LHeC Detector Working Group Status

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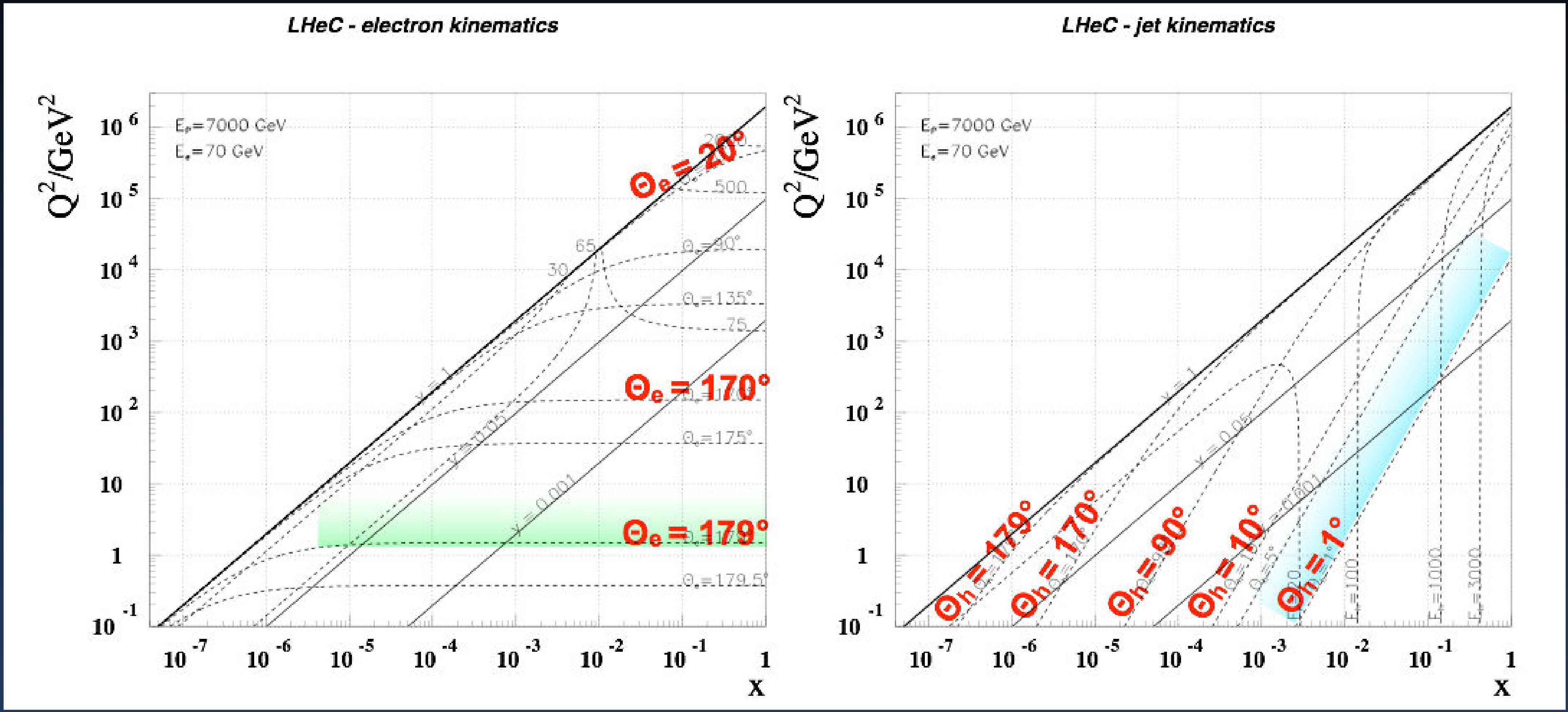
Outline

- Short Introduction
  - Physics requirements
  - IR/ACC boundaries
  - Detector requirements
- Present detector design status
- Starting point for discussion
- Outlook and Plans

LHeC Kinematics



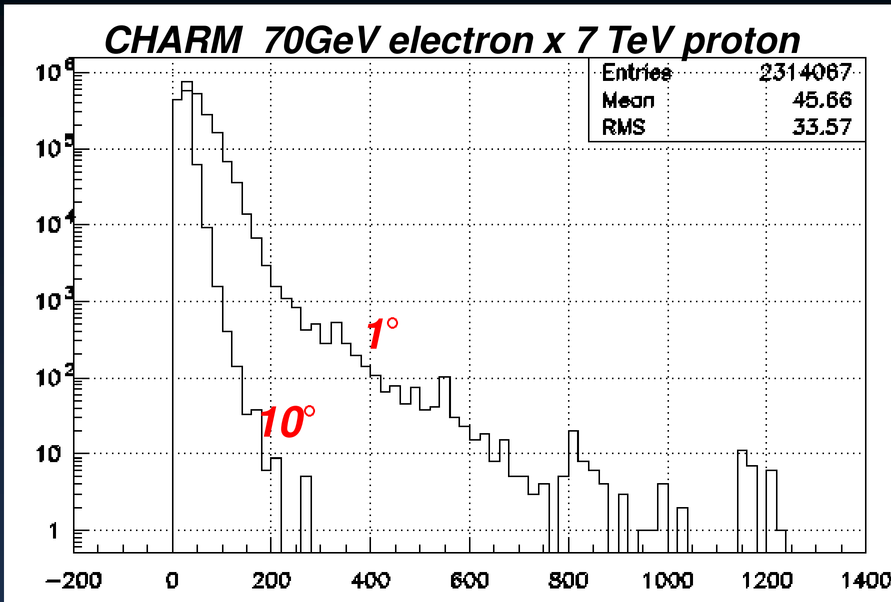
•High x and high Q²: few TeV HFS scattered forward:

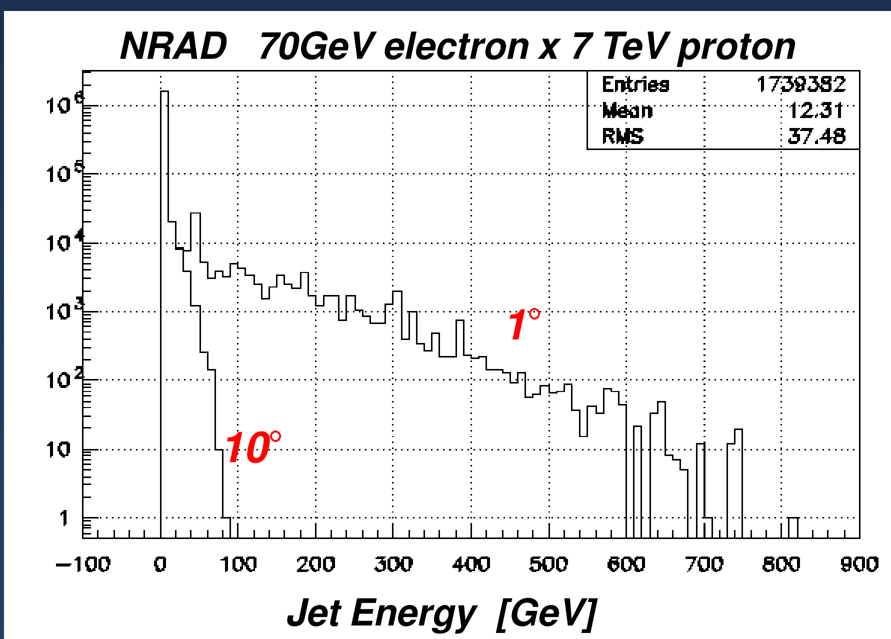
→ Need forward calorimeter of few TeV energy range down to 10° and below ▇. Mandatory for charged currents where the outgoing electron is missing. Strong variations of cross section at high x demand hadronic energy calibration as good as 1%

• Scattered electron:

→ need very bwd angle acceptance for accessing the low Q² and high y region ▇.

