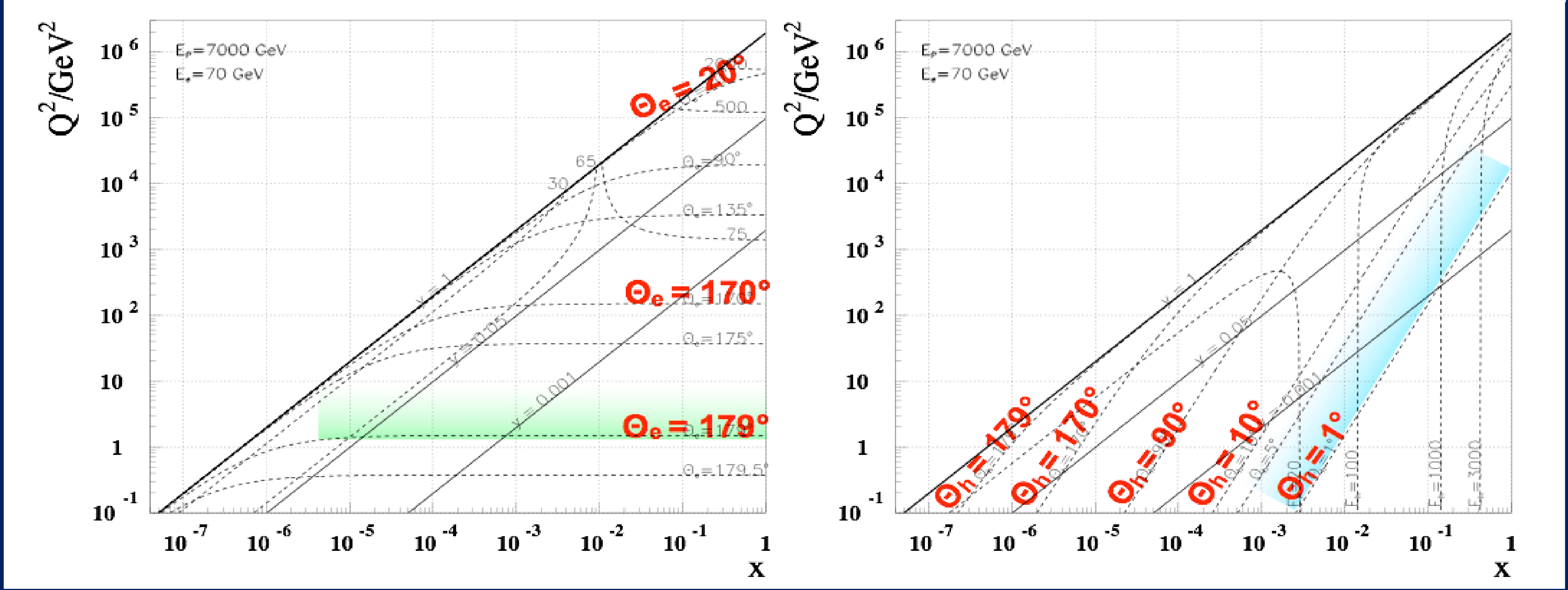
- Low x frontier [x below 10^{-6} at $Q^2 \sim 1$ GeV²]

→ novel QCD

LHeC Kinematics



LHeC - electron kinematics *LHeC - jet kinematics*



- High x and high Q^2: few TeV HFS scattered forward:

➔ Need forward calorimeter of few TeV energy range down to 10° and below 🟦
Mandatory for charged currents where the outgoing electron is missing

- Scattered electron:

➔ Need very bwd angle acceptance for accessing the low Q^2 and high y region 🟩

Detector Design Approach

- Provide a baseline design which satisfies the Physics requirements along with the constraints from the machine and interaction region for running during the PHASE II of LHC

- Having to run along with the LHC, the detector needs to be designed and constructed in about 10 years from now to be able to run concurrently with the other LHC experiments designed for *pp* and *AA* studies in the *ep*/*eA* mode, respectively.

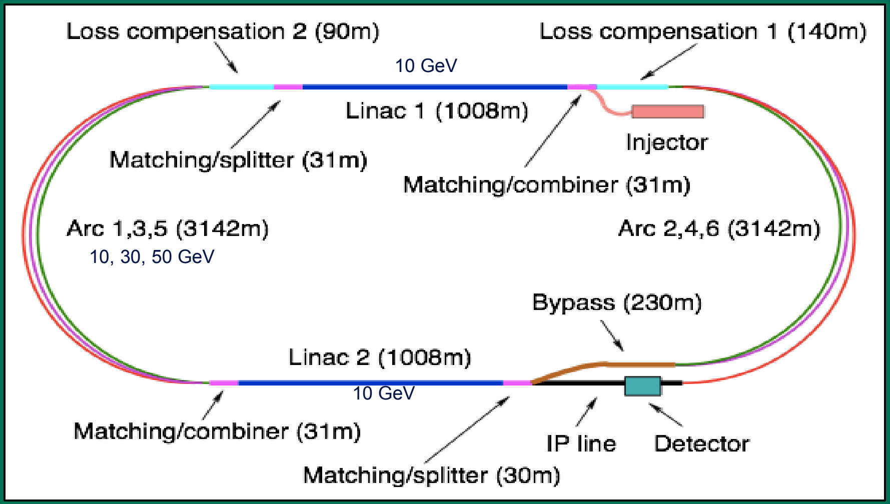
- While avoiding large R&D programs, the final LHeC detector can profit from the technologies used nowadays at the LHC and the related developments and upgrades

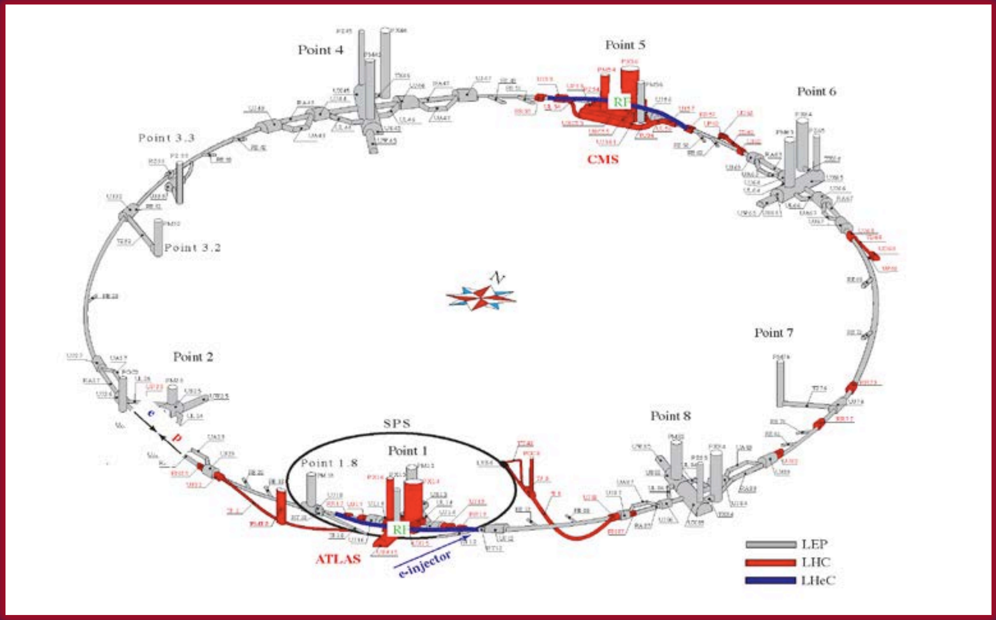
- Modular and flexible design to accommodate with upgrade programs; Detector assembly above ground; Detector maintenance (shutdown)

- Affordable - comparatively reasonable cost.

- More refined studies are required and will follow with the TDR and once a LHeC collaboration has been founded

$e^{\pm}$ beam: two alternative designs





- Ring-Ring
  - e-p and e-A (A=Pb, Au,   ) collisions
  - More “conventional” solution, like HERA, no difficulties of principle - at first sight - but constrained by existing LHC in tunnel
  - polarization 40% with realistic misalignment assumptions
- Linac-Ring
  - e-p and e-A (A=Pb, Au,   ) collisions, polarized e^- from source, somewhat less luminosity for e^+
  - New collider type of this scale, Energy Recovery Linac

Machine Parameters

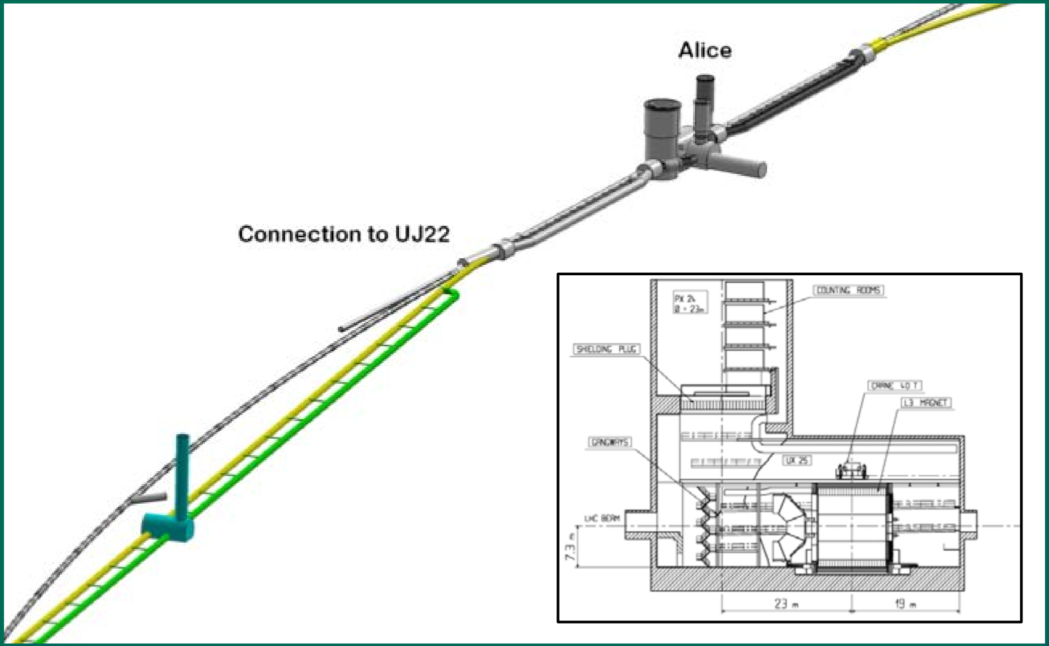
R. Thomas et al. 2013

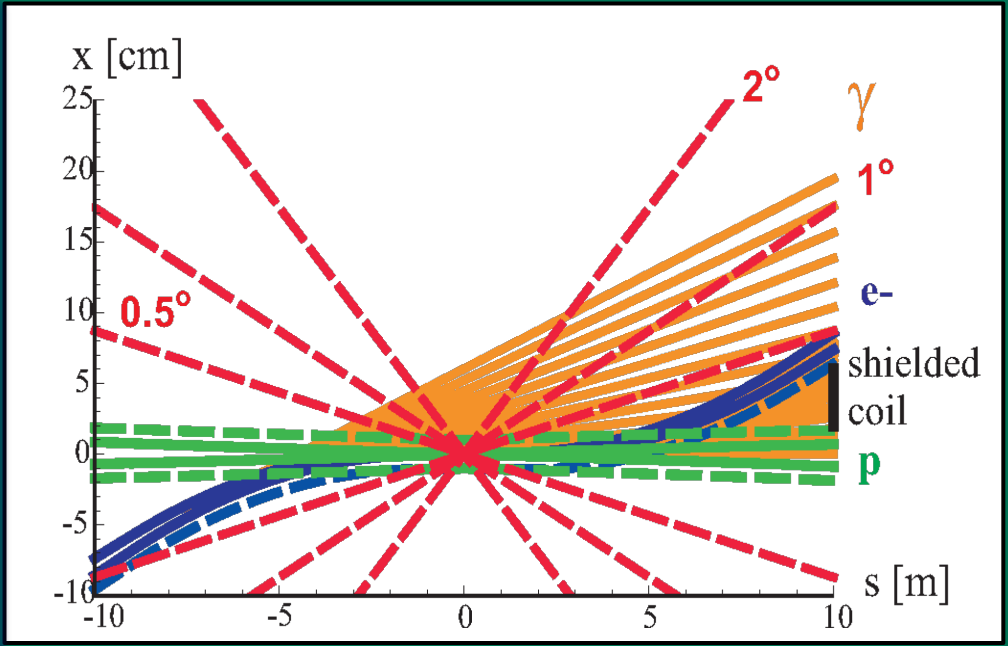
	Ring-Ring Hi Lumi/Hi Acc	Linac-Ring
Luminosity [$10^{33} cm^{-2} s^{-1}$]	1.3/0.7	1
Detector acceptance [deg]	10/1	1
Polarization [%]	40	90
IP beam sizes [μm]	30, 16	7
Crossing angle [mrad]	1	0
e- L* [m]	1.2/6.2	30
Proton L* [m]	23	15
e- $beta^*_{x,y}$ [m]	0.2,0.1/0.4,0.2	0.12
Proton $beta^*_{x,y}$ [m]	1.8, 0.5	0.1
Synchrotron power [kW]	33/51	10

Linac Ring: Favored Option

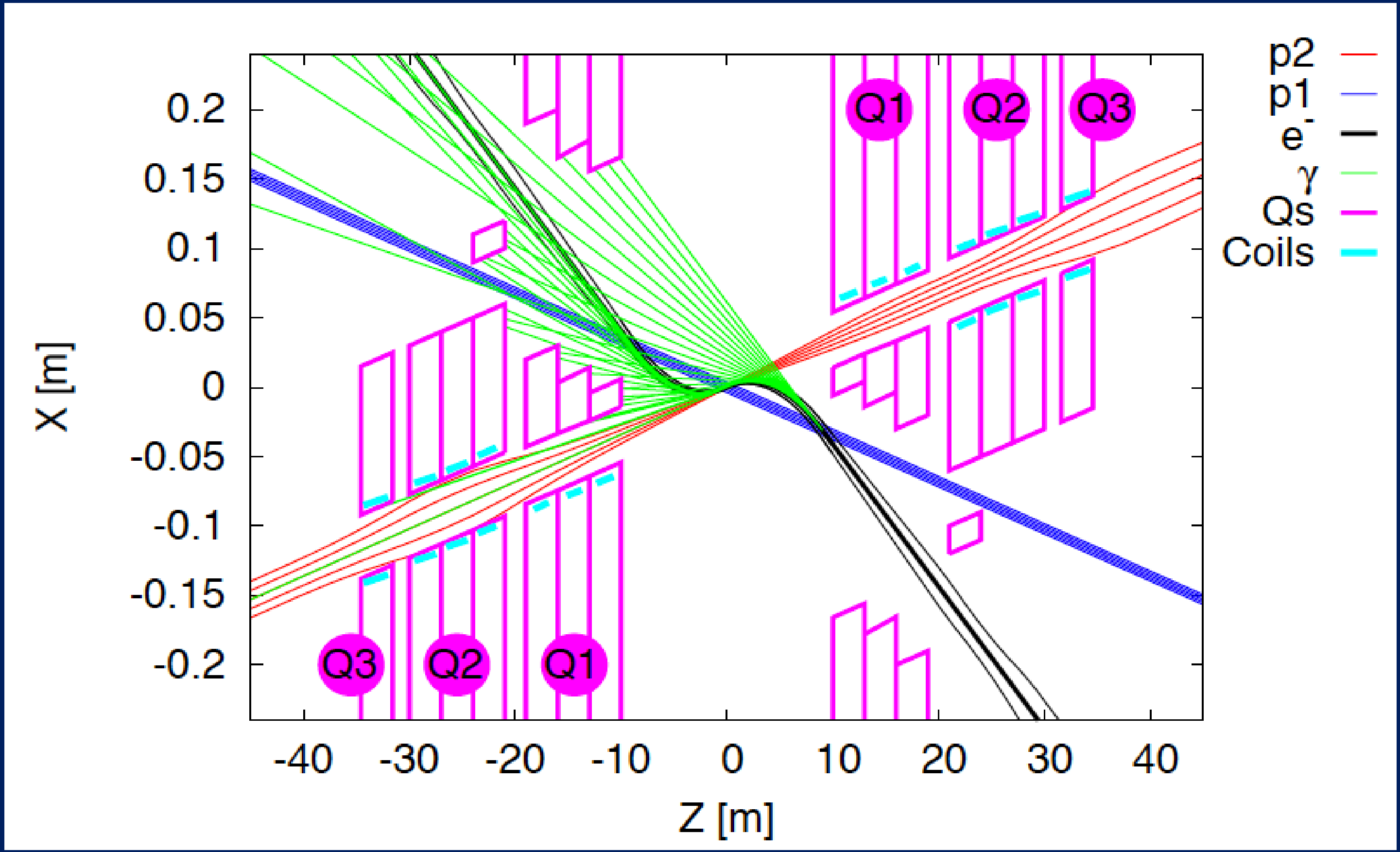
Linac-Ring:

- Reduced impact on the LHC schedule
- New Accelerator Design (Energy Recovery Linac)
- Dipole Field along the whole interaction region
- LHC Interaction Point P2

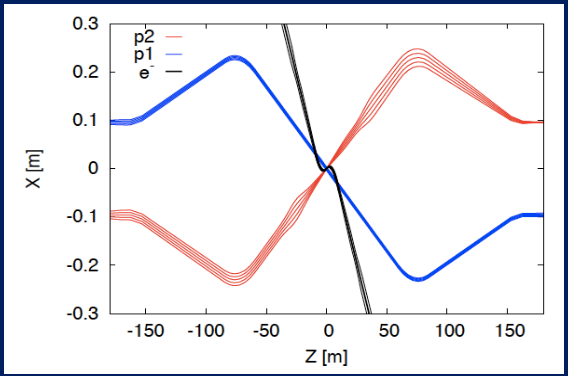




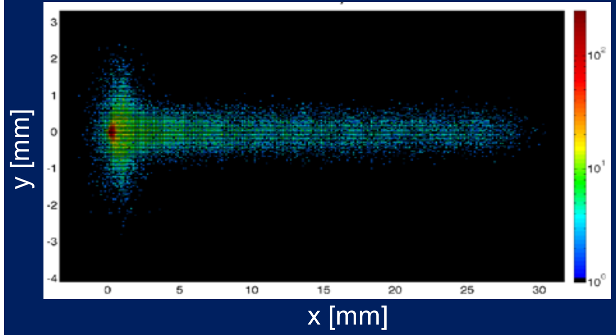
The Interaction Region



3 beams, head-on collisions



Photon Number Density at the IP



- Optics compatible with LHC and $\beta^*=0.1$m
- Head-on collisions mandatory → High synchrotron radiation load, dipole in detector
- 3 beam interaction region
- Optimisation: High Luminosity-LHC uses IR2 quads to squeeze IR1 (“ATS” achromatic telescopic squeeze). Might improve further luminosity [~ 10^{34} $cm^{-2}s^{-1}$]

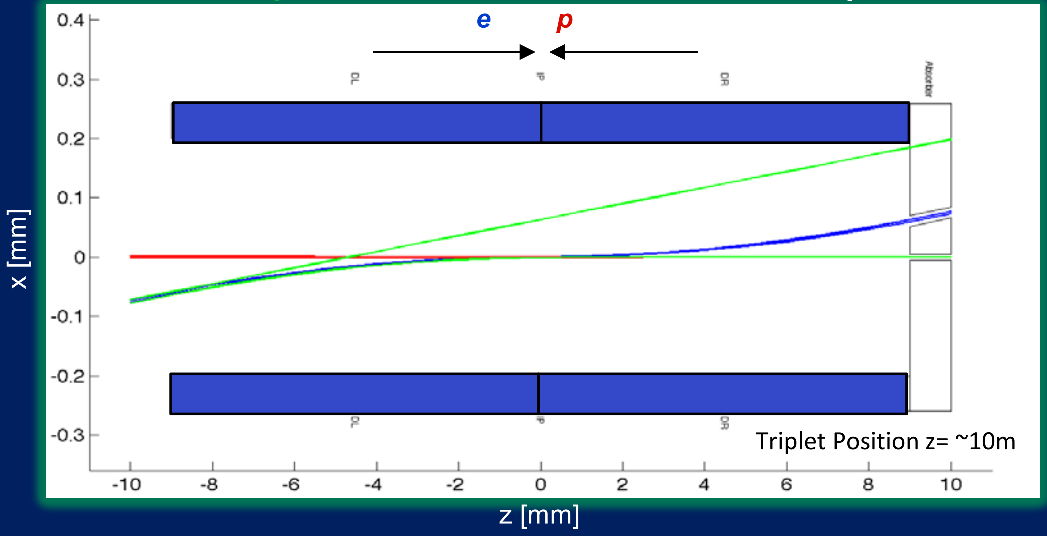
LR Interaction Region

Dipole Field along the full interaction region needed

$B = \pm 0.3$ Tesla
for $z = [-9\text{m}, +9\text{m}]$

SR Fan growth with z

LR Option - Beam & Fan Envelopes



Linac-Ring Beampipe:

Inner Dimensions

Circular(x)=2.2cm; Elliptical(-x)=-10., y=2.2cm

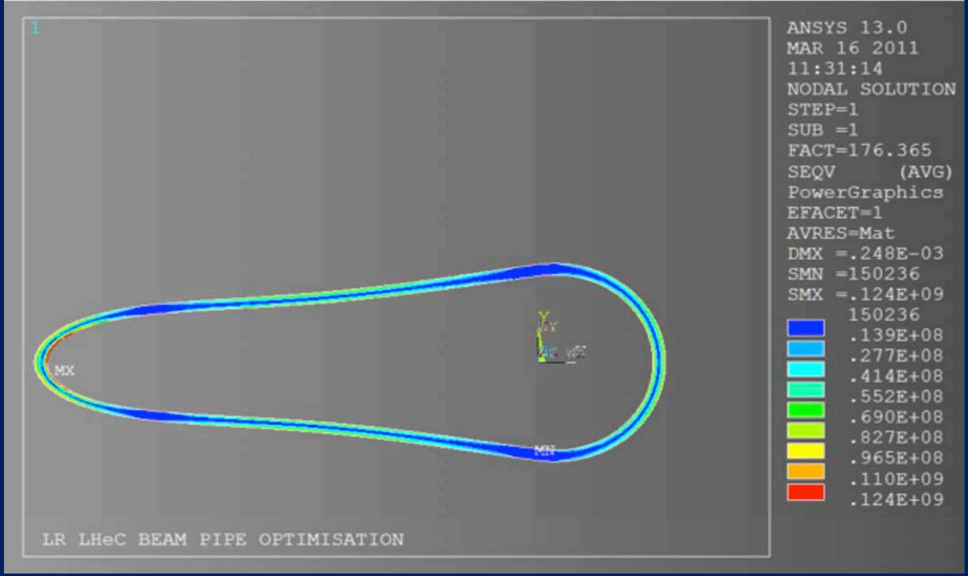
Material: Be 2.5-3.0 mm wall thickness

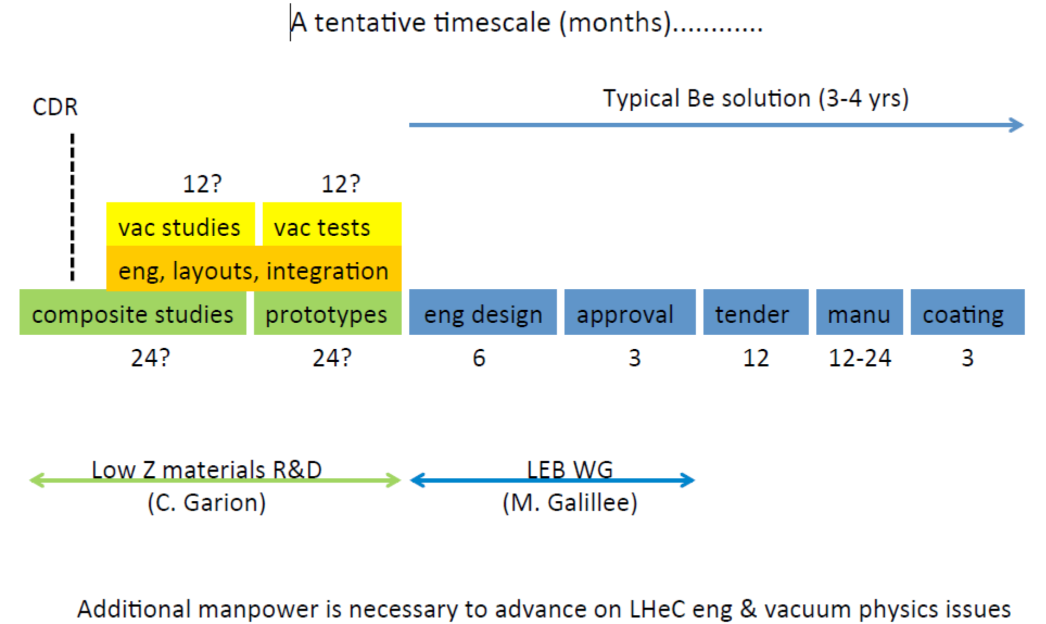
Stress Test: Pipes would be sufficient to resist the external pressure

Note: 1^0 track passing 1.5 ~ 3.0mm thick Be wall -
X/X_0=21% ~ 45% → R&D and/or move to composite beampipe

Beam Pipe Considerations

J, Bosch, P. Krushank, R. Veness, - LHeC Chavannes 2012





A tentative timescale (months)…………

CDR

Typical Be solution (3-4 yrs)

12? vac studies

12? vac tests

eng, layouts, integration

composite studies 24?

prototypes 24?

eng design 6

approval 3

tender 12

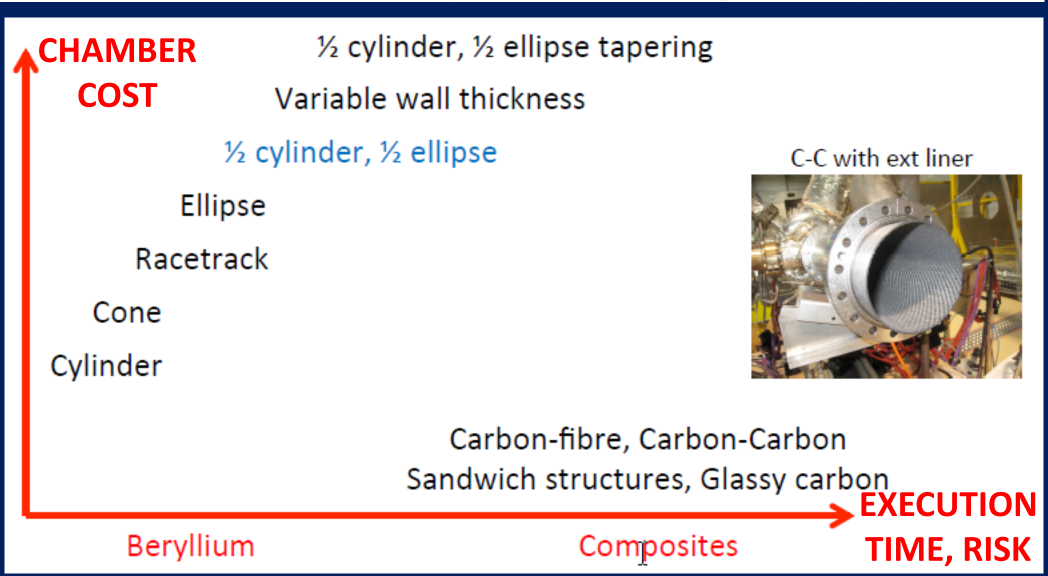
manu 12-24

coating 3

Low Z materials R&D (C. Garion)

LEB WG (M. Galillee)

Additional manpower is necessary to advance on LHeC eng & vacuum physics issues



CHAMBER COST

½ cylinder, ½ ellipse tapering

Variable wall thickness

½ cylinder, ½ ellipse

Ellipse

Racetrack

Cone

Cylinder

C-C with ext liner

Carbon-fibre, Carbon-Carbon
Sandwich structures, Glassy carbon

EXECUTION TIME, RISK

Beryllium

Composites

CDR Design:

- Beryllium 2.5-3 mm thickness
- Central beam pipe ~ 6 meters
- Constant x-section
- TiZrV NEG coated
- Periodic bakeout/NEG activation at ~220C (permanent system?)
- Wall protected from primary SR (upstream masks)
- Minimised end flanges, minimised supports

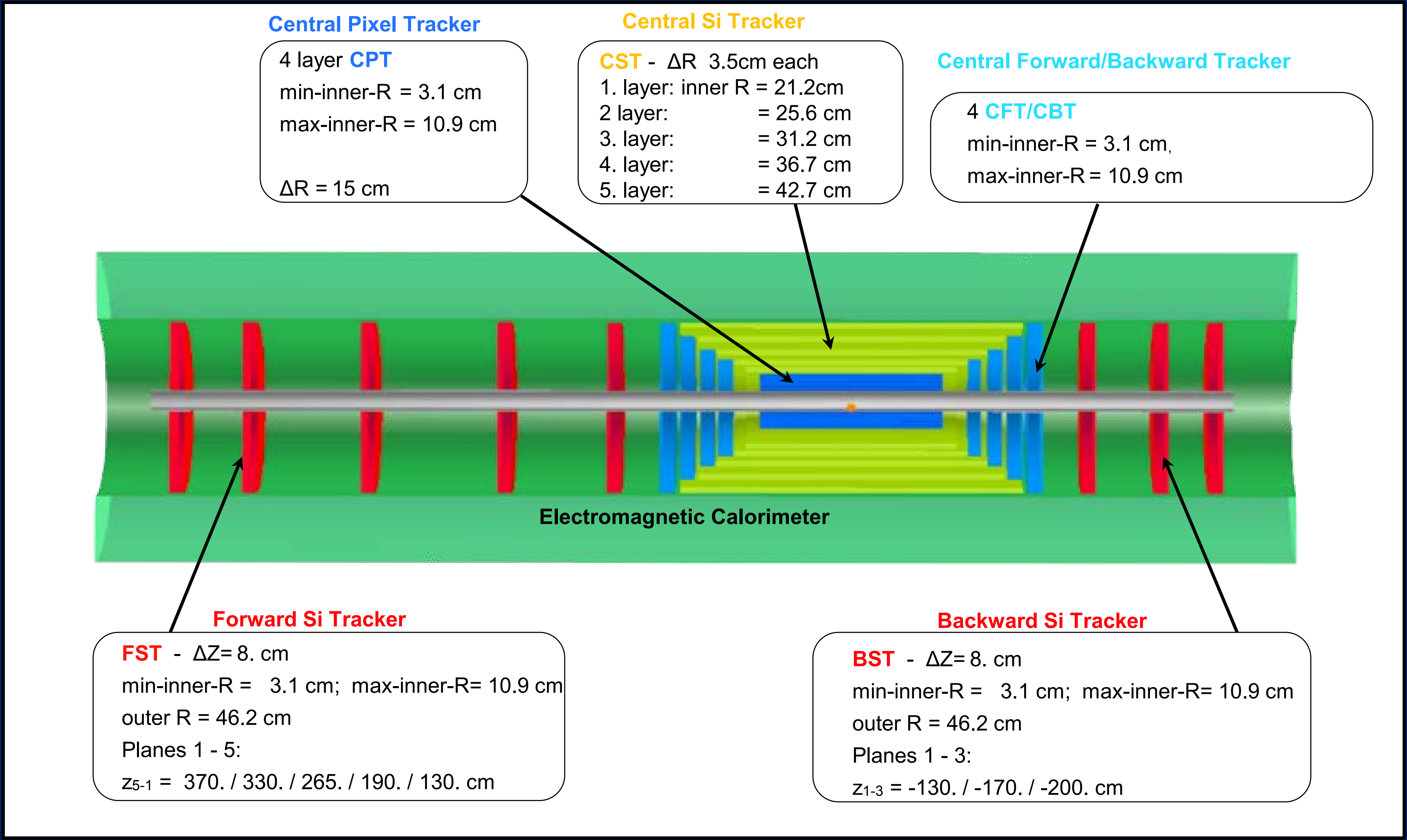
Detector: Requirements from Physics

- High resolution tracking system
  - excellent primary vertex resolution
  - resolution of secondary vertices down to small angles in forward direction for high x heavy flavor physics and searches
  - precise p_t measurement matching to calorimeter signals (high granularity), calibrated and aligned to 1 mrad accuracy
- The calorimeters
  - electron energy to about $10\%/\sqrt{E}$ calibrated using the kinematic peak and double angle method, to permille level

    Tagging of γ's and backward scattered electrons -
    precise measurement of luminosity and photo-production physics
  - hadronic part $40\%/\sqrt{E}$ calibrated with p_{t_e}/p_{t_h} to 1% accuracy
  - Tagging of forward scattered proton, neutron and deuteron - diffractive and deuteron physics
- Muon system, very forward detectors, luminosity measurements

Tracking - High Acceptance

Dominant forward production of dense jets;
backward measurements relaxed



Central Pixel Tracker

4 layer **CPT**
min-inner-R = 3.1 cm
max-inner-R = 10.9 cm

ΔR = 15 cm

Central Si Tracker

CST - ΔR 3.5cm each
1. layer: inner R = 21.2cm
2 layer: = 25.6 cm
3. layer: = 31.2 cm
4. layer: = 36.7 cm
5. layer: = 42.7 cm

Central Forward/Backward Tracker

4 **CFT/CBT**
min-inner-R = 3.1 cm,
max-inner-R = 10.9 cm

Forward Si Tracker

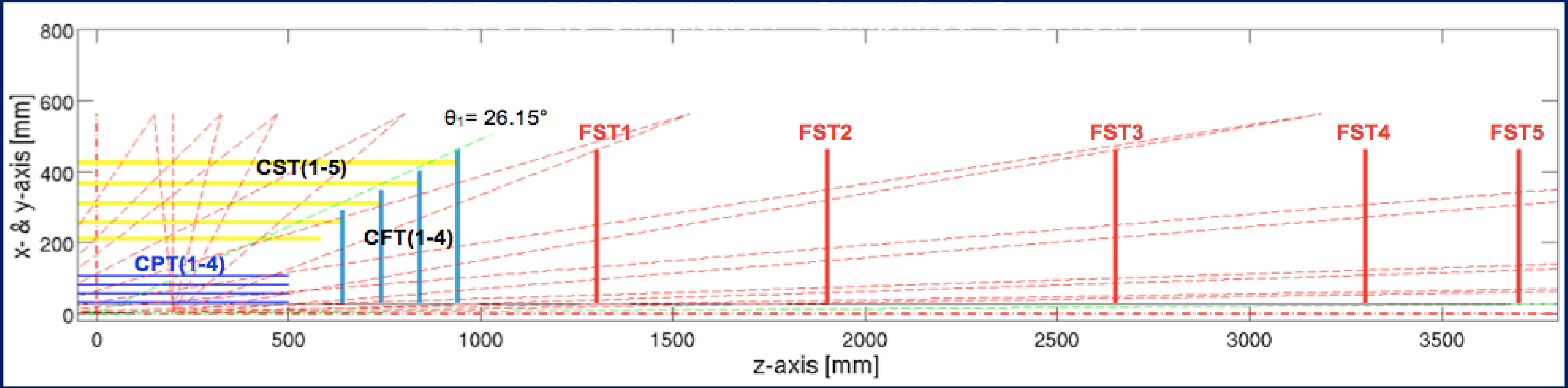
FST - ΔZ= 8. cm
min-inner-R = 3.1 cm; max-inner-R= 10.9 cm
outer R = 46.2 cm
Planes 1 - 5:
z_{5-1} = 370. / 330. / 265. / 190. / 130. cm