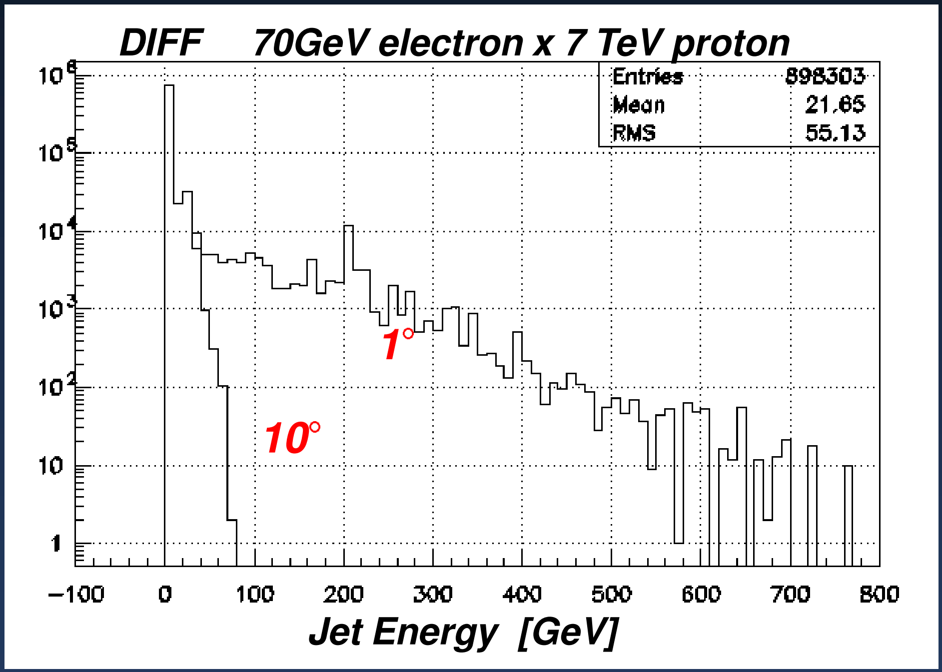
Detector Acceptance





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 - if possible

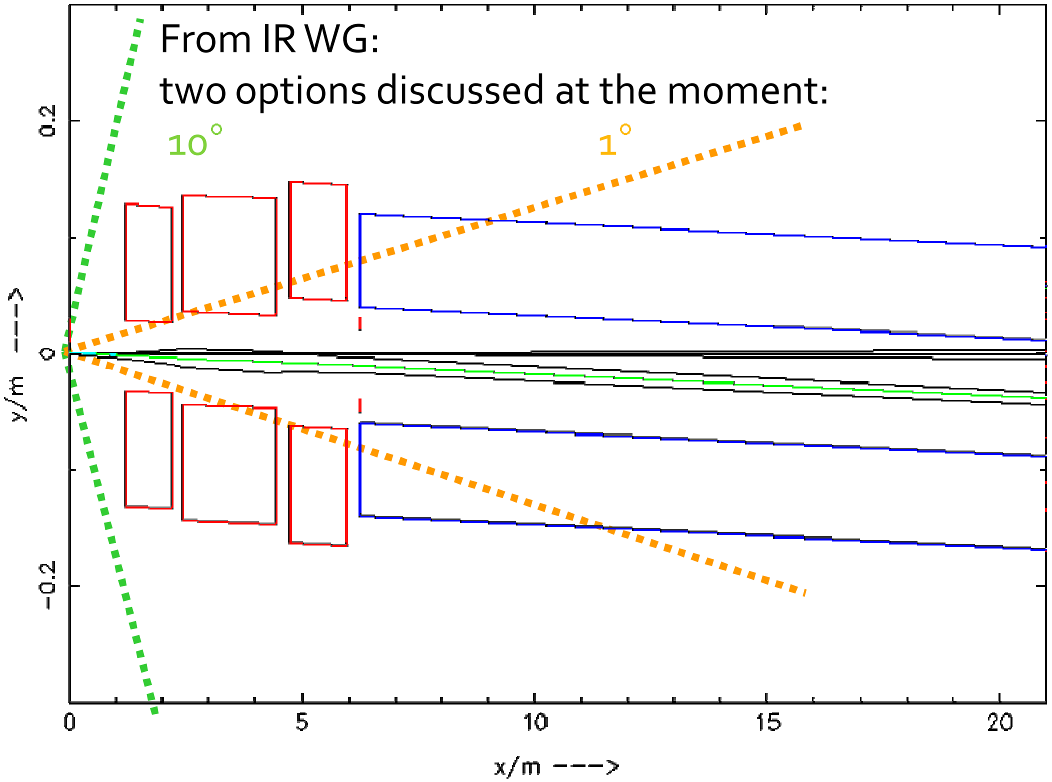
Requirements from Physics

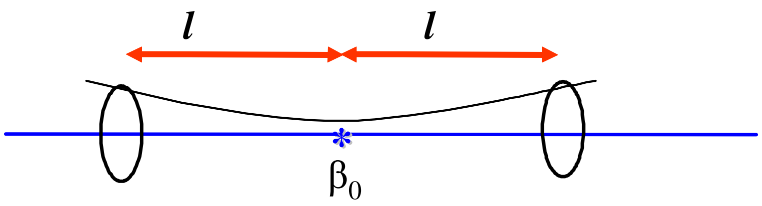
- High resolution tracking system
  - excellent primary vertex resolution
  - resolution of secondary vertices down to small angles in forward direction for high x heavy flavour physics and searches
  - precise pt measurement matching to calorimeter signals, calibrated and aligned to 1 mrad accuracy
- The calorimeters - Energy flow
  - 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 $30\%/\sqrt{E}$ calibrated with pT_e / pT_h to 1% accuracy

    Tagging of forward scattered proton, neutron and deuteron - diffractive and deuteron physics
- Muon system, very forward detectors, luminosity measurements

Beam Optics and Detector Acceptance





$$L = \frac{1}{2\pi e^2 f_0 n_b} * \frac{I_1 * I_2}{\sqrt{\left(\sigma_{xp}^2 + \sigma_{xe}^2\right)\left(\sigma_{yp}^2 + \sigma_{ye}^2\right)}}$$

$$\sigma = \sqrt{\varepsilon \cdot \beta} \qquad \beta(s) = \beta^* + \frac{l^2}{\beta^*}$$

Current design: strong-focusing magnets at 120 cm from IP
Could think of two detector options

- Low Lumi, Low x → high acceptance detector 1^0
- High Lumi,High Q^2 → Main detector 10^0 aperture

Accelerator / Interaction Region

- Lumi range: 10^{32} - 5 · 10^{33} $cm^{-2}s^{-1}$
- Beam spot: ~ 10 x 25 μm^2 - same for $e^{\pm}$·nucleon - stability?
- Center of mass energy range: $\sqrt{s}$ · 0.5 - 2 TeV
- Beam Pipe:

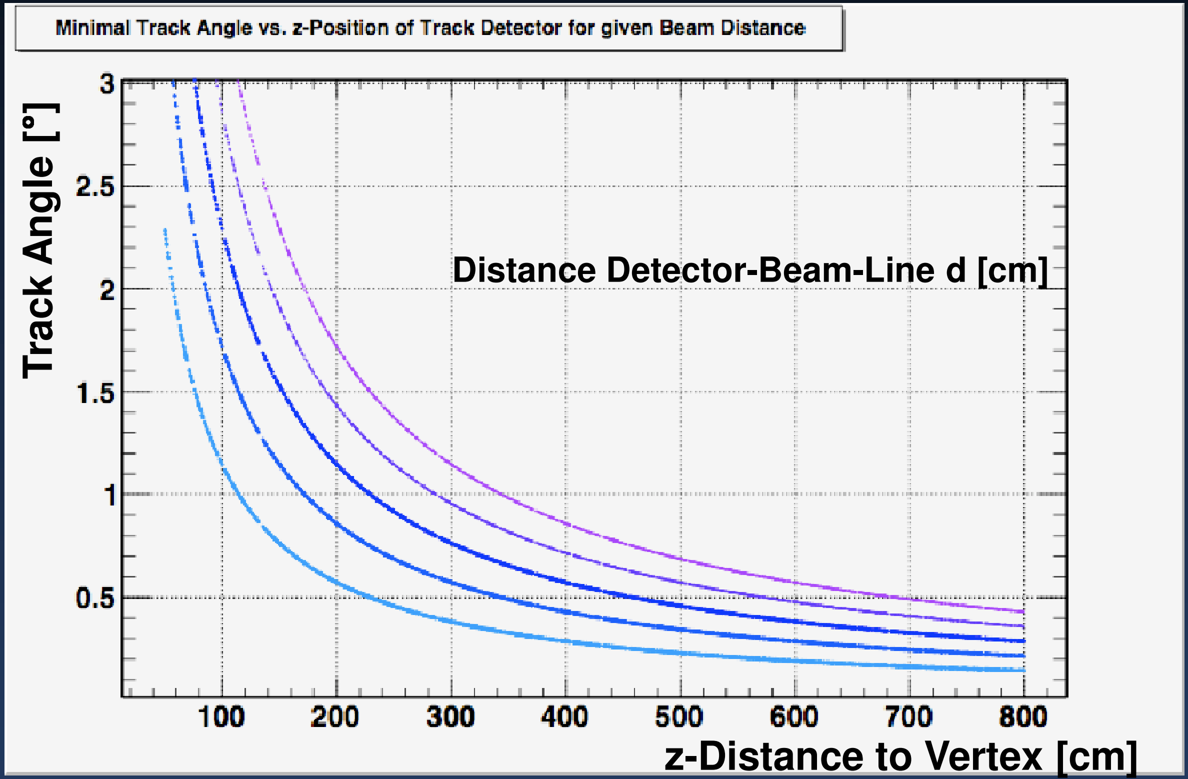
Recent review: (R.Veness, "Mechanical constraints", CERN, LEB 5 III 09):

  - Resistive wall beam heating:
    "Resistive wall impedance scales with $1/r^3$, so decreasing the beam pipe radius from 29 mm (LHC) to 25 mm (SLHC) would increase heat load by 56%"
  - Collimation, machine protection, background (Synchrotron Radiation Fan)
  - As soon as a provisional geometry for the beam pipe is available, we must feed this back to the relevant experts for analysis

Beam Pipe Considerations

Pipe dimensions – very essential choice: to large extent it determines the size of the detector.