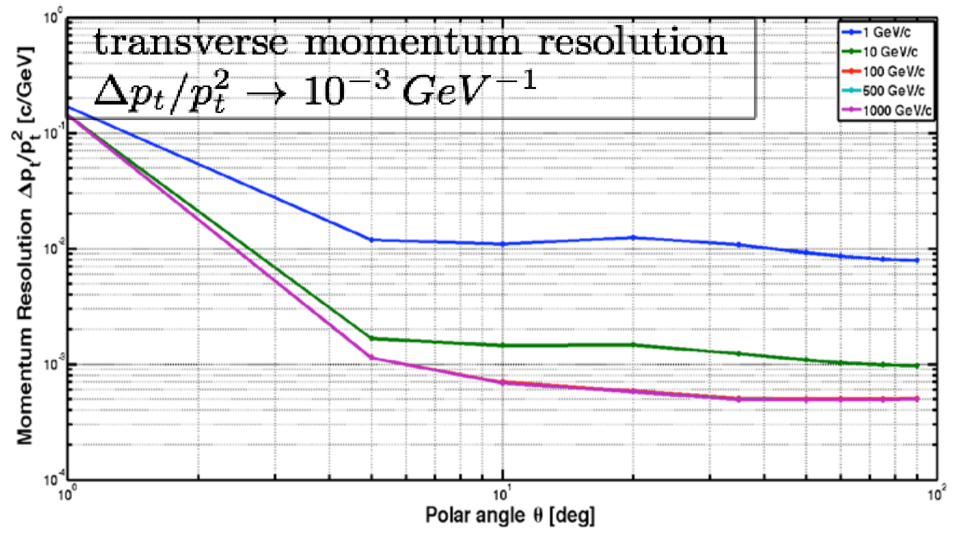
Backward Si Tracker

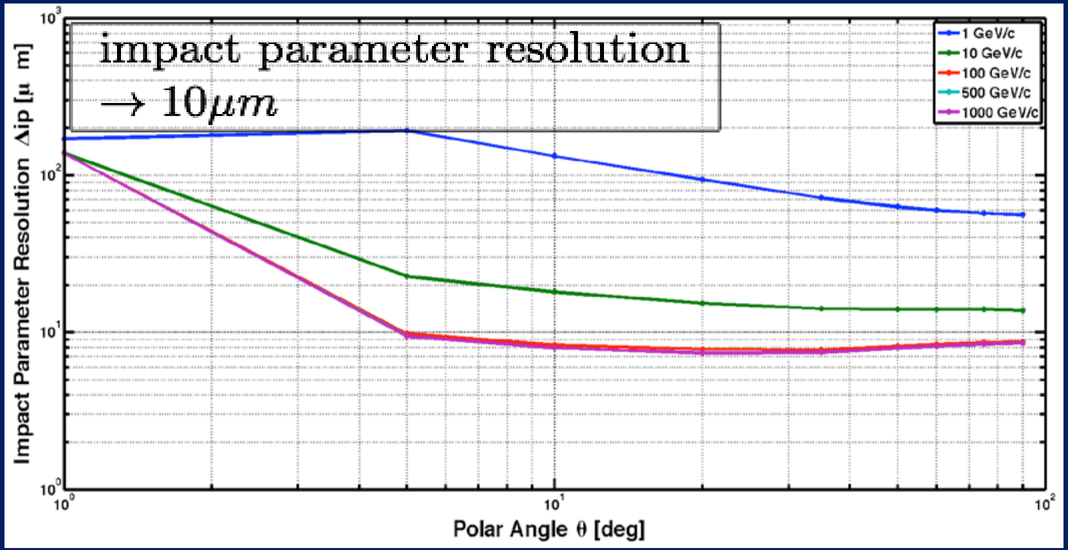
BST - ΔZ= 8. cm
min-inner-R = 3.1 cm; max-inner-R= 10.9 cm
outer R = 46.2 cm
Planes 1 - 3:
z_{1-3} = -130. / -170. / -200. cm

Tracker Simulation

LicToy http://wwwhephy.oeaw.ac.at/p3w/ilc/lictoy/UserGuide_20.pdf







- Silicon: compact design, low budget material, radiation hard

Services and Infrastructure

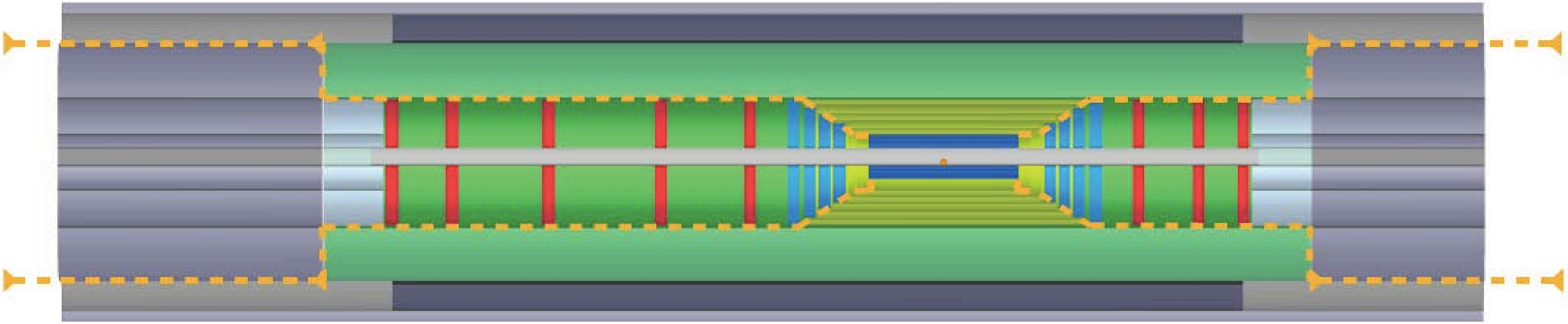
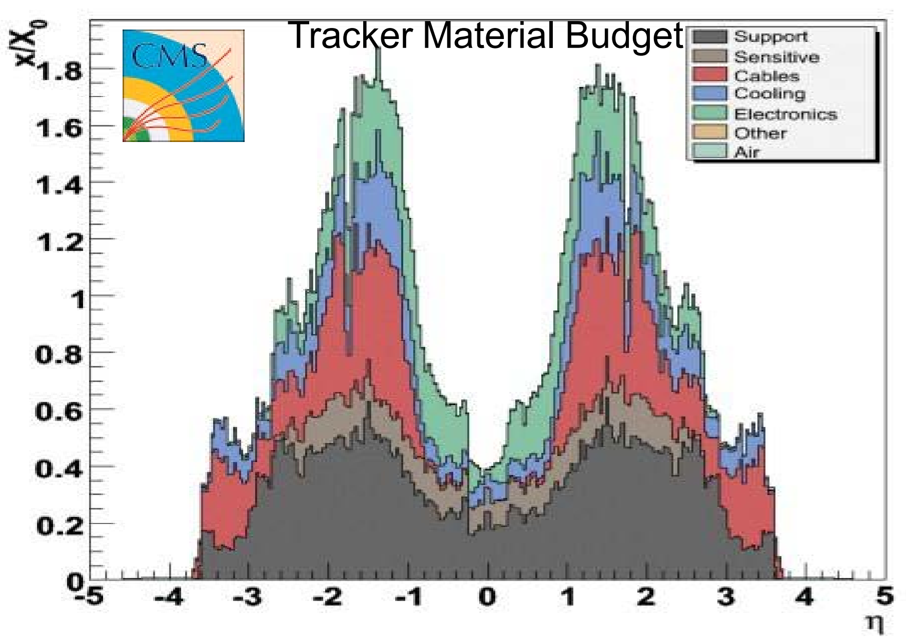
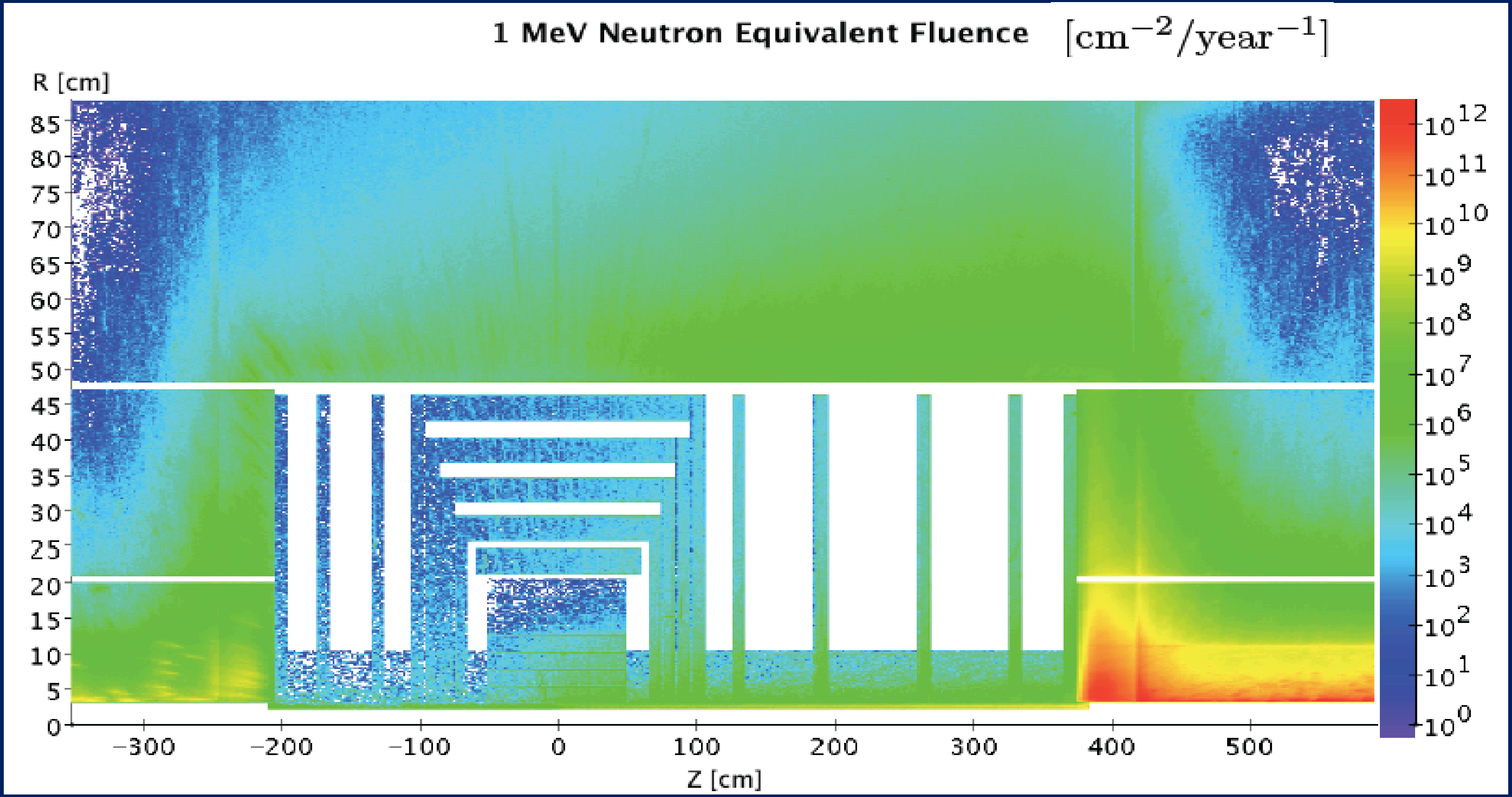


Figure 13.29: Path of services for all tracking detectors (shown in orange). The services are integrated into support structures whenever possible

- Detector of very compact design; It might be necessary to open places/grooves/tunnels for services affecting the aperture of the detector; Optimum between costs and detector acceptance needs to be found.
- Service and Infrastructure need very careful design being the main contributor to Material Budget →



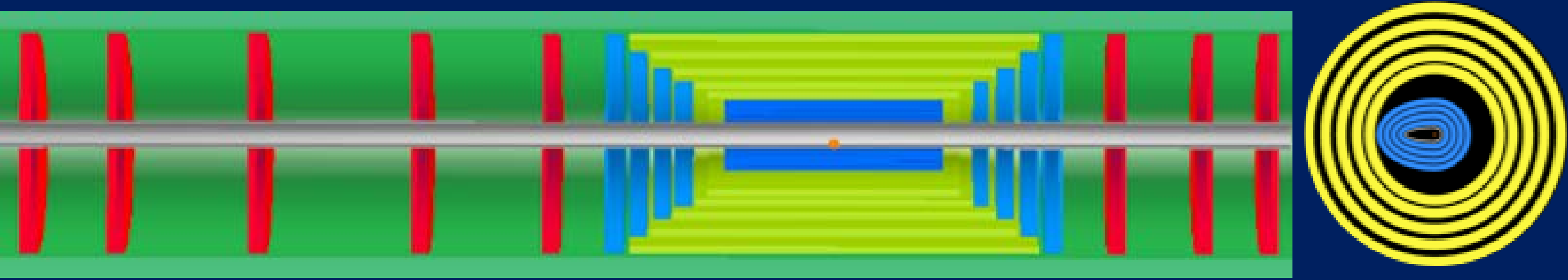
GEANT4 - Fluences



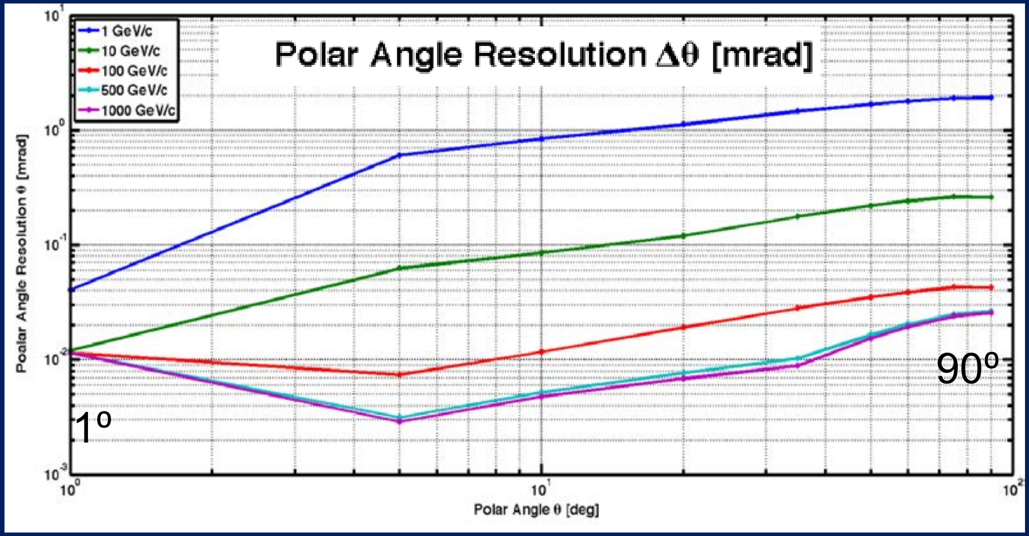
- Similar studies being done with FLUKA
- Most critical the forward region
- Rates far lower than LHC (LHC ~5 x 10^{14})

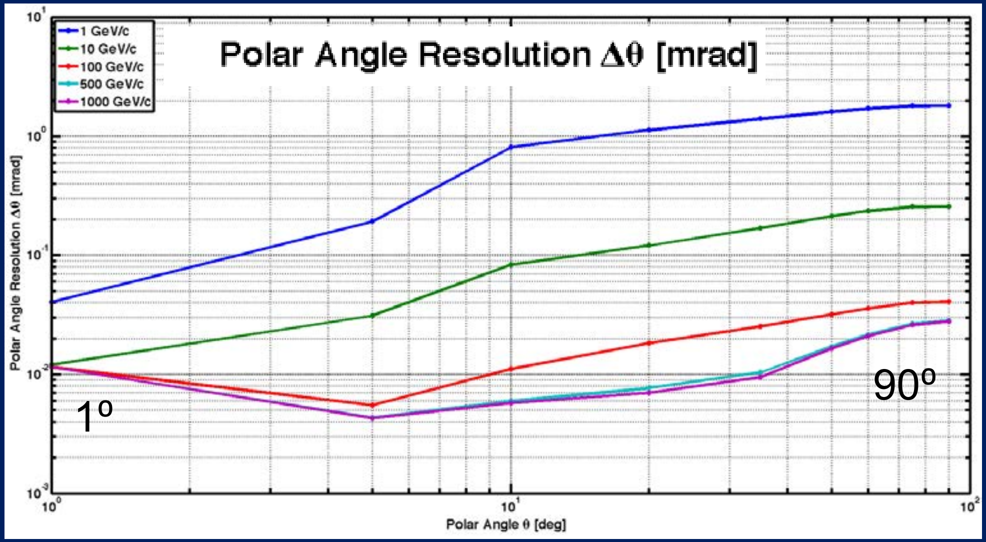
Tracker Detector Technology

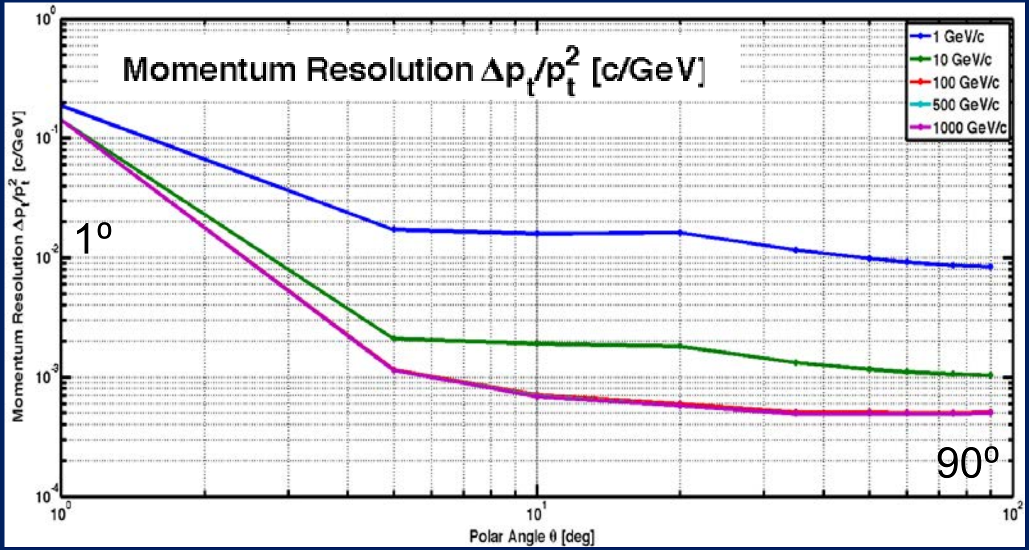
- Choose among available technologies
  n-in-p (sLHC) or n^+-in-n (ATLAS/CMS/LHCb)
- Radiation hardness in LHeC not as challenging as in LHC
- Silicon Pixel, Strixel, Strips
- Detailed simulation to best understand the needs and implications
- Readout/Trigger, Services, # silicon layers
- Analog/Digital Readout
- Modular structure for best replacement / maintenance and detector adoption: RR high luminosity / high acceptance running
- Pixel Detector*) (barrel CPT 1-4 and inner forward/backward FST/BST)

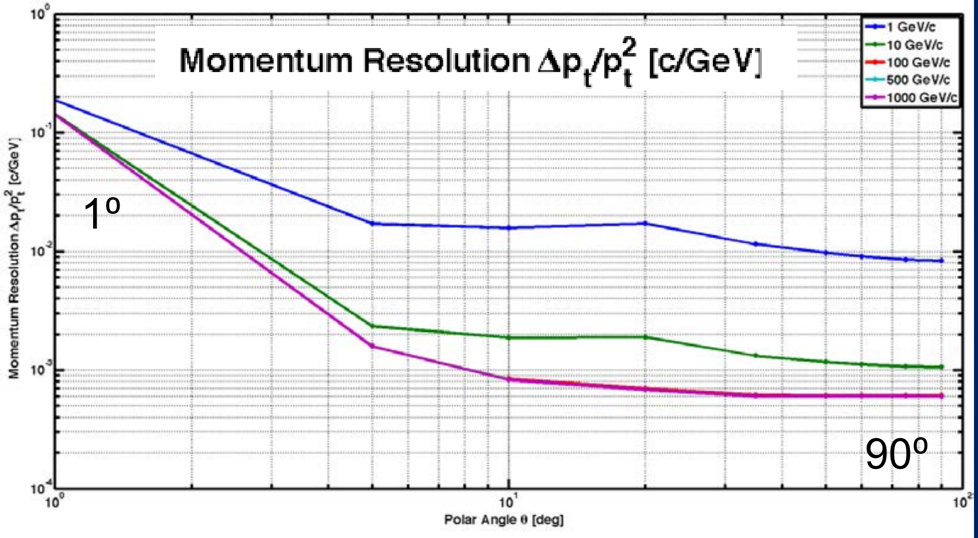


Tracker Simulation (ii)



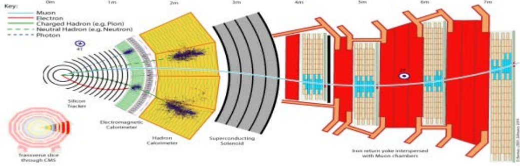






- Same plots (left) and (small) deterioration in case of innermost barrel layer failure (right)

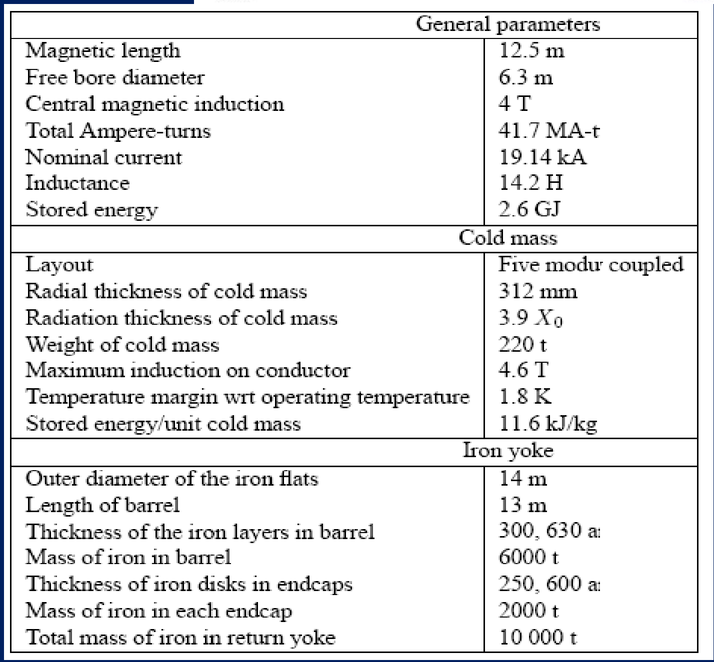
Solenoid Options



Large Coil

- Large Solenoid containing the Calorimeter
- 3.5 T Solenoid of similar to CMS/ILC
- Precise Muon measurement
- Large return flux either enclosed with Iron or

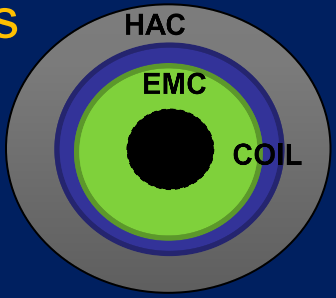
  Option of active B shielding with 2nd solenoid

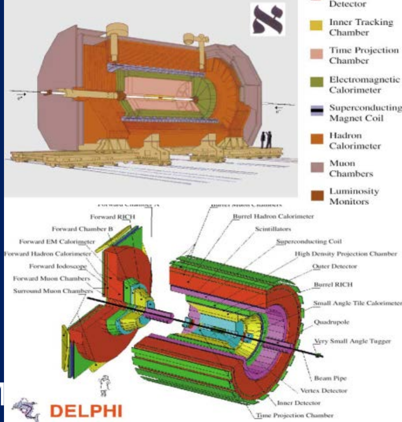


General parameters	
Magnetic length	12.5 m
Free bore diameter	6.3 m
Central magnetic induction	4 T
Total Ampere-turns	41.7 MA-t
Nominal current	19.14 kA
Inductance	14.2 H
Stored energy	2.6 GJ
Cold mass	
Layout	Five modu coupled
Radial thickness of cold mass	312 mm
Radiation thickness of cold mass	3.9 X_0
Weight of cold mass	220 t
Maximum induction on conductor	4.6 T
Temperature margin wrt operating temperature	1.8 K
Stored energy/unit cold mass	11.6 kJ/kg
Iron yoke	
Outer diameter of the iron flats	14 m
Length of barrel	13 m
Thickness of the iron layers in barrel	300, 630 a
Mass of iron in barrel	6000 t
Thickness of iron disks in endcaps	250, 600 a
Mass of iron in each endcap	2000 t
Total mass of iron in return yoke	10 000 t

Small Coil

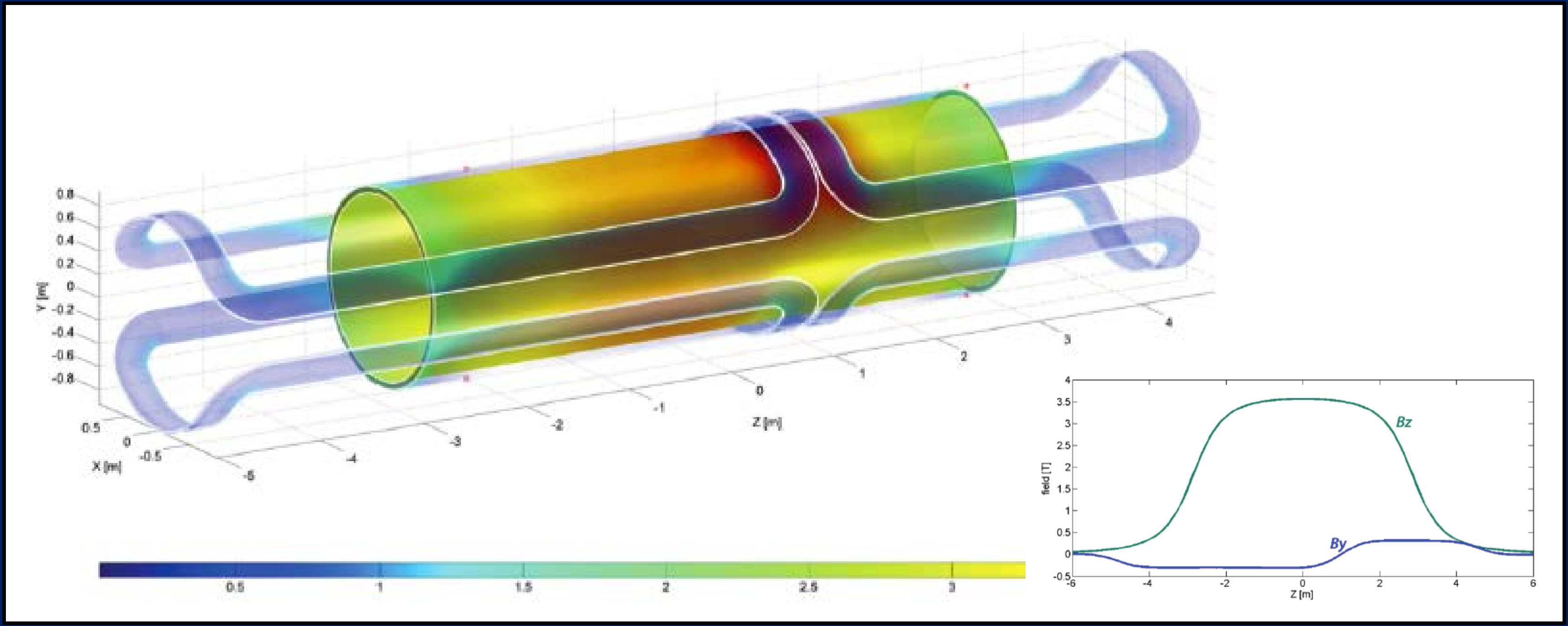
- Smaller Solenoid placed between EMC and HAC
- Cheaper option
- Convenient displacement of Solenoid and Dipoles in same cold vacuum vessel (Linac-Ring only)
- Smaller return flux (less iron required)
- Muon p, p_t measurement compromised





Magnets

A. Dudarev, H. Tenkate, -Chavannes 2012

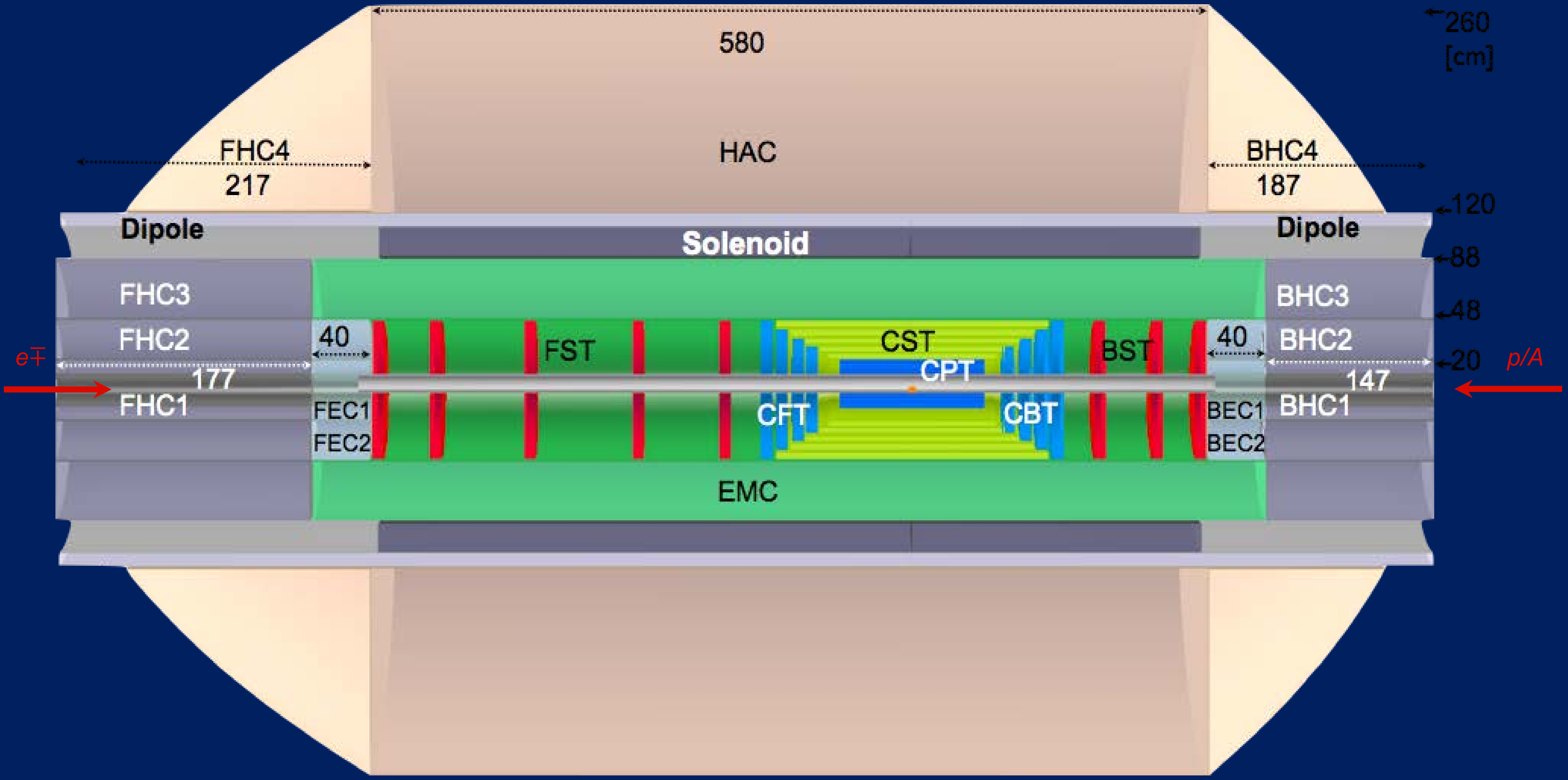


Baseline Solution:

- Solenoid (3.5 T) + dual dipole 0.3 T (Linac-Ring Option)
- Magnets (may be) embedded into EMC LAr Cryogenic System

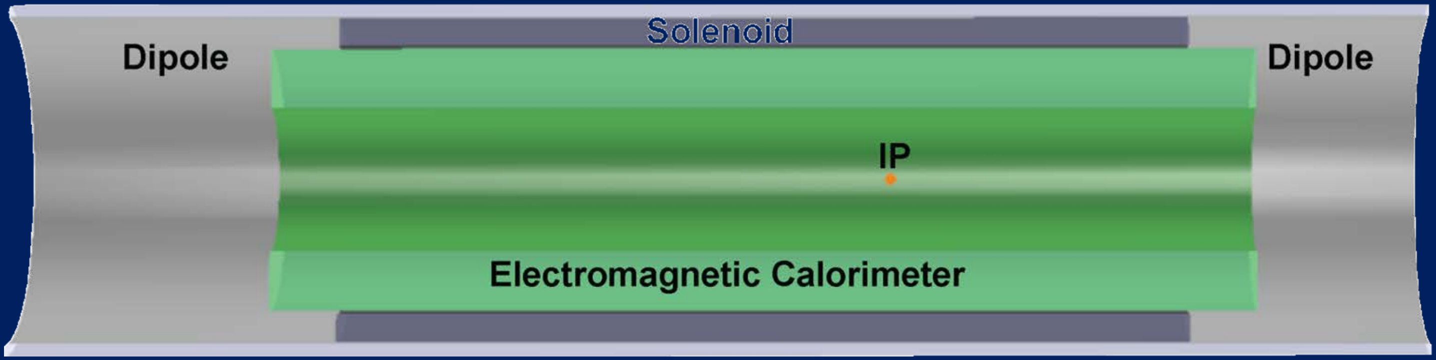
➔ Need of study the Calorimeter Performance and impact of dead material between EMC and HAC sections; it might be possible placing the magnet system even in front of the EMC - at even lower radius at just outside of the tracking system

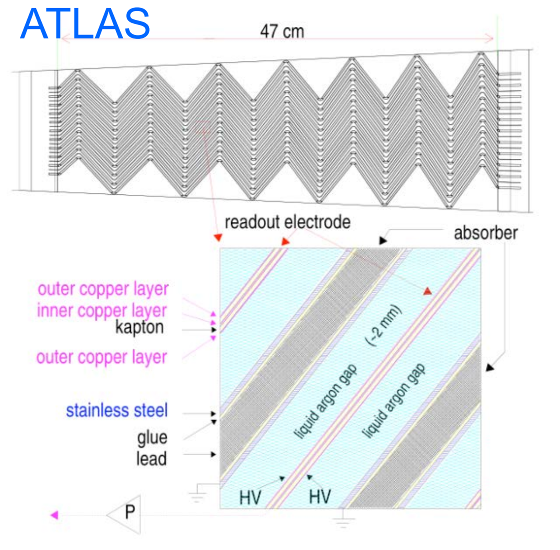
Baseline Detector

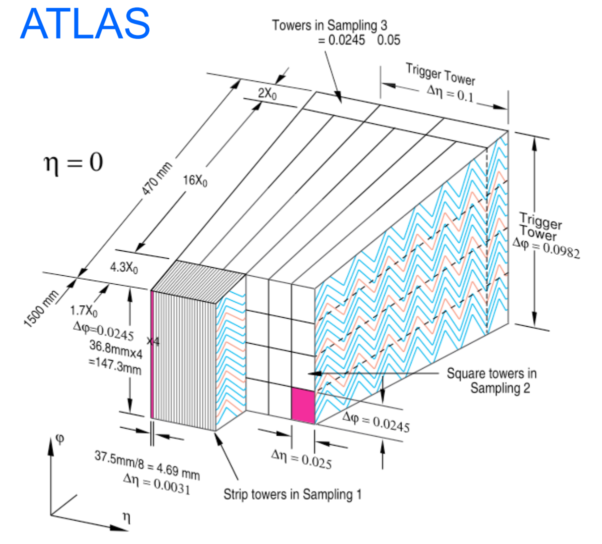


Electromagnetic Calorimeter (i)

- Baseline Electromagnetic Calorimeter
- LAr for barrel EMC calorimetry - ATLAS (~25-30 X_0)



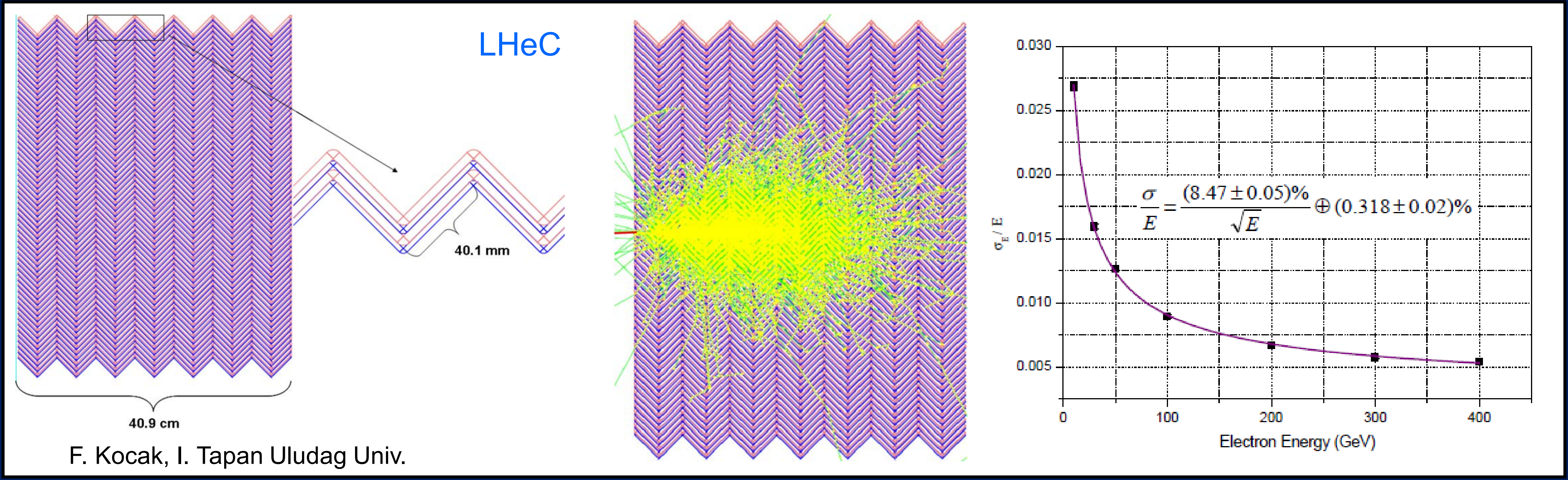




- Advantage: same cryostat used for solenoid and dipoles
- GEANT4 simulation (*)
- Simulation results compatible with ATLAS
- barrel cryostat being carefully optimized
  pre-sampler optimal
- 3 different granularity sections longitudinally

(*) F. Kocak, I. Tapan Uludag Univ.