Strong implications in terms of costs and acceptance



Present design: elliptical Be beam pipe from SLHC for now: r_y=2.50 cm (radius of SLHC design) and r_x=3.07 cm (scaled from HERA experience)

➔ Dedicate simulation of Interaction region needed (synchr. background)

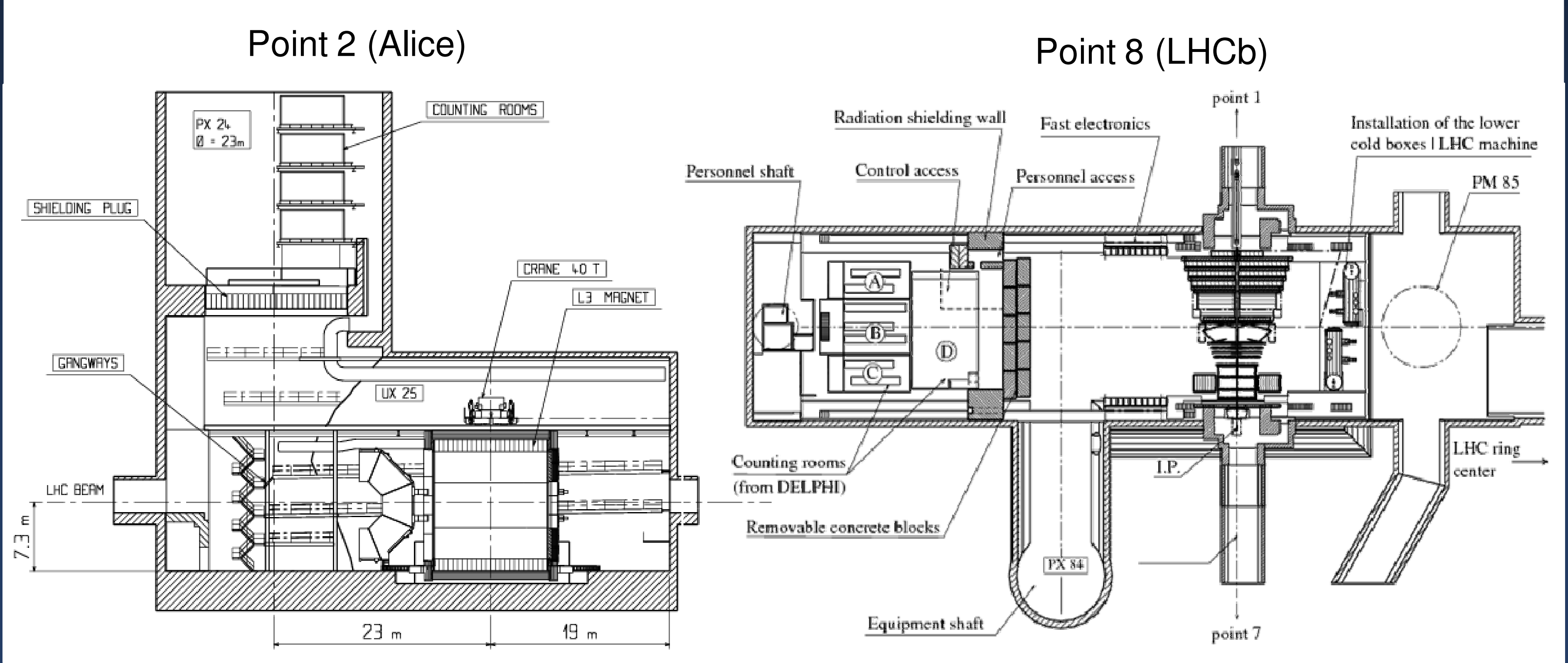
Infrastructure

ALICE

- Round access shaft of 23m diameter, cavern about 50m along the beamline

LHCb

- Shaft: 100m depth, 10.10m diameter, very slightly non vertical; experiment: length 19.90m from IP, max width at the muon station 12m; cavern: 50m x 20m



Boundary Conditions Summary

Modular Experiment Set Up

- Given the time constraints - CMS-type logistics to be considered?
  - Assembling in surface level hall (building(s) sufficient?)
  - ~5 years before real installation in or near to the beam line - start of assembling
  - 2-3 years for installation, tests

Two detector options

(w/out and with strong-focusing magnets at 120 cm from the IP)

- high-Q^2 / high-luminosity / "low" acceptance ($\theta_e > 10°$, $\theta_h < 170°$)
- low-x / low-luminosity / "high" acceptance ($\theta_e > 1°$, $\theta_h < 179°$)

- Other options available? (discussion with ACC/IR)
- Asymmetric design of optics and interaction region feasible?
- Maximize acceptance in the forward region at High Q^2?

Detector Requirements (I)

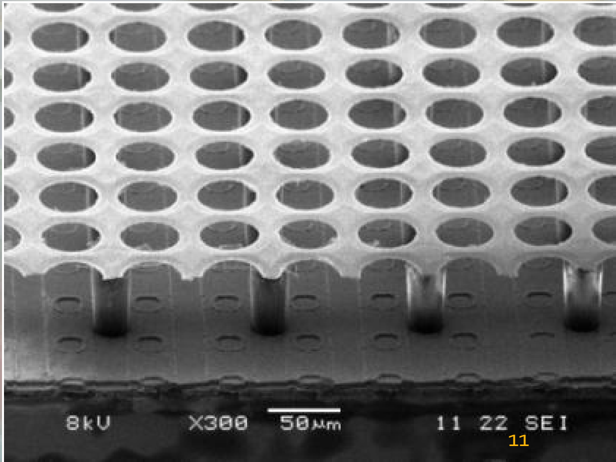
- Tracking
  - lowest mass tracker - essential for $\gamma/e^{\pm}$ ident (specifically bwd)
  - early π^0 ident - vertex detector/trigger
  - TPC - economical coverage of a large volume with essentially continuous tracking, low material budget - high quality detector performance, dE/dx particle identification and good V_0 recognition.
    TPC near the beam line - TPC background tolerant / BG tolerable? outer radii only?
  - high resolution track definition in front of forward calo
  - tracking trigger in front of fwd/bwd calo, p_t trigger there too?

Precision Tracking: Si-Gas Tracker – GOSSIP

Gas on Slimmed Silicon Pixels (see talk of H.Van De Graaf)

- Gas for charge creation, Si-pixel/strips/pads for signal collection
- Lightweight detector
- More than one hit per track - defines track segments
- Si radiation hard - standard CMOS (90 nm process)
- Trigger capable: 25ns, Gossipo 3|4 readout chip ~O(1) ns time resolution.
- Large volume detector affordable, industrial production
- Time measurement - digital TPC R/O system
- Gas choice: radiator : Transition Radiation Tracker - e/π identification
- Diffusion and drift velocity limits position measurement currently to ~<<20μm

- If needed innermost layer possibly still with pixel



Detector Requirements (II)

Calorimeter

- Minimize longitudinal and lateral energy leakage
- Fwd/bwd Particle Flow Detector to achieve desired mass resolution/ γ/$e^{\pm}$ / π^{0} / …
  This technique combines the tracking/calorimetry information in an optimal way in order to get the best possible jet-energy resolution.
- Both electromagnetic and hadron calorimetry inside the solenoid coil; minimum material inside ECal;
  (the effective granularity is increased by moving the calorimeter further from the IP - the right effect in our context)

Magnetic Field

- 3.5 Tesla solenoidal field

Calorimeter Technologies

Particle Flow and high granularity devices:

- promising at ILC energies(E_{CMS}<500GeV)
- need a transition to "normal" calorimetry if to be used at higher energies
- Rely heavily on software, microelectronics and SiPM (or Gas chambers ?)

rms90	PandoraPFA v03-β	
E_{JET}	$\sigma_E/E = \alpha/\sqrt{E_{jj}}$ $\lvert\cos\theta\rvert<0.7$	σ_E/E_j
45 GeV	23.8 %	3.5 %
100 GeV	29.1 %	2.9 %
180 GeV	37.7 %	2.8 %
250 GeV	45.6 %	2.9 %
500 GeV	84.1 %	3.7 %
500 GeV	64.3 %	3.0 %

Dual Readout:

Attractive idea: reading independently (in a non-compensating cal.)

1) a Cerenkov response only sensitive to relativistic shower components (mostly $e^{\pm}$)
2) a Scintillation response sensitive to all dE/dx and correcting event by event and cell by cell the main (scintillation) response.

- Usable up to highest energies
- Require hardware developments, some of them still at the "generic" level.
- Need to be demonstrated with large prototypes (DREAM Collaboration)

Conventional technologies:

- LAr (ATLAS, H1) especially in in barrel/rear region. Possibly problematic for infrastructure and modularity boundaries

Particle Flow (see talk C.Grefe)

- Use the best energy information available for each particle in a jet
  - Tracker information for charged hadrons and low to mid-energy electrons
  - ECAL information for photons and high-energy electrons
  - HCAL information for long-lived neutral hadrons
- Pointing geometry - minimizing transversal and longitudinal Energy leakage
- High granularity to allow geometrical separation of particles
- PFA calorimetric performance = HARDWARE + SOFTWARE

F.Simon - MPI Munich
LHeC Divonne 2008

And here it is …

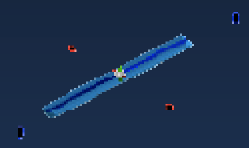
… the detector

… the detector

… a very first draft

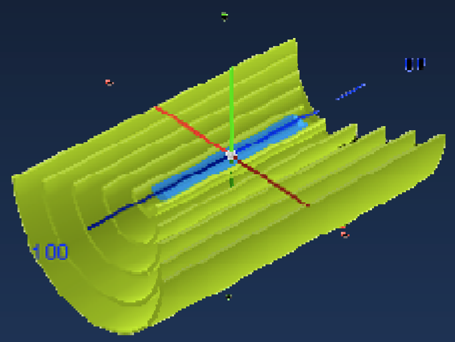
LowQ^2-Detector

	Radius [cm]
Elliptical pixel detector:	2.9–4.6/3.47-6.05



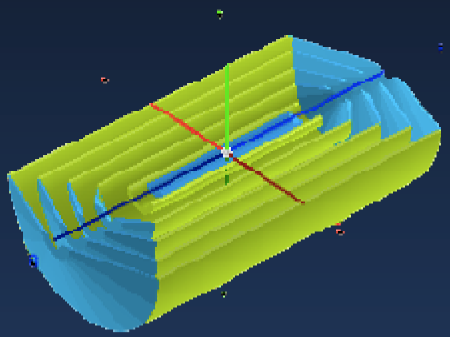
LowQ^2-Detector

	Radius [cm]
Elliptical pixel detector:	2.9–4.6/3.47-6.05
Barrel layer 1-5:	7.5–61