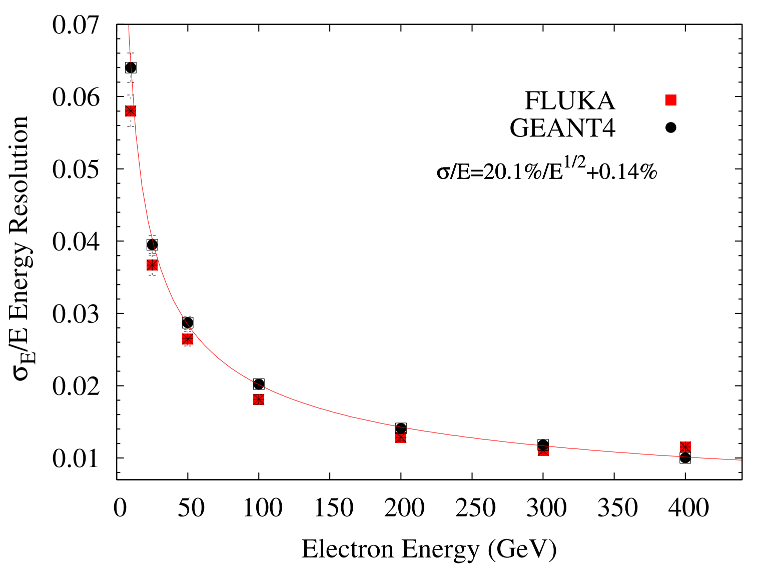
Electromagnetic Calorimeter (ii)



$$\frac{\sigma}{E} = \frac{(8.47 \pm 0.05)\%}{\sqrt{E}} \oplus (0.318 \pm 0.02)\%$$

F. Kocak, I. Tapan Uludag Univ.

- Simulation with simplified design w.r.t.Atlas
- LAr Calorimeter : good energy resolution, stable performance
- Simulation results compatible with ATLAS
- Warm (Pb/Sci) option also investigated
- $30X_0$ (X_0(Pb)=0.56 cm; 20 layers) ➔



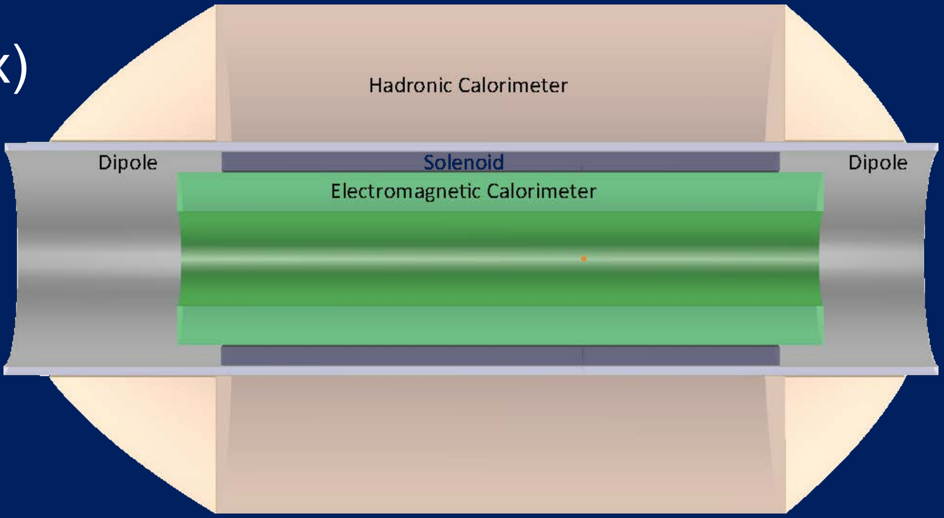
$\sigma/E = 20.1\%/E^{1/2} + 0.14\%$

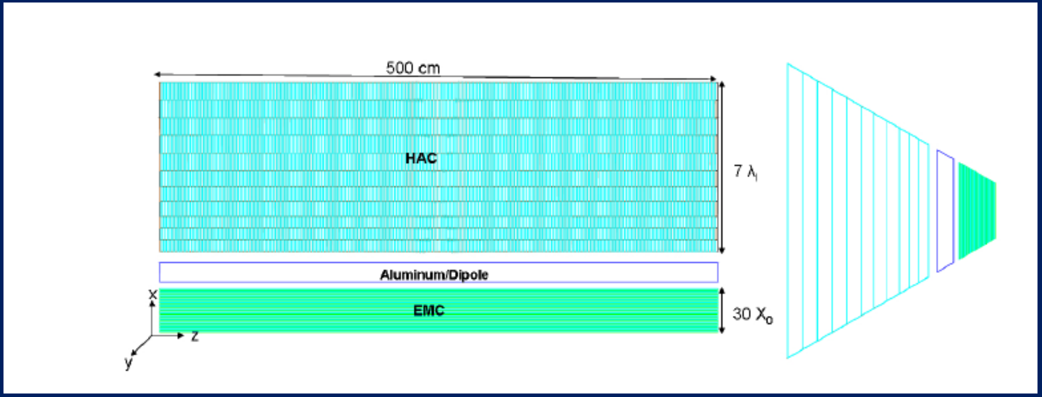
Hadronic Calorimeter (i)

- Baseline Design
  - HAC iron absorber (magnet return flux)
  - scintillating plates (similar to ATLAS TILE CAL)
  - Interaction Length: ~7-9 λ_I
- Setup:

Tile Rows	Height of Tiles in Radial Direction	Scintillator Thickness
1-3	97mm	3mm
4-6	127mm	3mm
7-11	147mm	3mm

- GEANT4 + FLUKA simulations
- performance optimization:
  - containment, resolution, combined HAC & EMC response
  - solenoid/dipoles/cryostat in between





Hadronic Calorimeter (ii)

- Preliminary studies of the impact of the magnet system on calorimetric measurements (GEANT4 & FLUKA *)
- Energy resolutions
- Shower profiles

*) F.Kocak, I.Tapan, A.Kilic, E.Pilicer Uludag Univ.; E.Arikan, H.Aksakal Nigde Univ.

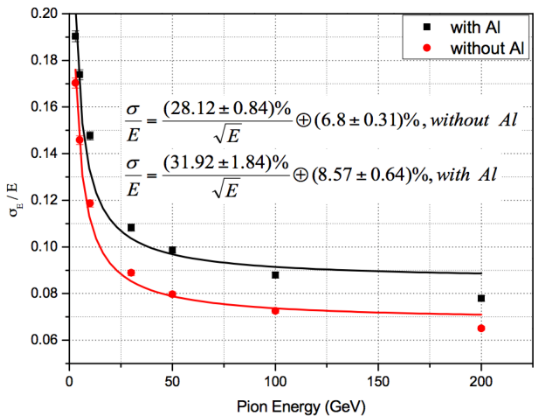


Figure 12.37: Combined LAr Accordion and Tile Calorimeter energy resolution for pions with and without 14 cm Al block (**GEANT4**)

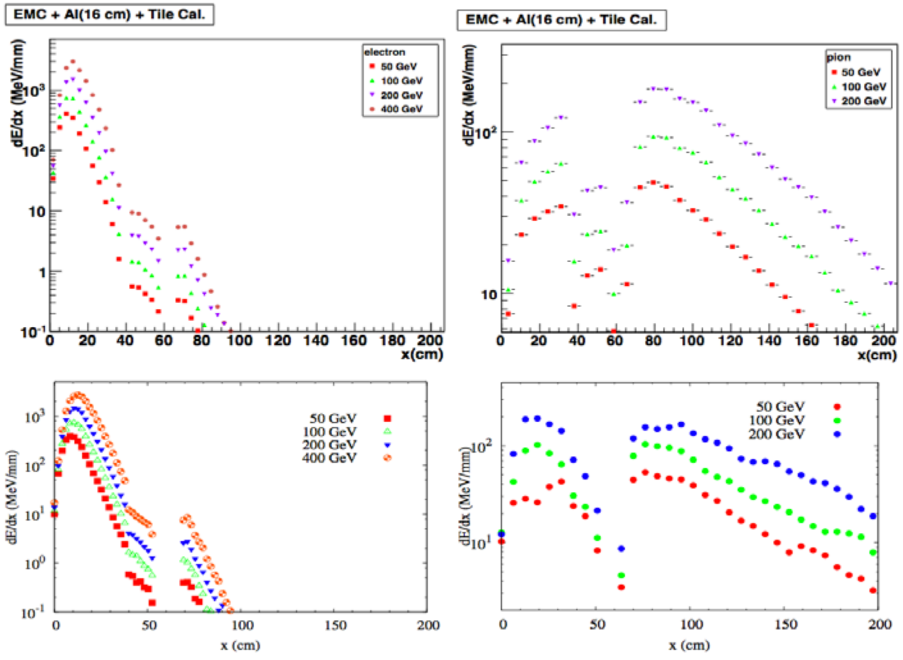


Figure 12.41: Electron (left) and Pion (right) longitudinal shower profile for the EMC$_{Pb-Sc}$ / solenoid-dipole-system (Al-block) / HAC at various energies (**GEANT4** (top) and **FLUKA** (bottom)).

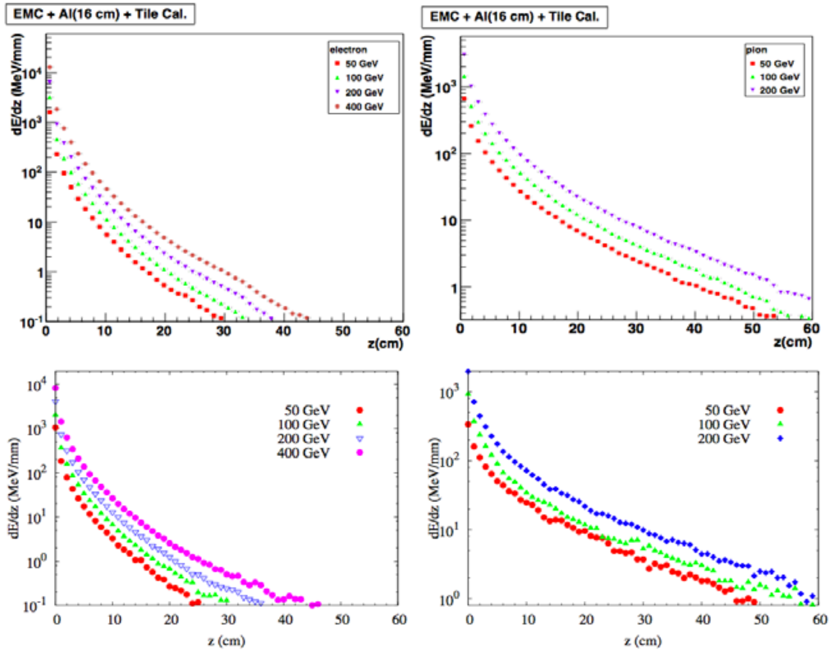


Figure 12.42: Energy deposit and transverse shower profiles for electron (left) and pion (right) - both for the EMC$_{Pb-Sc}$ stack (**GEANT4** (top) and **FLUKA** (bottom)).

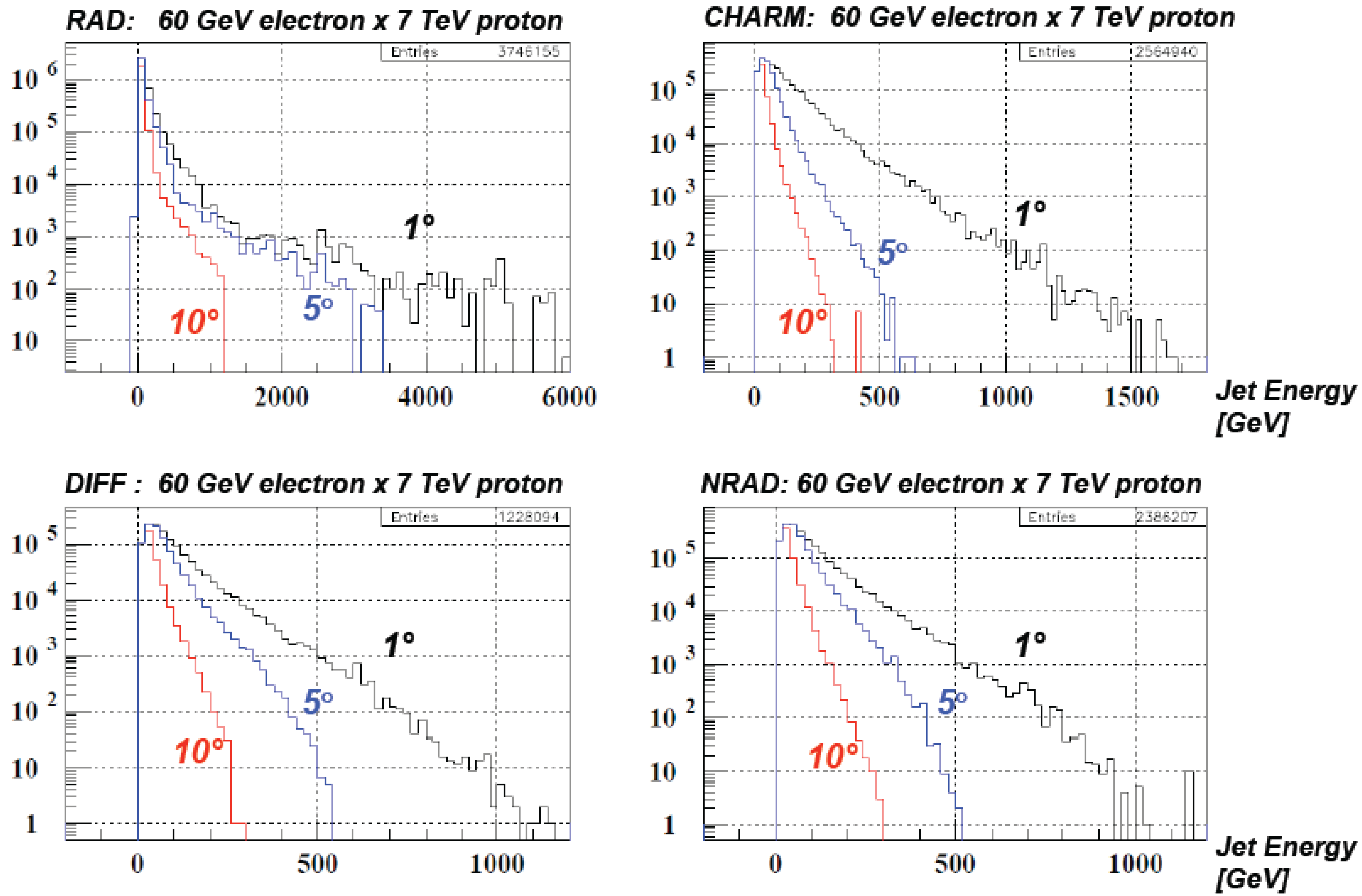
Forward Energy and Acceptance

RAPGAP-3.2 (H.Jung et.al.- http://www.desy.de/~jung/rapgap.html)