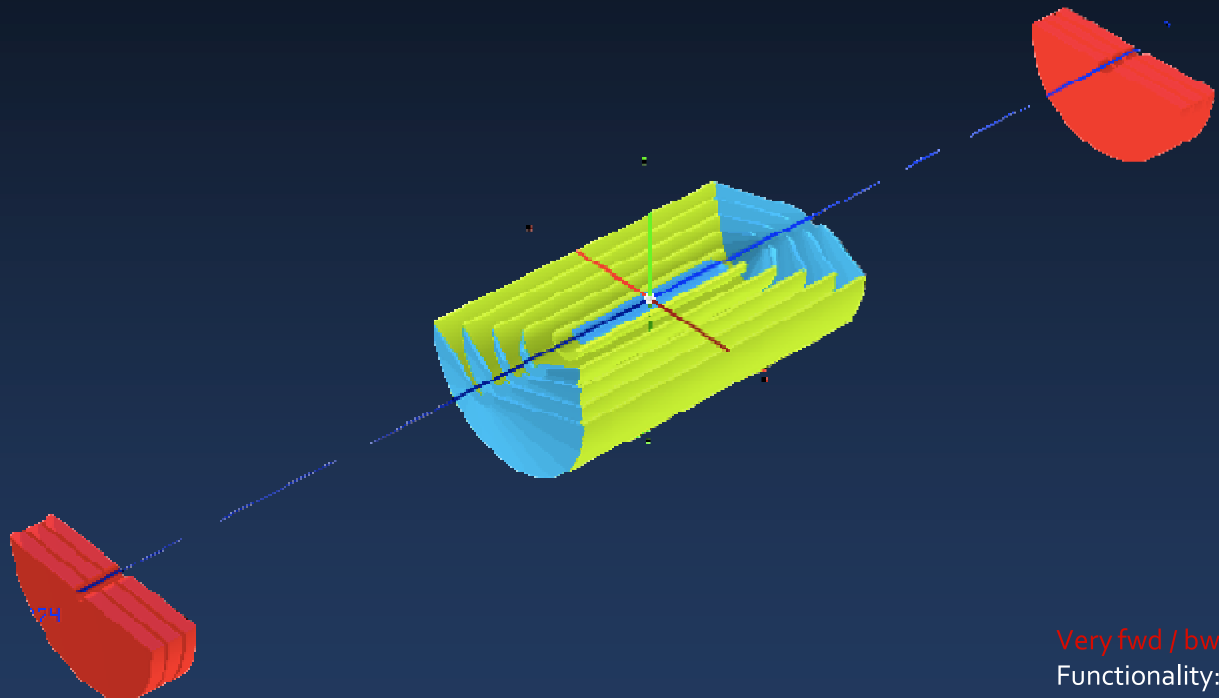
LowQ^2-Detector

	Radius [cm]
Elliptical pixel detector:	2.9–4.6/3.47-6.05
Barrel layer 1-5:	7.5–61
Barrel cone 1-4:	5–61



LowQ²-Detector

	Radius [cm]
Elliptical pixel detector:	2.9–4.6/3.47-6.05
Barrel layer 1-5:	7.5–61
Barrel cone 1-4:	5–61
Very fwd/bwd Plane 1-3:	5–60



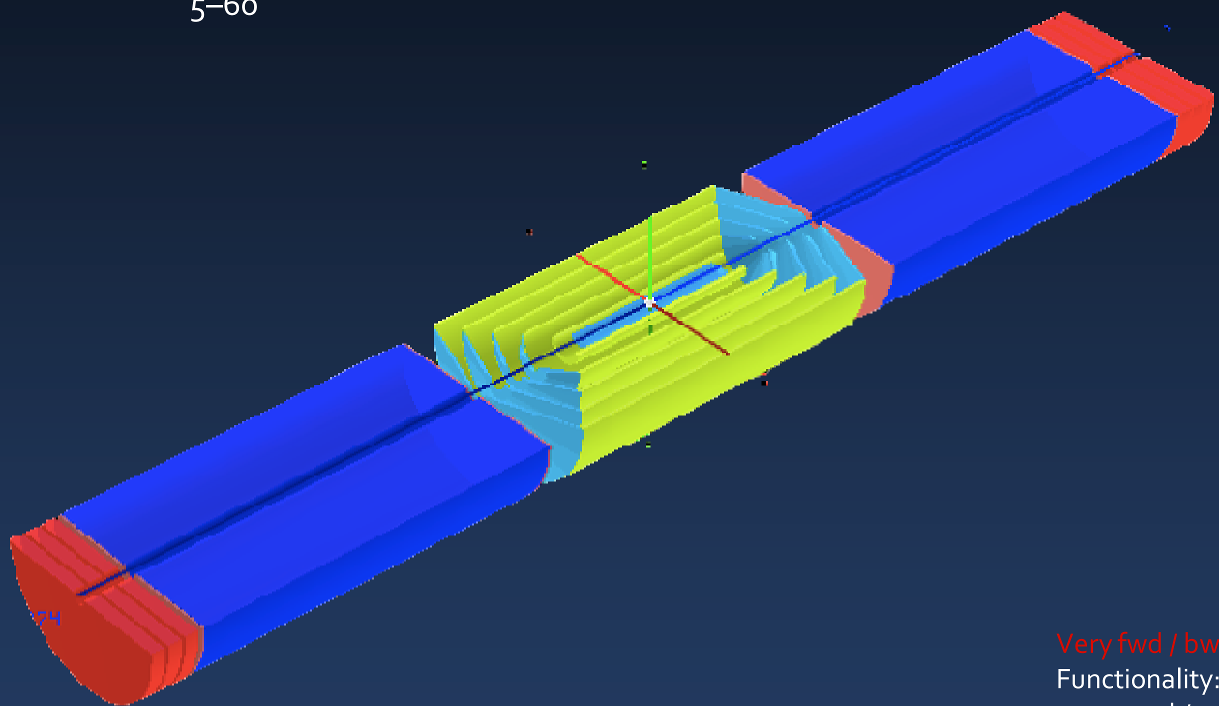
Very fwd / bwd Plane 1-3:

Functionality:

- track/multiplicity trigger
- transition radiation - e/π ident
- precise track segment, γ/$e^{\pm}$ ident

LowQ^2-Detector

	Radius [cm]
Elliptical pixel detector:	2.9–4.6/3.47-6.05
Barrel layer 1-5:	7.5–61
Barrel cone 1-4:	5–61
Very fwd/bwd Plane 1-3:	5–60
Fwd/Bwd TPC:	5–60

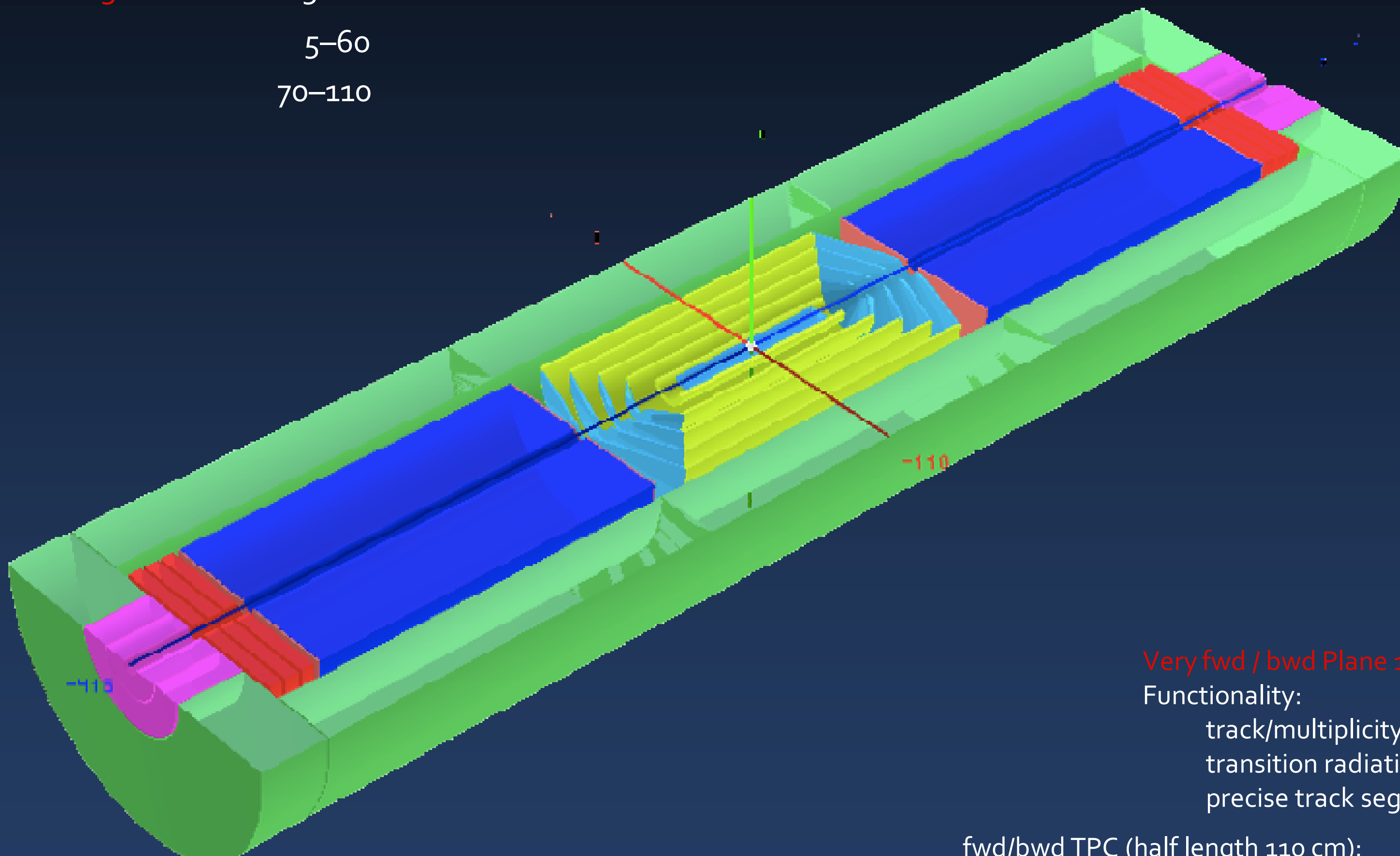


Very fwd / bwd Plane 1-3:
Functionality:
- track/multiplicity trigger
- transition radiation - e/π ident
- precise track segment, $\gamma/e^{\pm}$ ident

fwd/bwd TPC:
Functionality:
coverage of a large volume with essentially continuous tracking, low material budget - high quality detector performance, dE/dx particle identification and good V_0 recognition