HzTooL-4.2 (H.Jung et.al. - http://projects.hepforge.org/hztool/)

selection: q^2.gt.5

→ Highest acceptance desirable



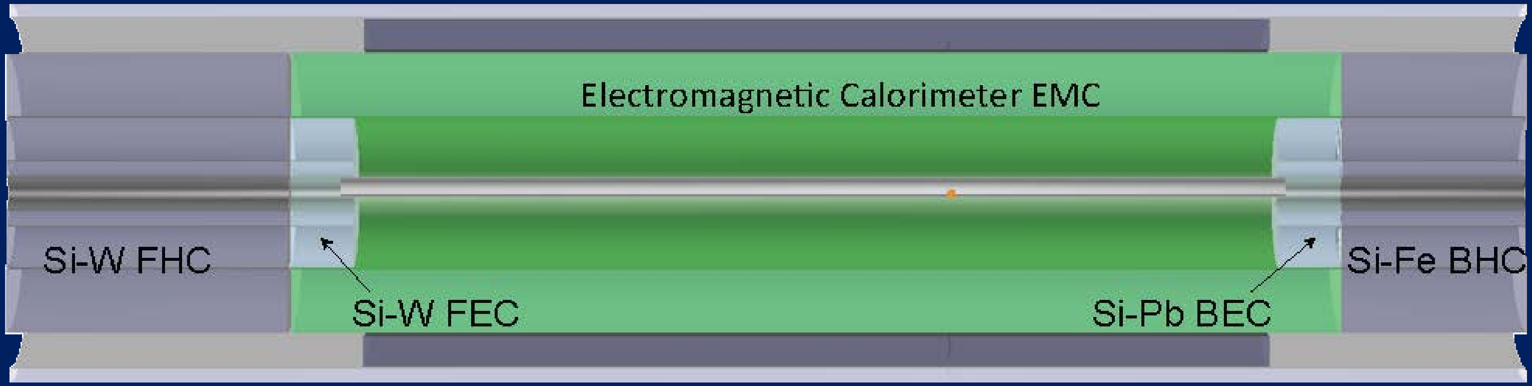
RAD: 60 GeV electron x 7 TeV proton

CHARM: 60 GeV electron x 7 TeV proton

DIFF : 60 GeV electron x 7 TeV proton

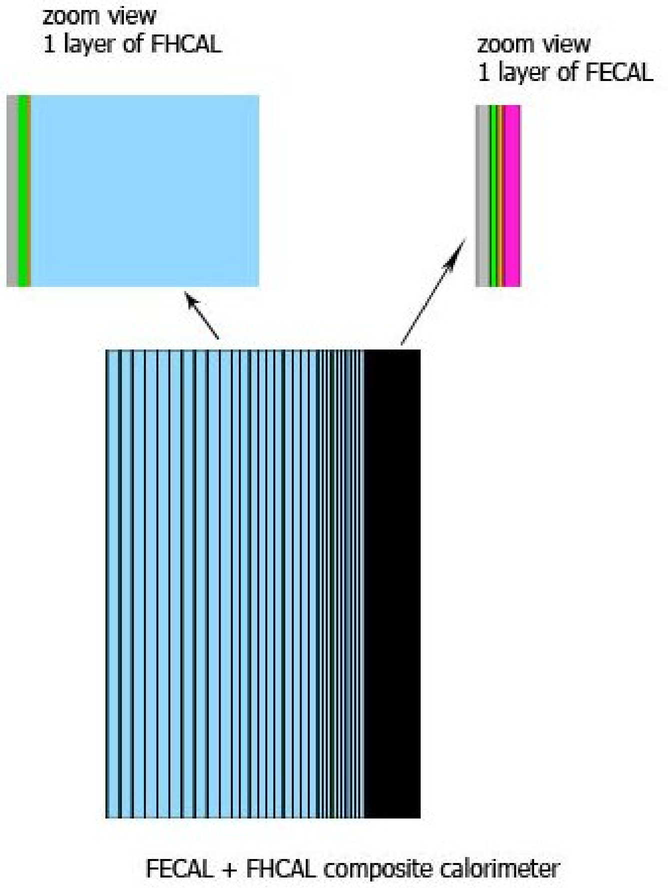
NRAD: 60 GeV electron x 7 TeV proton

Forward/Backward Calorimeters (i)



Forward/Backward Calorimeters

- Forward FEC + FHC:
  - tungsten high granularity
  - Si (rad-hard)
  - high energy jet resolution
  - FEC: ~30X_0; FHC: ~8-10 λ_I
- Backward BEC + BHC:
  - need precise electron tagging
  - Si-Pb, Si-Fe/Cu (~25X_0, 6-8 λ_I)
- GEANT4 simulation *
  - containment, multi-track resolution (forward)
  - e± tagging/E measurement (backwards)

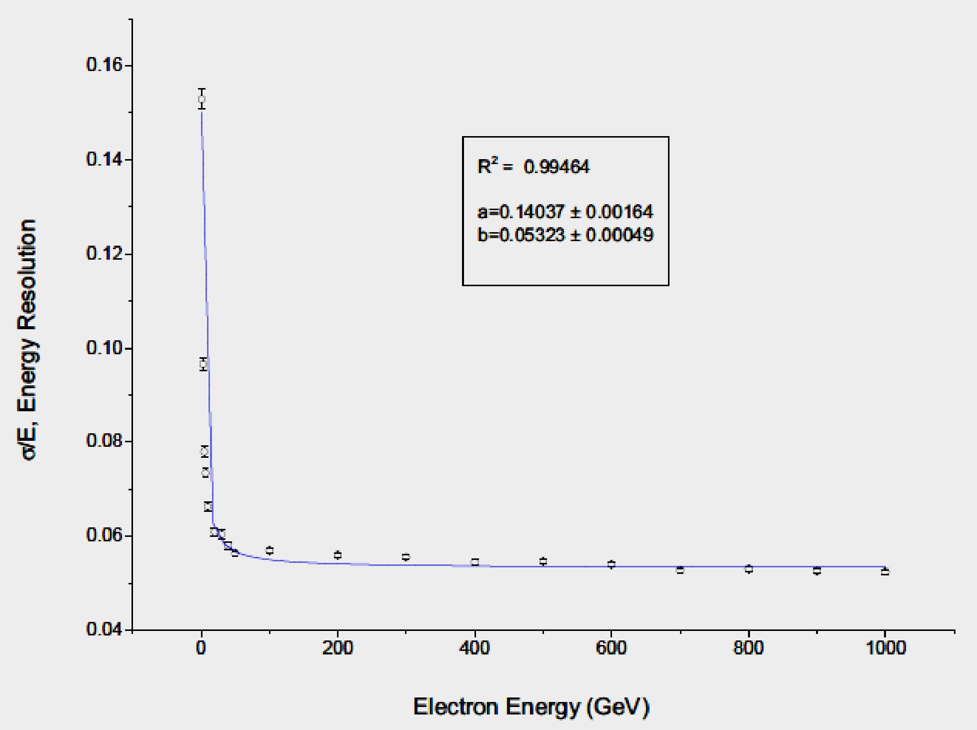


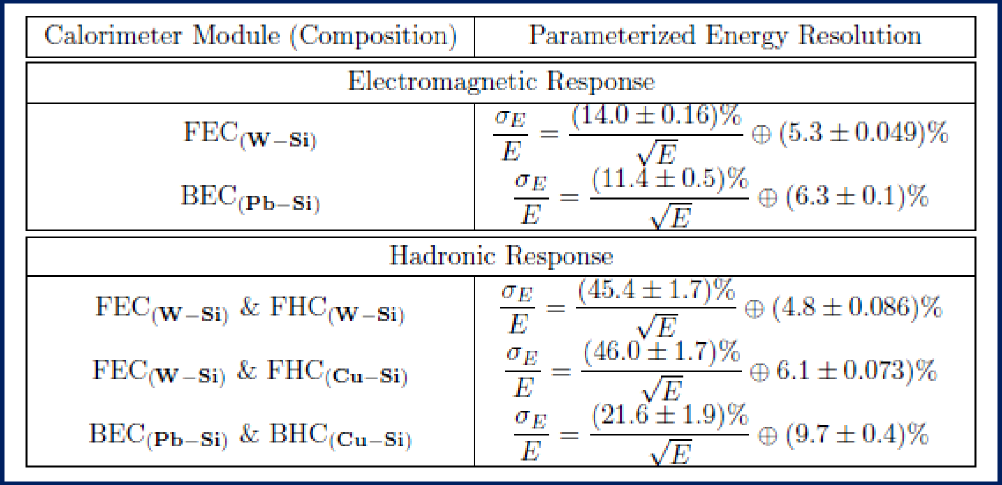
* A. Kilic, I. Tapan - Uludag University

Forward/Backward Calorimeters (ii)

- Highest energies in forward region
- Radiation hard
- High Granularity
- Linearity

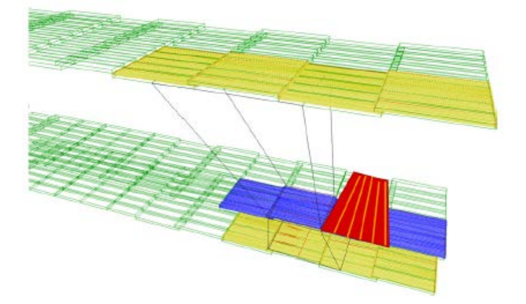
Calorimeter Module	Layer	Absorber	Thickness	Instrumented Gap	Total Depth
FEC(W-Si) 30x0	1-25 26-50	1.4 mm 2.8 mm	16 cm 19.5 cm	5 mm	35.5 cm
FHC (W-Si)	1-15 16-31 32-46	1.2 cm 1.6 cm 3.8 cm	39 cm 48 cm 78 cm	14 mm	165 cm
FHC (Cu-Si)	1-10 11-20 21-30	2.5 cm 5 cm 7.5 cm	30 cm 55 cm 80 cm	5 mm	165 cm
BEC (Pb-Si)	1-25 26-50	1.8 mm 3.8 mm	17 cm 22 cm	5 mm	39 cm
BHC(Cu-Si) 7.9	1-15 16-27 28-39	2.0 cm 3.5 cm 4.0 cm	39.75 cm 49.8 cm 55.8 cm	6.5 mm	145.35cm

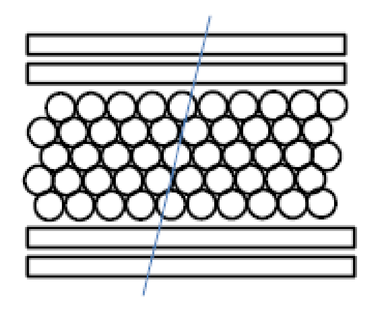


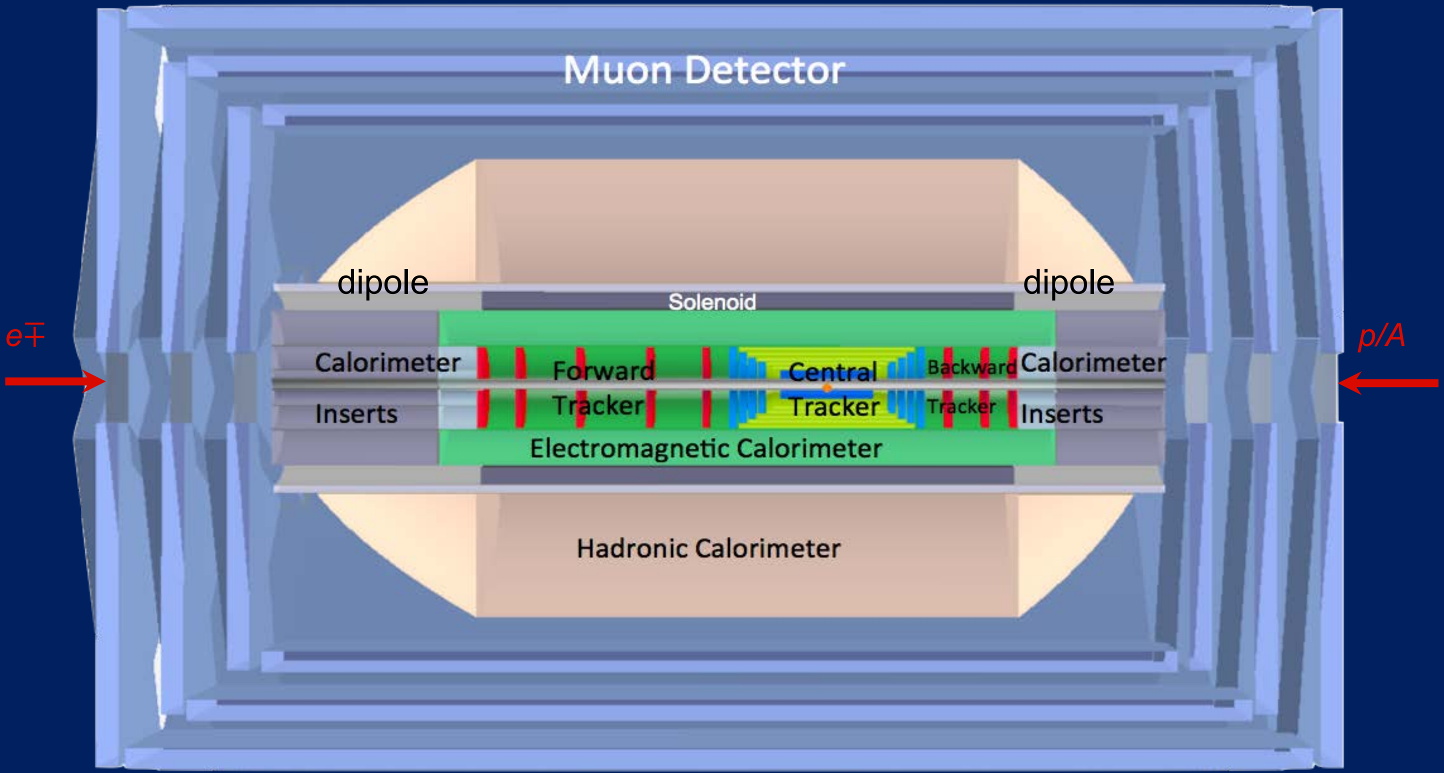


Calorimeter Module (Composition)	Parameterized Energy Resolution
Electromagnetic Response	
$\mathrm{FEC}_{(\mathbf{W-Si})}$	$\frac{\sigma_E}{E} = \frac{(14.0 \pm 0.16)\%}{\sqrt{E}} \oplus (5.3 \pm 0.049)\%$
$\mathrm{BEC}_{(\mathbf{Pb-Si})}$	$\frac{\sigma_E}{E} = \frac{(11.4 \pm 0.5)\%}{\sqrt{E}} \oplus (6.3 \pm 0.1)\%$
Hadronic Response	
$\mathrm{FEC}_{(\mathbf{W-Si})}$ & $\mathrm{FHC}_{(\mathbf{W-Si})}$	$\frac{\sigma_E}{E} = \frac{(45.4 \pm 1.7)\%}{\sqrt{E}} \oplus (4.8 \pm 0.086)\%$
$\mathrm{FEC}_{(\mathbf{W-Si})}$ & $\mathrm{FHC}_{(\mathbf{Cu-Si})}$	$\frac{\sigma_E}{E} = \frac{(46.0 \pm 1.7)\%}{\sqrt{E}} \oplus 6.1 \pm 0.073)\%$
$\mathrm{BEC}_{(\mathbf{Pb-Si})}$ & $\mathrm{BHC}_{(\mathbf{Cu-Si})}$	$\frac{\sigma_E}{E} = \frac{(21.6 \pm 1.9)\%}{\sqrt{E}} \oplus (9.7 \pm 0.4)\%$

Muon System Baseline



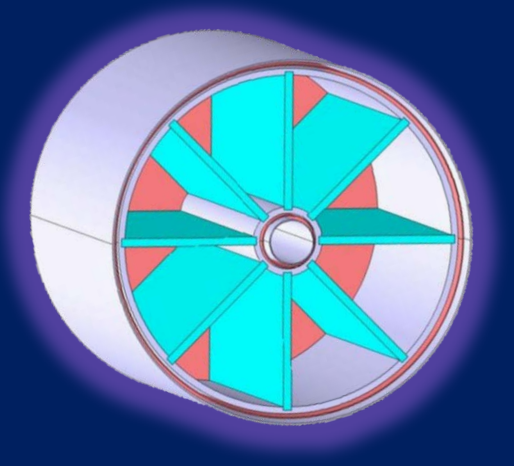




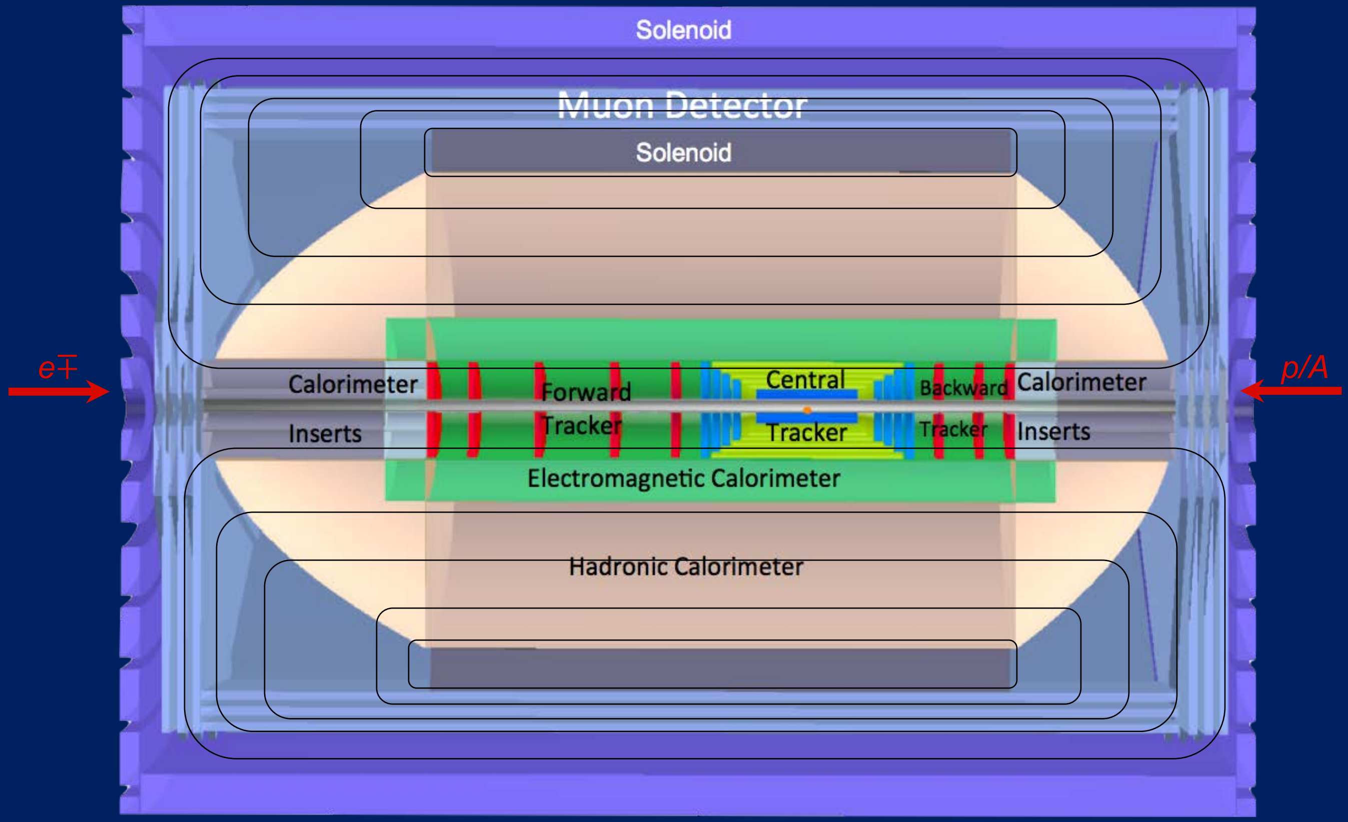
Baseline Solution:

- Muon system providing tagging, no independent momentum measurement
- Momentum measurement done in combination with inner tracking
- Present technologies in use in LHC exp. sufficient (RPC, TGC, MDT)

Muon System Extensions



Forward Air Core Toroid



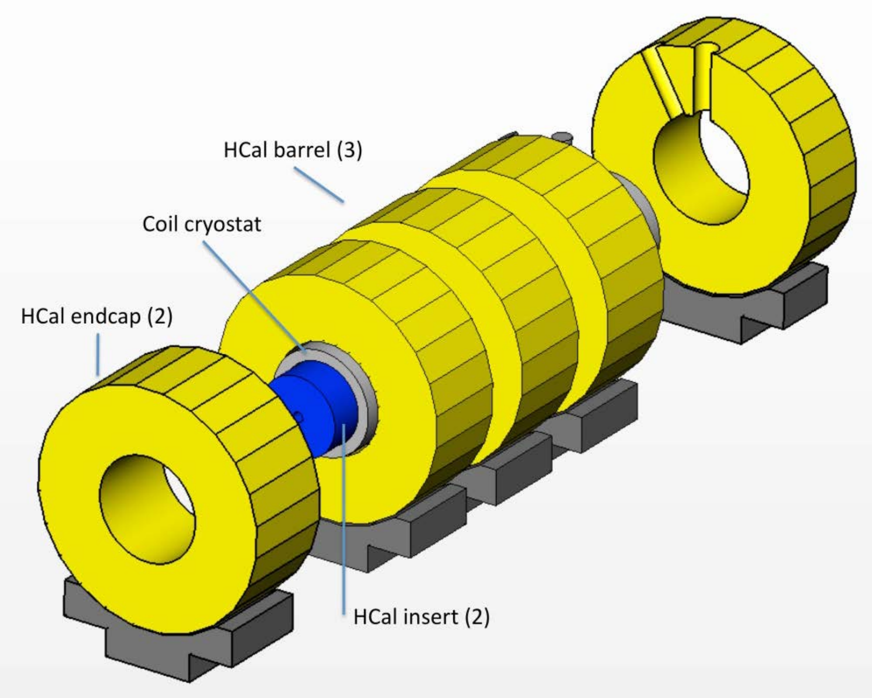
Extensions:

- Independent momentum measurement
- Large solenoid (incompatible with LR dipoles)
- Dual Coil System (homogeneous return field)
- Forward Toroid System

LHeC Detector Installation (i)

LHeC Detector assembly on surface

A. Herve, A. Gaddi - LHeC Chavannes 2012



- The strategy proposed is to complete as much as possible the assembly of the detector on surface. The detector has been split in the following main parts:

  1) Coil cryostat, including the superconducting coil, the two dipoles and eventually the EMCal, if the LAr version is retained.