LowQ^2-Detector

	Radius [cm]
Elliptical pixel detector:	2.9–4.6/3.47-6.05
Barrel layer 1-5:	7.5–61
Barrel cone 1-4:	5–61
Very fwd/bwd Plane 1-3:	5–60
Fwd/Bwd TPC:	5–60
EmCAL:	70–110

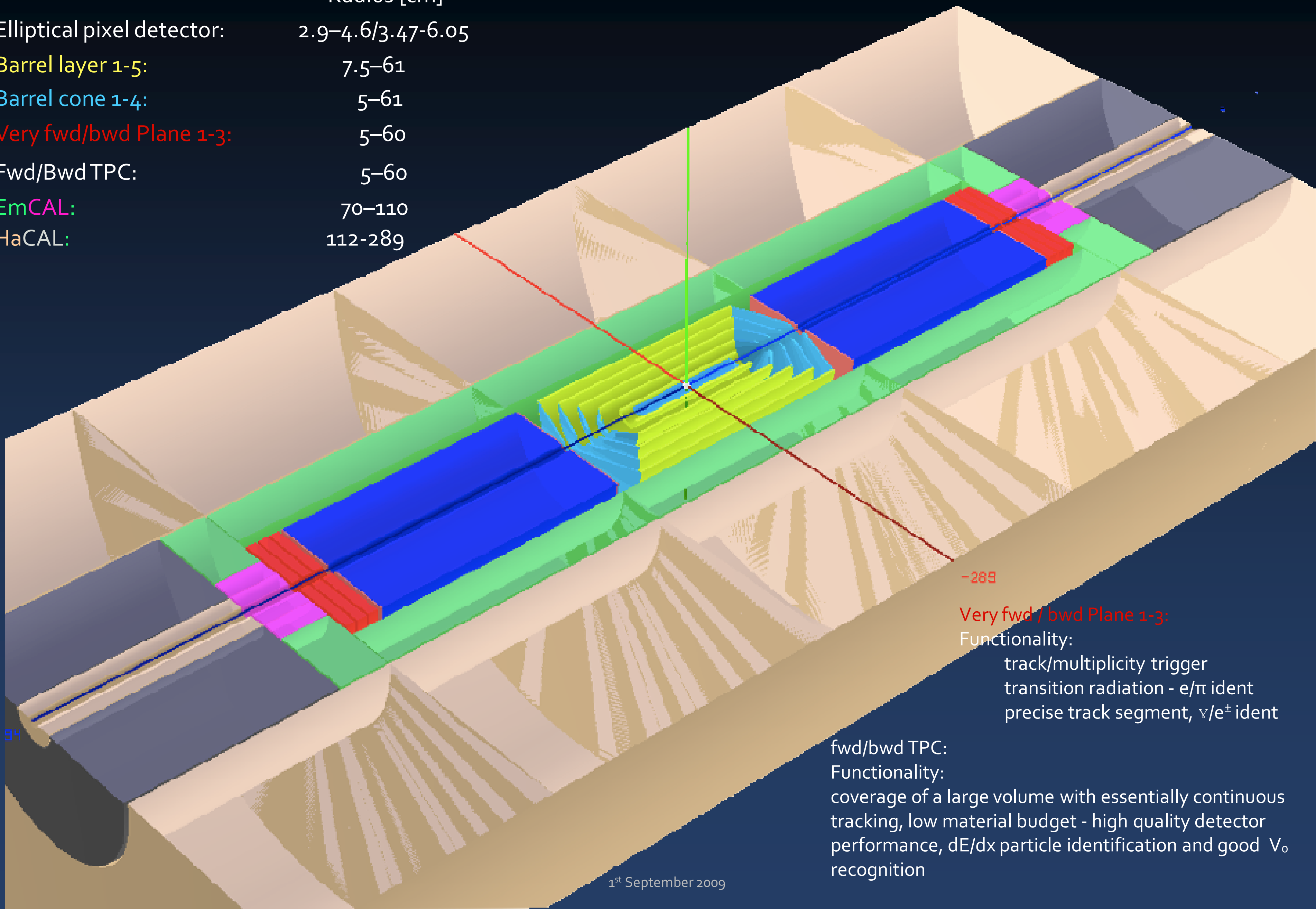


Very fwd / bwd Plane 1-3:
Functionality:
- track/multiplicity trigger
- transition radiation - e/π ident
- precise track segment, γ/e$^{\pm}$ ident

fwd/bwd TPC (half length 110 cm):
Functionality:
coverage of a large volume with essentially continuous tracking, low material budget - high quality detector performance, dE/dx particle identification and good V_0 recognition

LowQ^2-Detector

	Radius [cm]
Elliptical pixel detector:	2.9–4.6/3.47-6.05
Barrel layer 1-5:	7.5–61
Barrel cone 1-4:	5–61
Very fwd/bwd Plane 1-3:	5–60
Fwd/Bwd TPC:	5–60
EmCAL:	70–110
HaCAL:	112-289

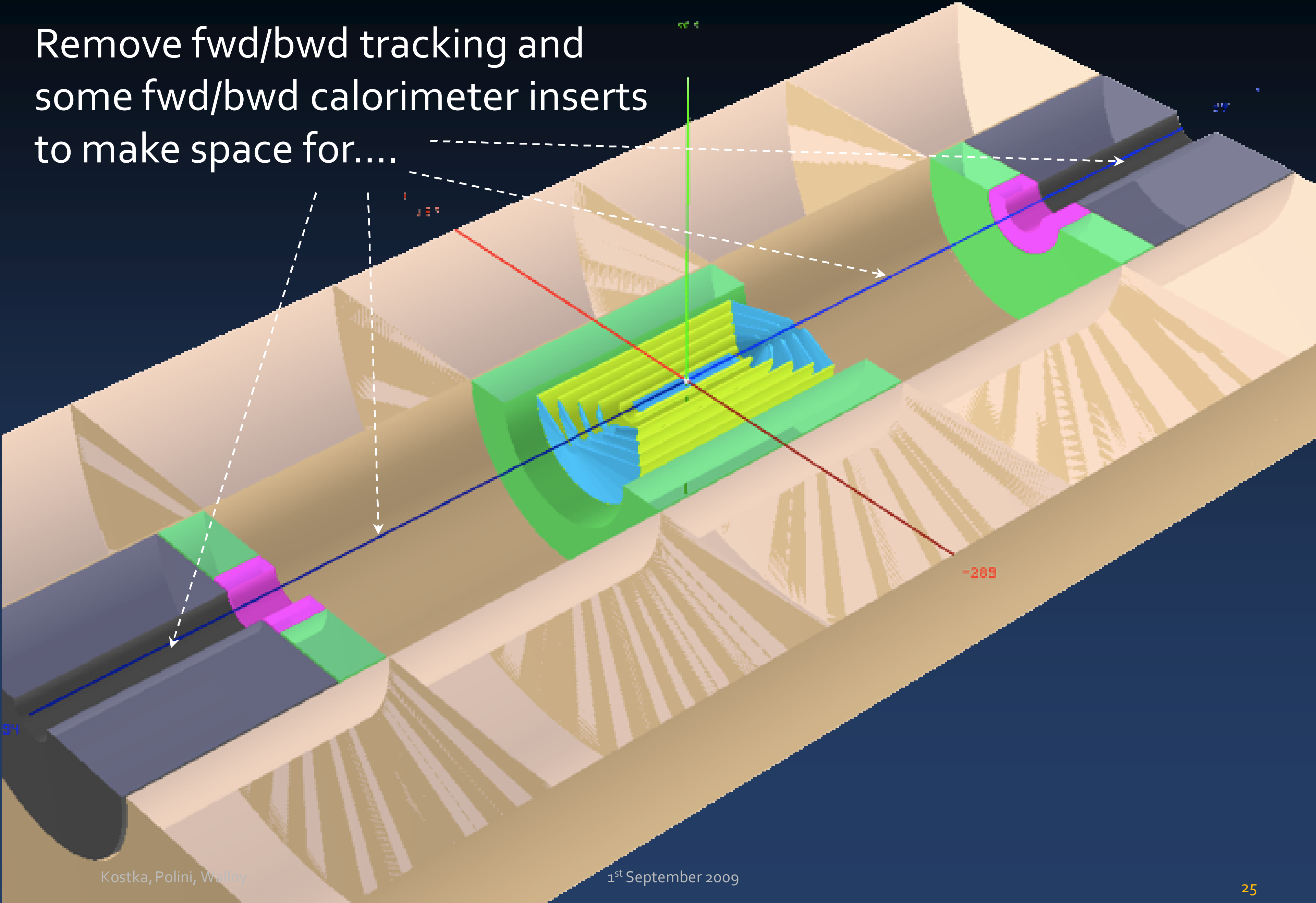


Very fwd / bwd Plane 1-3:
Functionality:
- track/multiplicity trigger
- transition radiation - e/π ident
- precise track segment, γ/e$^\pm$ ident

fwd/bwd TPC:
Functionality:
coverage of a large volume with essentially continuous tracking, low material budget - high quality detector performance, dE/dx particle identification and good V_0 recognition

LowQ²-Detector

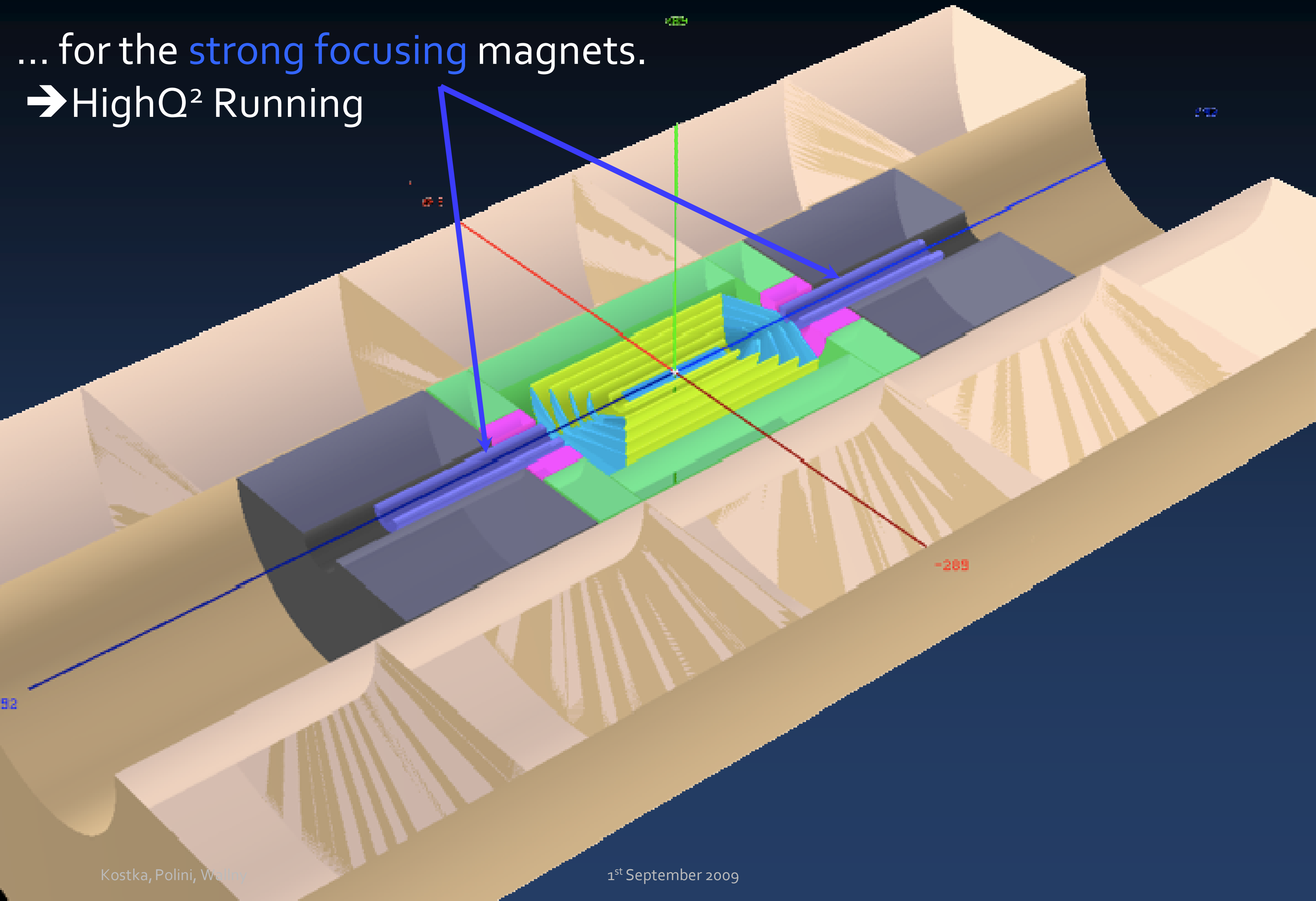
Remove fwd/bwd tracking and some fwd/bwd calorimeter inserts to make space for....



High Q^2 configuration

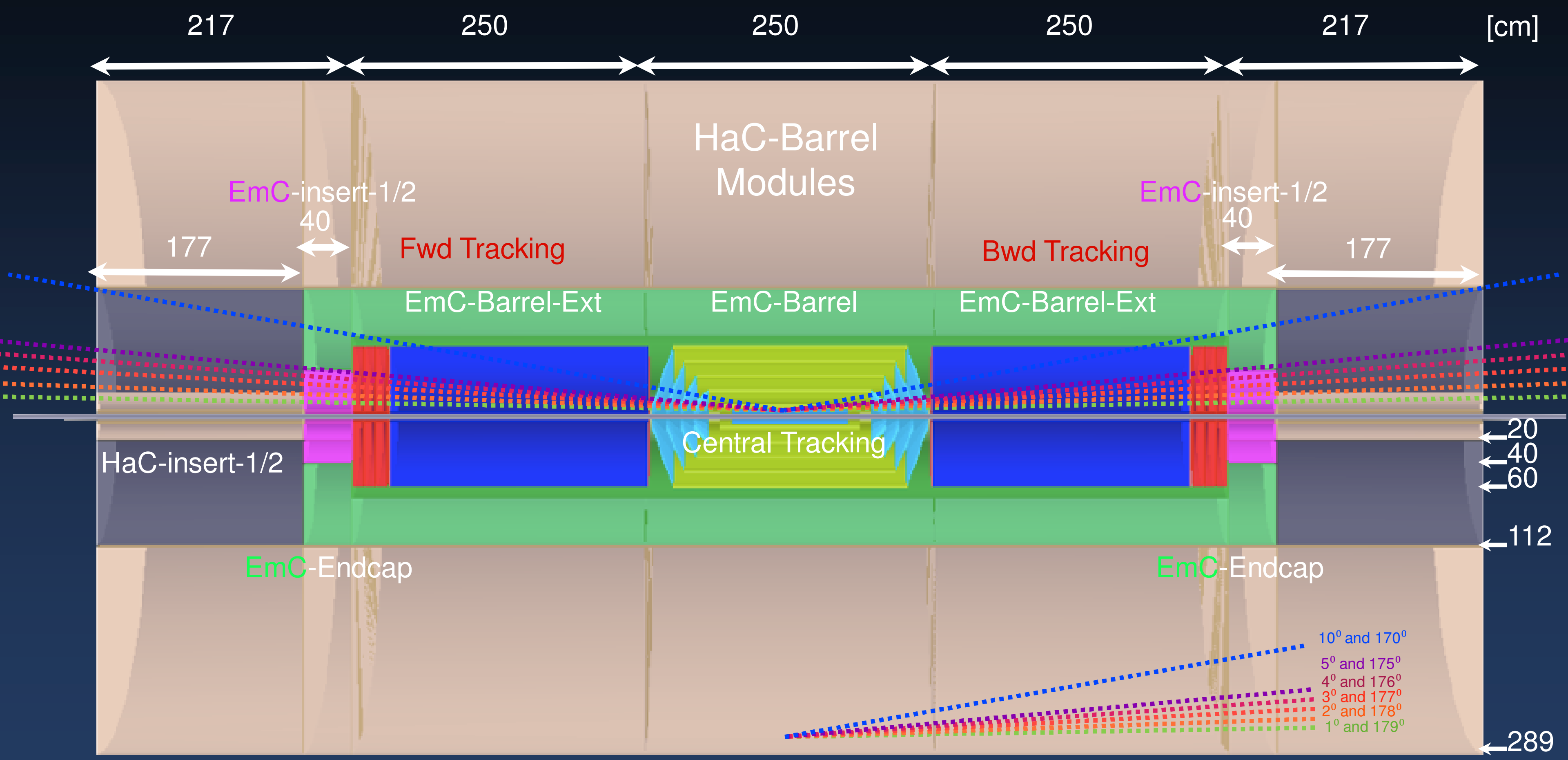
... for the strong focusing magnets.

➔ HighQ² Running



The Detector - Low Q^2 Setup

(to be optimised)