  2) Three barrel wheels and two endcaps HCal tile calorimeter, fully instrumented and cabled.

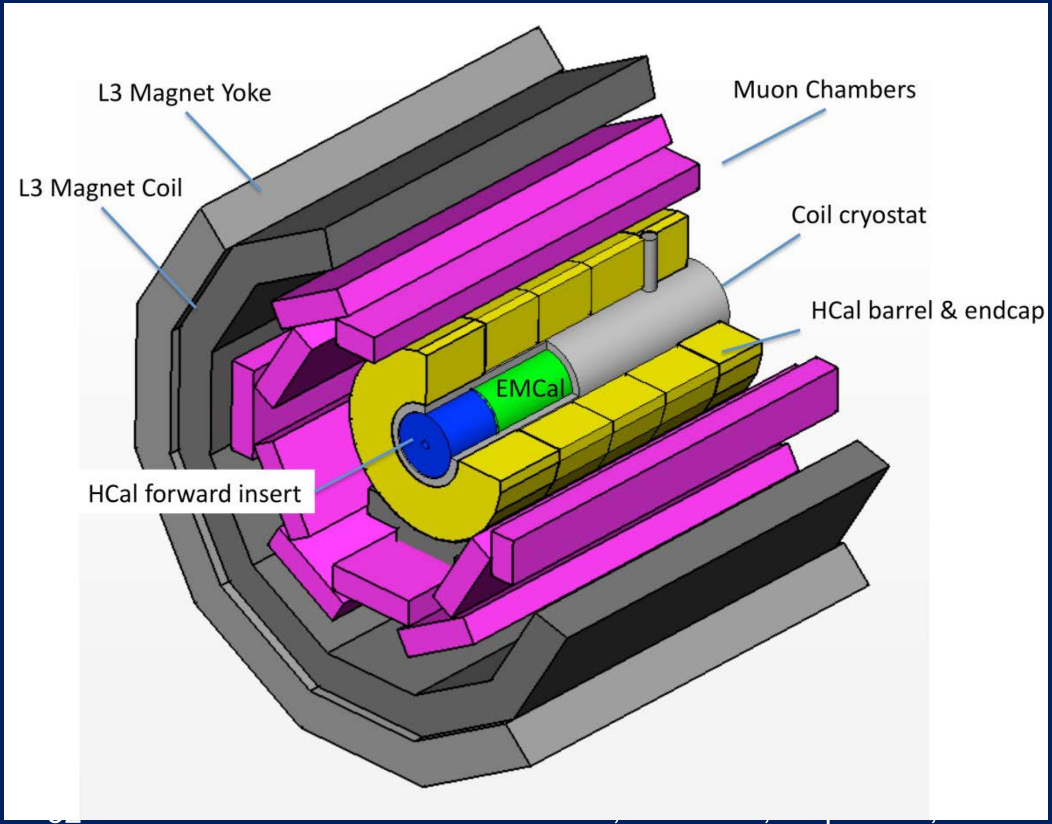
  3) Two HCal inserts, forward and backward.

- The maximum weight of a single element to be lowered from surface to underground has been limited to 300 tons, in order to make possible the lowering by renting a standard crane, as already applied by L3 for its barrel HCal. The superconducting coil and the two integrated dipoles will be tested at nominal current on surface, whilst the field mapping will be performed underground.

LHeC Detector Installation (ii)

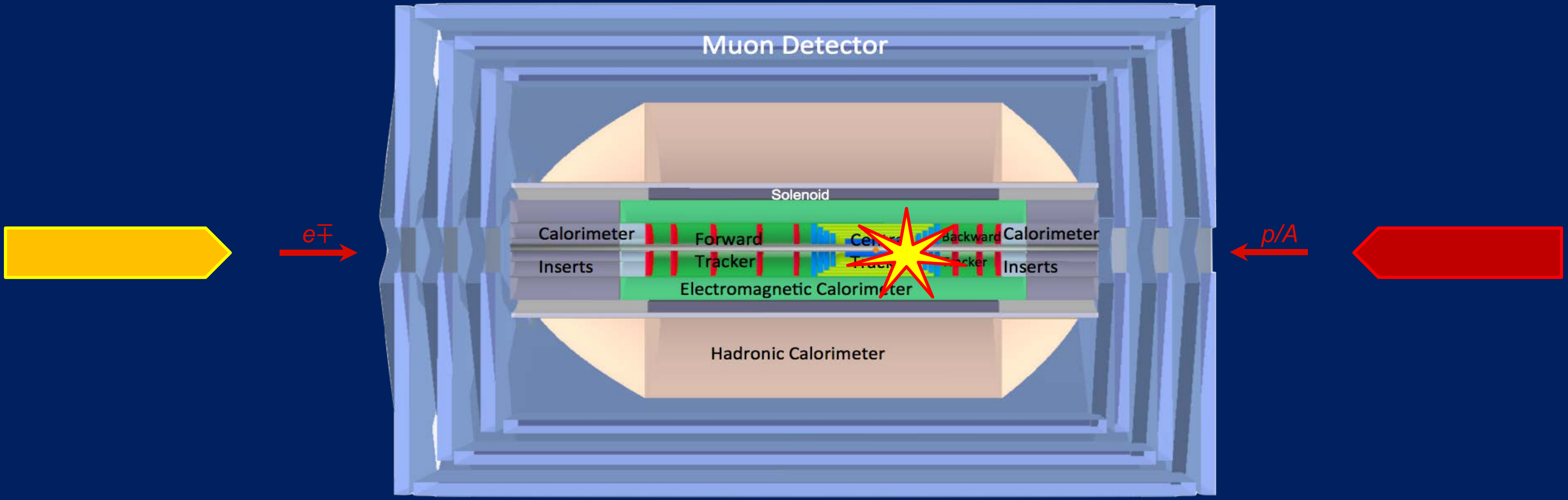
- The assembly on surface of the main detector elements as approximately 16 months
- The Coil system commissioning on site three additional month, preparation for lowering one month and lowering one week per piece
- Underground completion of the integration of the main detector elements inside the L3 Magnet would require about two months, cabling and connection to services
- Some six months, in parallel with the installation of Muons Tracker and the EMCal
- The total estimated time is thus 30 months
- The field map would take one extra month.
- Some contingency is foreseen between the integration inside the L3 Magnet of the same elements (2 months).
- Tight but doable

A. Herve, A. Gaddi - LHeC Chavannes 2012



Outer Detectors

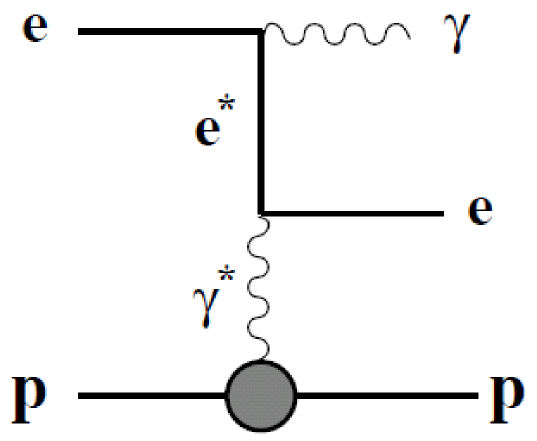
Present dimensions: LxD =14x9m^2 [CMS 21 x 15m^2 , ATLAS 45 x 25 m^2]



Detector option 1 for LR and full acceptance coverage

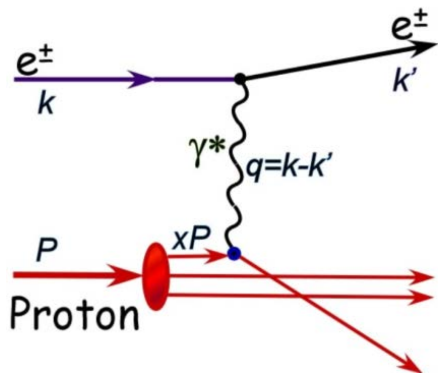
- **Electron outgoing direction:**
  → Tag photo-production (Q2~0), Luminosity Detectors, Electron Taggers
- **Proton/Ion outgoing direction: Very forward nucleons**
  → Zero Degree Calorimeter, Forward Proton Spectrometer

Luminosity measurement: physics processes



BH σ^{vis} **>100μb**
QEDC σ^{vis} **>100nb**

NC σ^{vis} **>1nb**



Bethe-Heitler (collinear emission):

- very high rate of ‘zero angle’ photons and electrons, but sensitive to the details of beam optics at IP
- requires precise knowledge of geometrical acceptance
- suffers from synchrotron radiation
- aperture limitation
- pile-up

QED Compton (wide angle bremsstrahlung):

- lower rate, but
- stable and well known acceptance of central detector

Methods are complementary, different systematics

NC DIS in (x,Q^2) range where F_2 is known to O(1%)

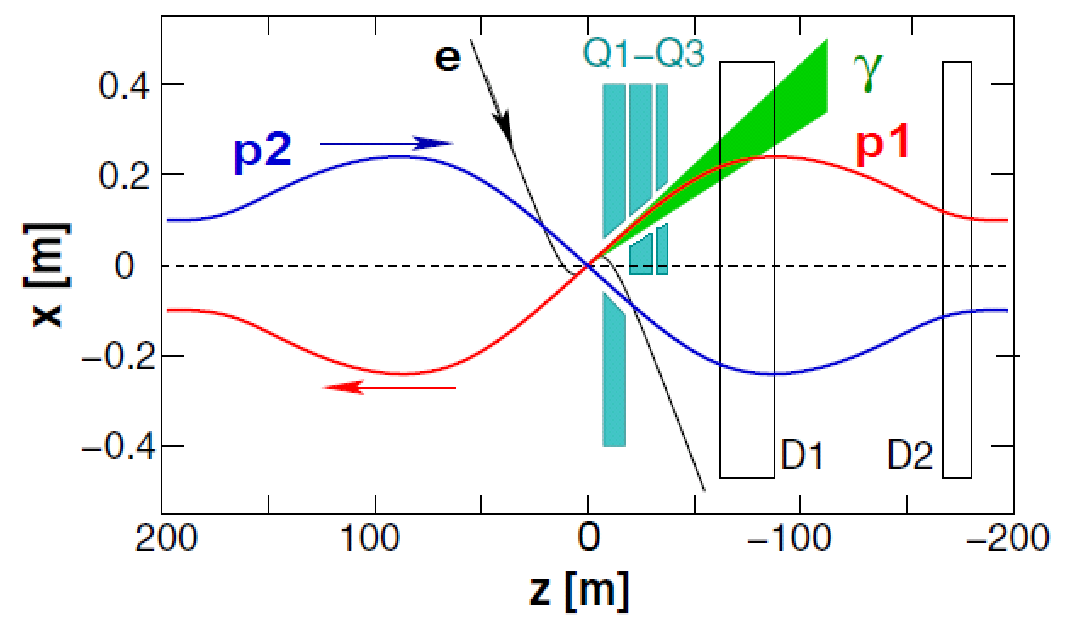
for relative normalisation and mid-term yield control

($\sigma_{vis}^{DIS,Q^2>10GeV^2}$ ~ 10nb for 10° and ~150nb for 1° setup)

Luminosity measurement: Bethe-Heitler (ep→eγp)

For **LR** option (zero crossing angle) the photons travel along the proton beam direction and can be detected at z≈-120m, after the proton bending dipole.

→ Place the photon detector in the median plane next to interacting proton beam



Main limitation – geometrical acceptance, defined by the aperture of Q1-Q3.
May be need to split dipole D1 to provide escape path for photons.

Geometrical acceptance of 95% is possible, total luminosity error δL≈1%.

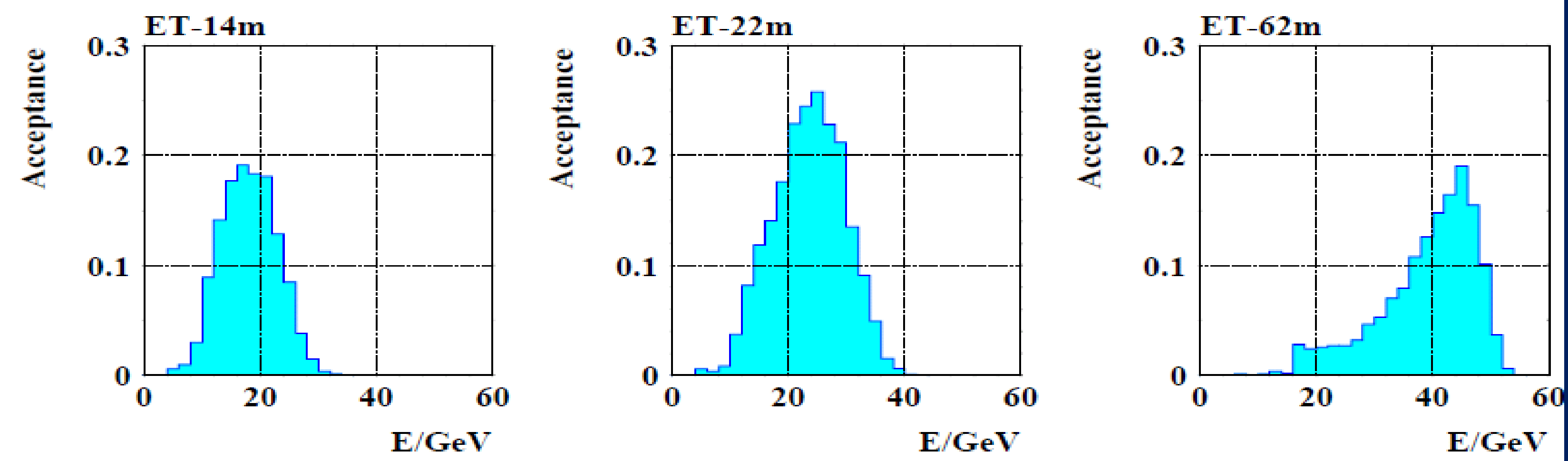
- clarify p-beamline aperture in the range z=0-120m
- need to calculate acceptance and its variations due to beam optics; (but this is essentially HERA setup, so we can use similar detectors/methods)

Electron Tagger

Detect scattered electron from Bethe-Heitler
(also good for photoproduction physics and for control of γp background to DIS)

Clean sample – background from e-gas can be estimated using pilot bunches.