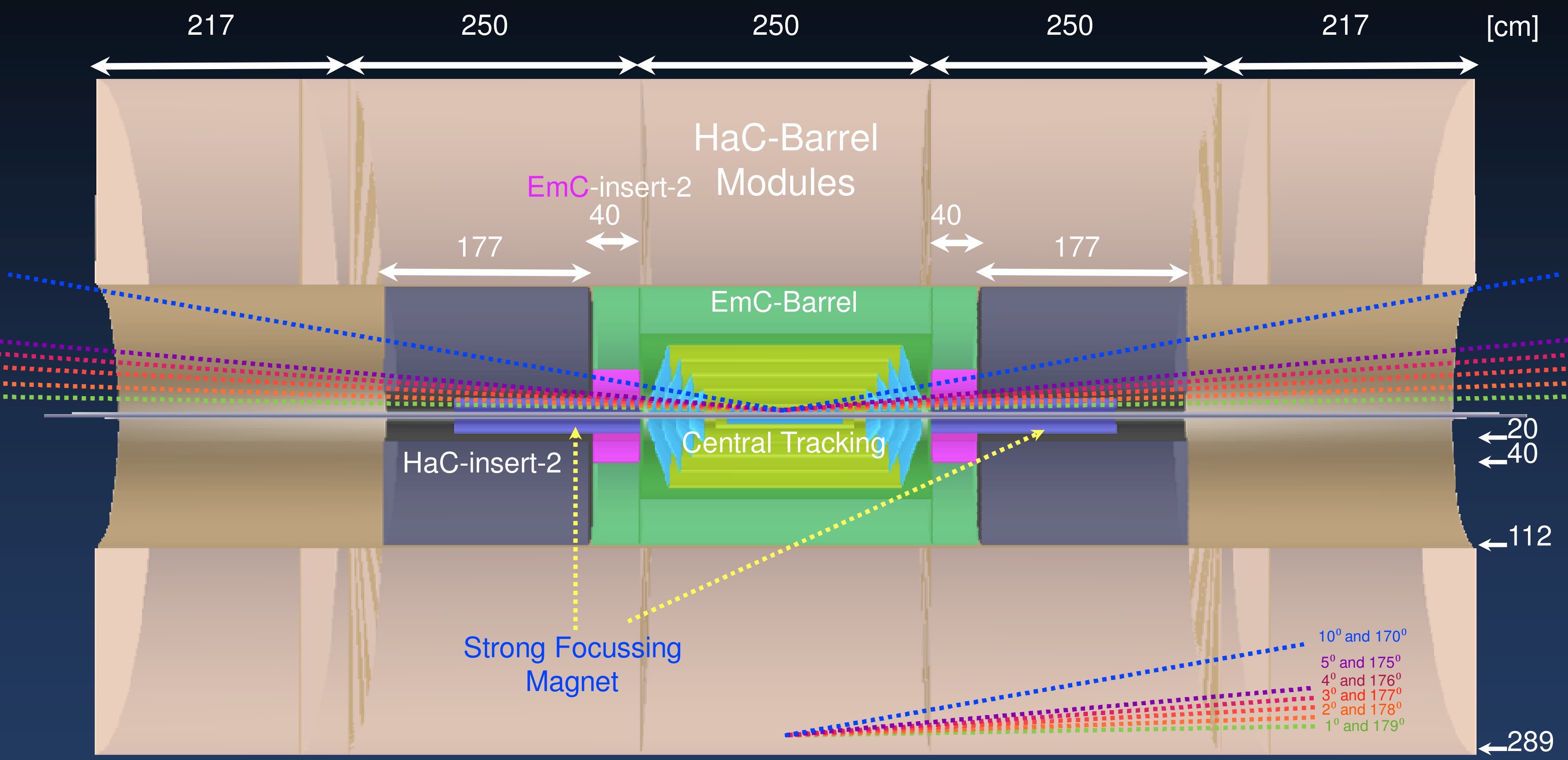


- Solenoid surrounding the HAC modules
- Outer detectors (HAC tailcatcher/muon detectors not shown)

Not discussed either: very forward detector setup – very essential – but postponed

The High Q^2 Setup

(to be optimised)

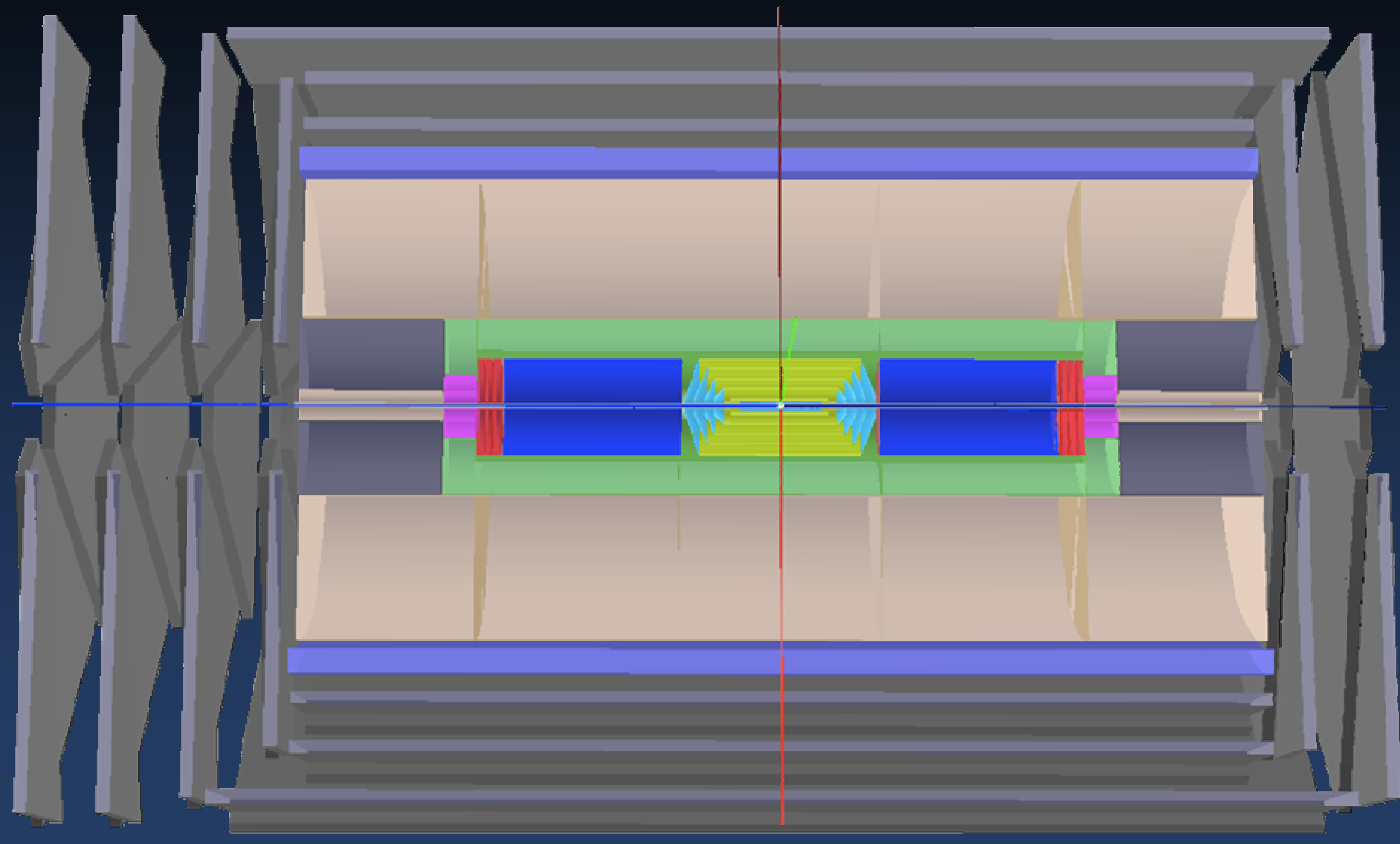


L1 Low Q^2 SetUp → High Q^2 SetUp

- Fwd/Bwd Tracking & EmC-Extensions, HaC-Insert-1 removed
- Calo-Inserts in position
- Strong Focussing Magnet installed

Adding Muon Chambers

(to be optimised)

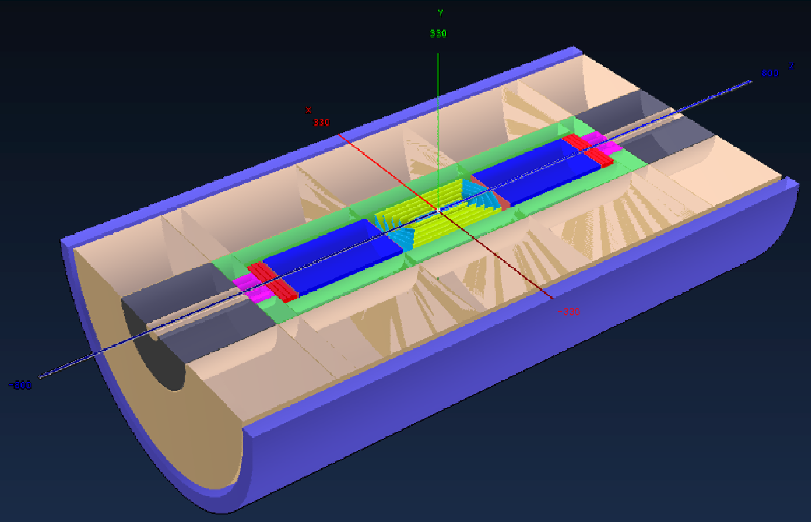


Calorimeter

Present choice: Energy Flow Calorimetry:

For the geometry given:

- Electromagnetic Calorimeter:
  ~30 x Xo Pb/W & different det./R/O
- Hadronic Calorimeter:
  6 - 10 x λ_I Fe/Cu & different det./R/O



- Presently the fwd/bwd calorimeter asymmetry more in functionality/detector response rather then in geometry