Three possible positions simulated→ acceptances reasonable (up to 20÷25%)



62m is preferable – less SR, more space available.
Next steps: detailed calculation of acceptance and variations due to optics
(beam-tilt, trajectory offset) and e-tagger position measurement and stability

Need a precise monitoring of beam optics and accurate position measurement of the e-tagger to control geometrical acceptance to a sufficient precision (e.g. 20mm instability in the horizontal trajectory offset at IP leads to 5% systematic uncertainty in the σ_{vis})

Main experimental difficulty would be good absolute calibration and resolution
(leakage over the detector boundary)

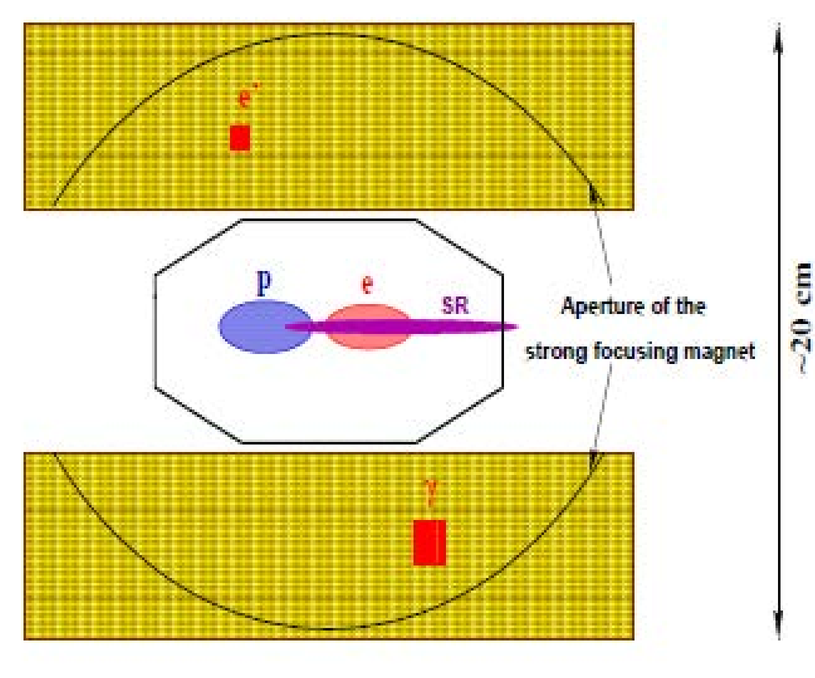
Luminosity measurement: QED Compton

electron and photon measured in the main detector (backward calorimeter)

σ_{vis} ~3.5nb (low Q^2 setup); 0.03nb (high Q^2 setup)

Install additional ‘QEDC tagger’ at z≈-6m →increase visible cross section for QEDC up to ~3-4 nb

→ e.g. two moveable sections approaching the beam-pipe from top and bottom (assume angular acceptance $\theta \approx 0.5 \div 1^o$)



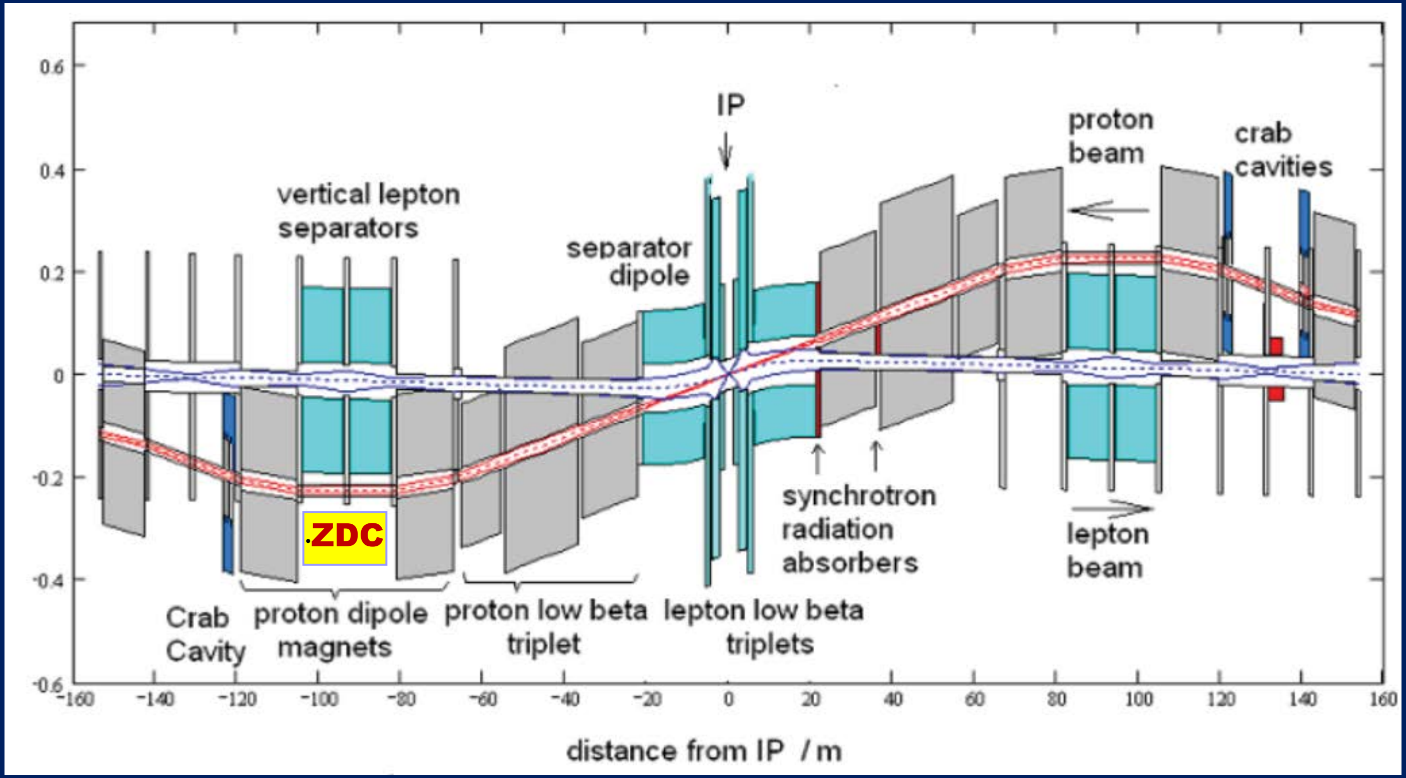
Detector requirements:

- good position measurement, resolution, alignment for the movable sections of QEDC tagger
- good energy resolution,linearity in 10-60 GeV range
- small amount of dead material in front (and well known/simulated)
- efficient e/γ separation → a small silicon tracker in front of calorimeter modules (this also allows z-vertex determination)

Zero Degree Calorimeter

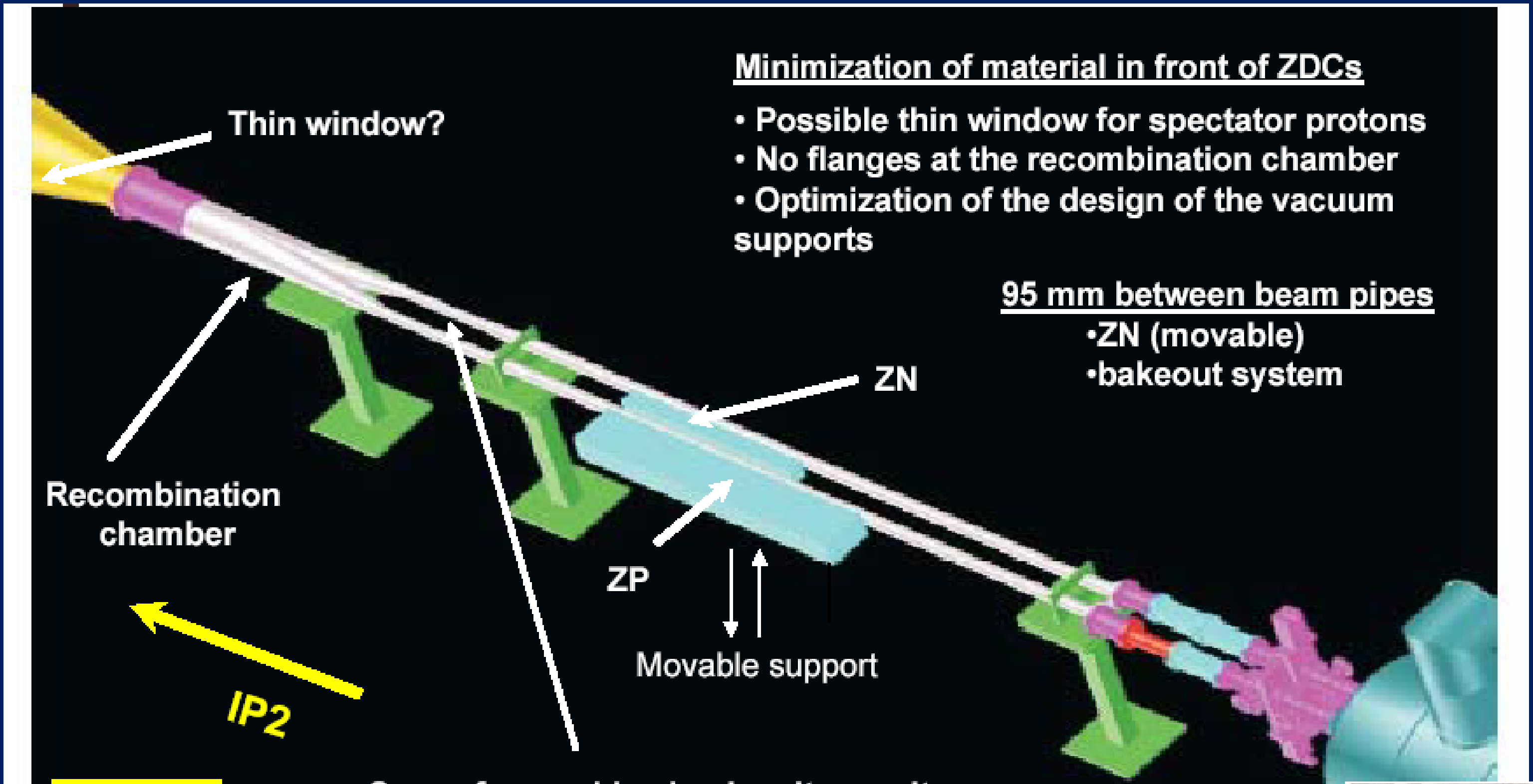
- The position of ZDC in the tunnel and the overall dimensions depend mainly on the space available for installation (~90mm space between two beampipes at z~ 100m)

→ need detailed info/simulation of beam-line



- One can consider also the ZDC for the measurement of spectator protons from eD or eA scattering (positioned external to proton beam as done for ALICE)

Zero Degree Calorimeter for the LHeC



Minimization of material in front of ZDCs

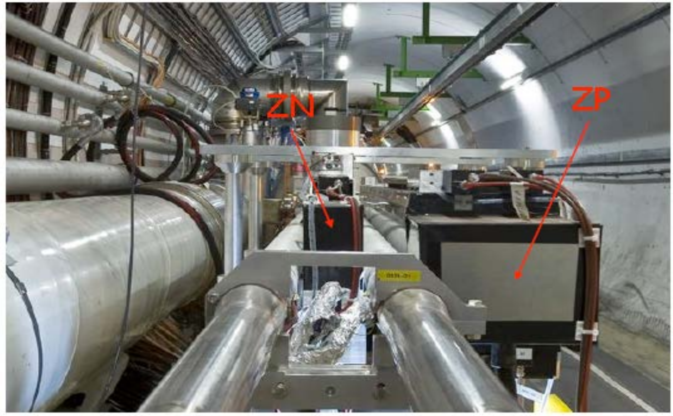
- Possible thin window for spectator protons
- No flanges at the recombination chamber
- Optimization of the design of the vacuum supports

95 mm between beam pipes

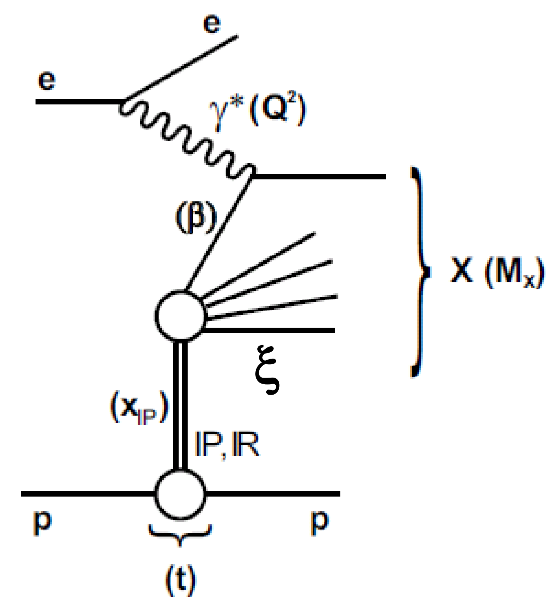
- ZN (movable)
- bakeout system

Space for machine luminosity monitor

ALICE ZDC



Forward Proton Detection



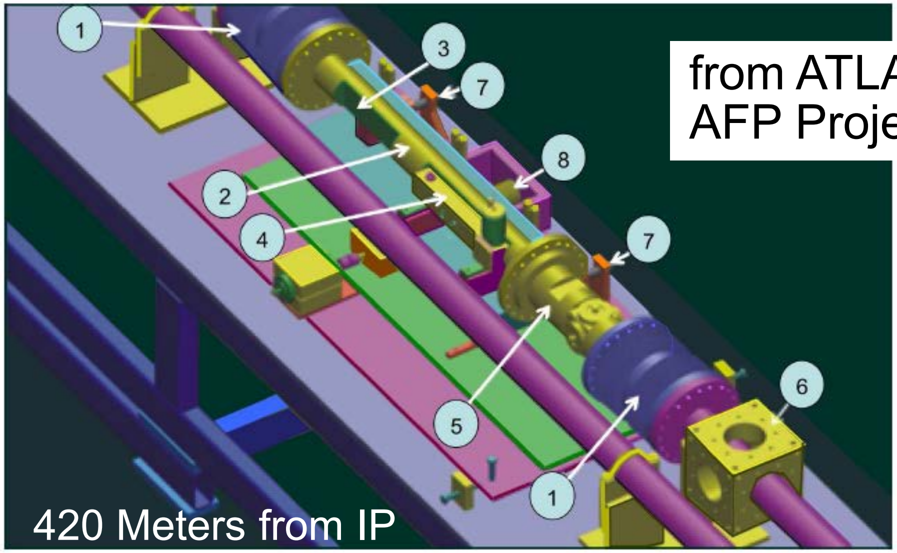
ep→ eXp' diffractive scattering

(proton survives a collision and scatters at a low angle along the beam-line)

$\xi \approx 1 - Ep'/Ep \sim 1\%$

The feasibility to install forward proton detectors along the LHC beamline investigated at the ATLAS and CMS

→ the results of R&D studies are relevant for LHeC



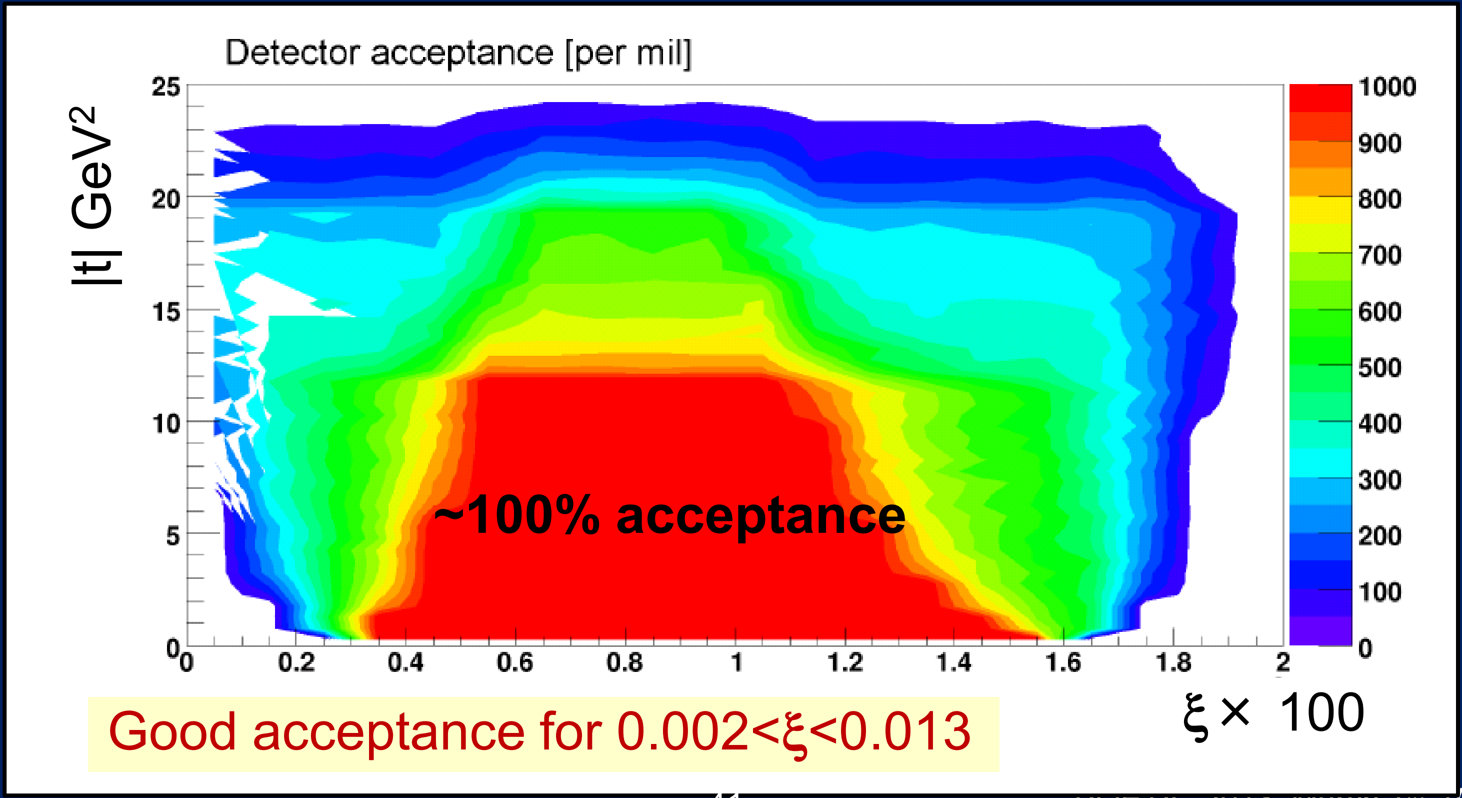
from ATLAS AFP Project

420 Meters from IP

Figure 3.2: Top view of one detector section: bellows (1), moving pipe (2), Si-detector pocket (3), timing detector (4), moving BPM (5), fixed BPM (6), LVDT position measurement system (7), emergency spring system (8).

Acceptance for Forward Protons

- Scattered protons are separated in space from the nominal beam: ($x_{offset}=D_x \times \xi$; D_x - energy dispersion function)
- Acceptance window is determined by the closest approach of proton detectors to the beam, and by the size of beam-pipe walls
- Assume closest approach $12\sigma_{beam}$ ($\sigma_{beam}=250\mu m$ at 420m), $R_{beampipe}\approx 2cm$, $D_x \approx 1.5m$



Good acceptance for 0.002<ξ<0.013

Summary and Outlook

Status

- A LHeC baseline detector concept has ben worked out
- The design depends heavily on the constraints from the machine and interaction region
- For all cases a feasible and affordable concept which fulfills the physics requirements has been presented
- As a baseline many improvements available. A more precise design will follow from more detailed simulations, engineering and the knowledge of the machine constraints

The Future

- Start a new phase in detector design
- A complete software simulation environment needed
- Collect people, experience, information
- Identify and address critical items, discuss the timeline for realization
- Build a collaboration and move next steps towards a Technical Design