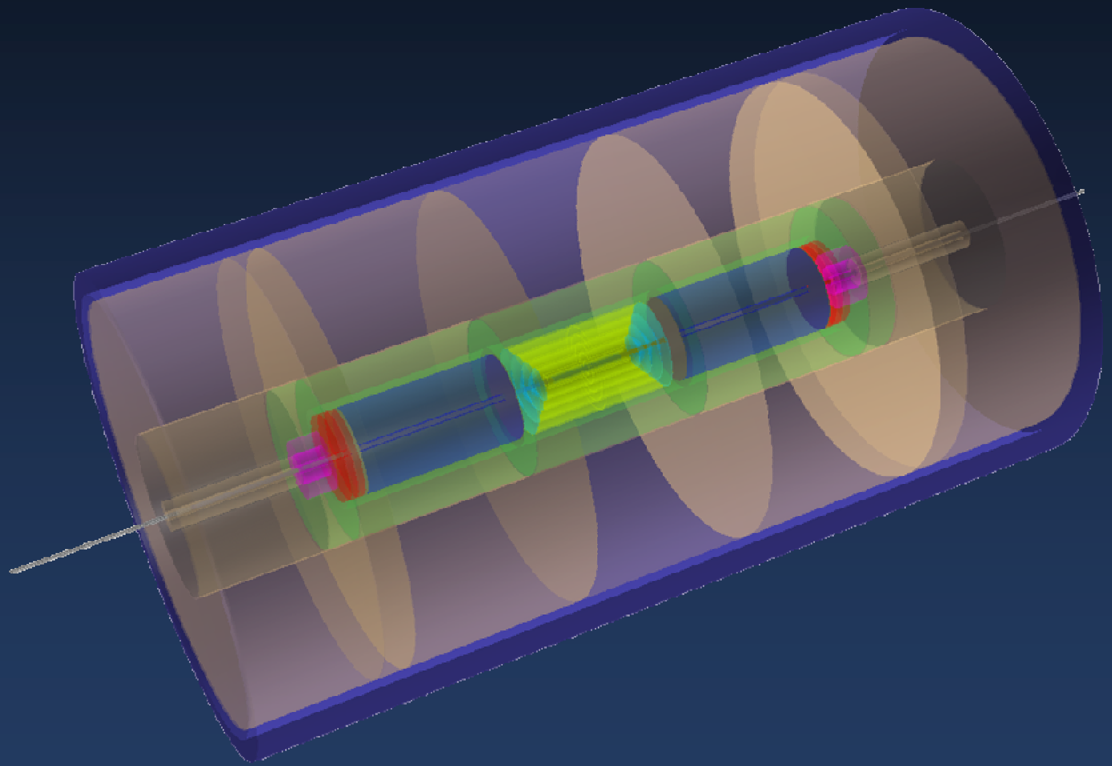
- A dense EmCAL with high granularity (small transverse size cells), high segmentation (many thin absorber layers), and with ratio λ_I/Xo large, is optimal for E-Flow measurement → 3-D shower reconstruction
- Example Fe, W

Material	Nuclear interaction length λ [cm]	Density $[\mathrm{g/cm^3}]$	Moliere radius [cm]	Radiation length X_0 [cm]	λ/X_0
Fe	16.98	7.87	1.66	1.77	9.59
W	10.31	19.3	0.92	0.35	29.46

- brass (Cu) an option also (CMS), λ_I =15.1cm - denser than Fe (adding λ_I)

Solenoid

Modular structure: assembly on surface level or in the experimental area depending on time constraints and access shaft opening



Solenoid dimensions:

- 480~594 cm half length
- 291 cm inner radius
- B field = 3.5 T

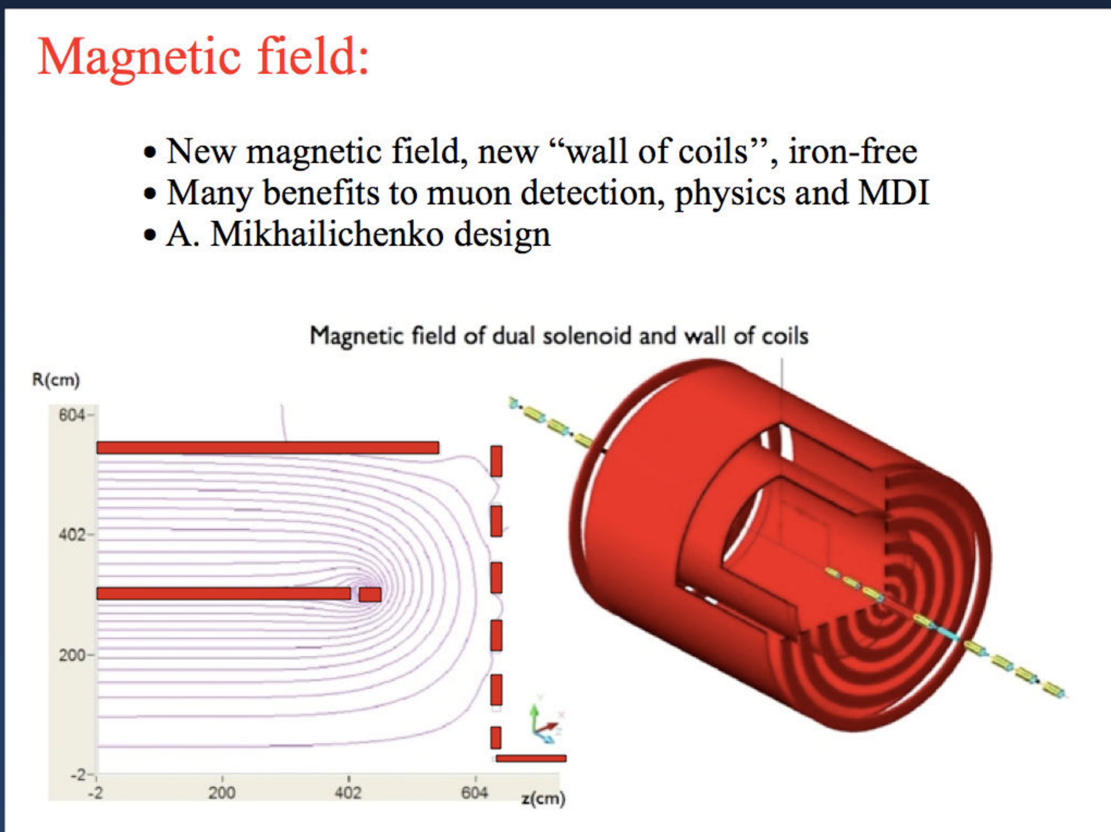
Geometry constraints:

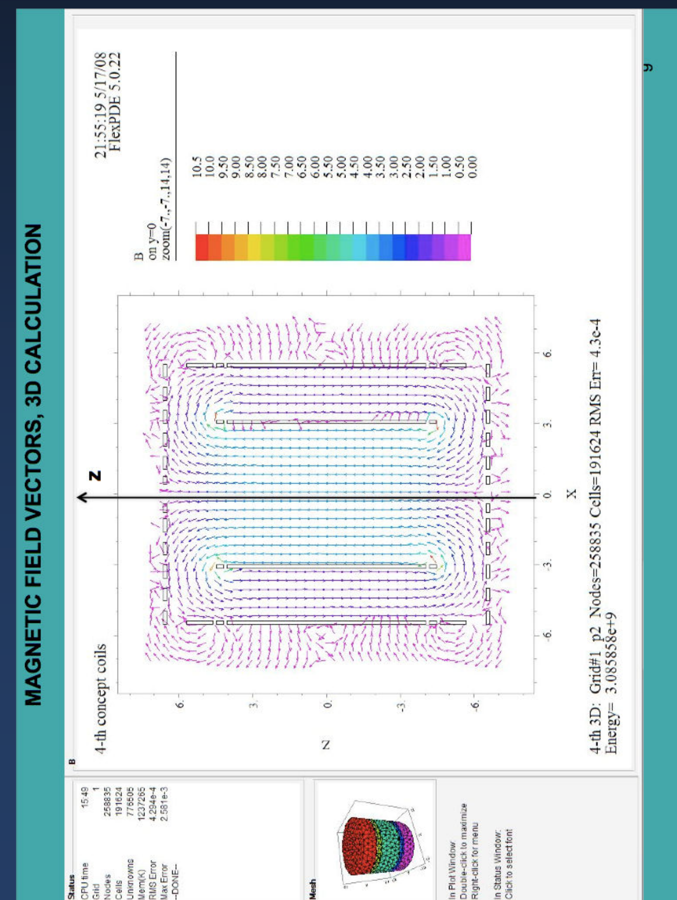
- Current beam pipe dimensions
- Requirement of 1° tracking coverage
- Homogeneous B field in the tracking area

Solenoid continued

- Two Coil Solution (4^{th} concept - ILC)
- 4^{th} almost exactly the dimensions for L1 (current design)

➔no-iron magnetic field configuration with flux return by a second solenoid allowing better muon measurement, open-detector survey and alignment, quick push-pull and (re)installations





Magnet Essentials

- Present option:
  Conservative Solenoid with B field =3.5 T

- Attractive design with a 2 solenoid solution,
  tracking: +5T and -1.5T in the muon area if 4^{th} concept design followed.

➔ Decide after detailed machine/physics studies and cost considerations

From discussion with experts (H. Ten Kate, A. Dudarev) any design feasible.

- The High Lumi detector setup requires strong focusing magnet at ~120 cm from IP. Severe acceptance limitations. Dimensions of strong focusing magnets (Ø = 30cm now)

➔ Instrumentation of focusing magnets - tracking/ calorimeter device *)

*) T.Greenshaw, Divonne LHeC 2008 → Update Tomorrow

Trigger & DAQ

- **LHeC DAQ requirements within specification and reach of the LHC/SLHC** (*W. Smith Divonne 2008)
- **Trigger (pipelined system 2-3 trigger levels):**
- **Active trigger components: CAL, Muon, Tracking**
- **Tracking Trigger:**
  - **b,τ-tagging in dense jet environment is a very demanding task**
  - **on higher level trigger or on level 1? Gossip usable for triggering**
  - Displaced Vertexing Trigger (see Alessandro Cerri, Divonne 2008)
    ➔ scalable system, use associative memory
  - Need for fast pattern recognition on large amounts of data (of different detectors, global tracking, RoI etc.)
- Fine detector segmentation
- Expect high-occupancy, high x, heavy flavor physics (b, c), New physics…
- Especially the forward region very challenging

→ detector response and full simulation environment needed

Detector Simulation

- What you have seen so far is a detector drawing
- Precise detector simulations are needed:
  - optimize full detector designs for physics performance on mission critical processes
  - optimize the designs of subsystems and subdetectors
  - compare proposed detector technologies with each other (in concert with test beam)
- The hardware selection aspect makes use of world wide efforts for the preparation of ILC and SLHC experiments
- The hope is that the developers involved there will share there knowledge/experience with us and new centre's are attracted to help developing the most advanced detector technologies - synergy wanted

Simulation Framework

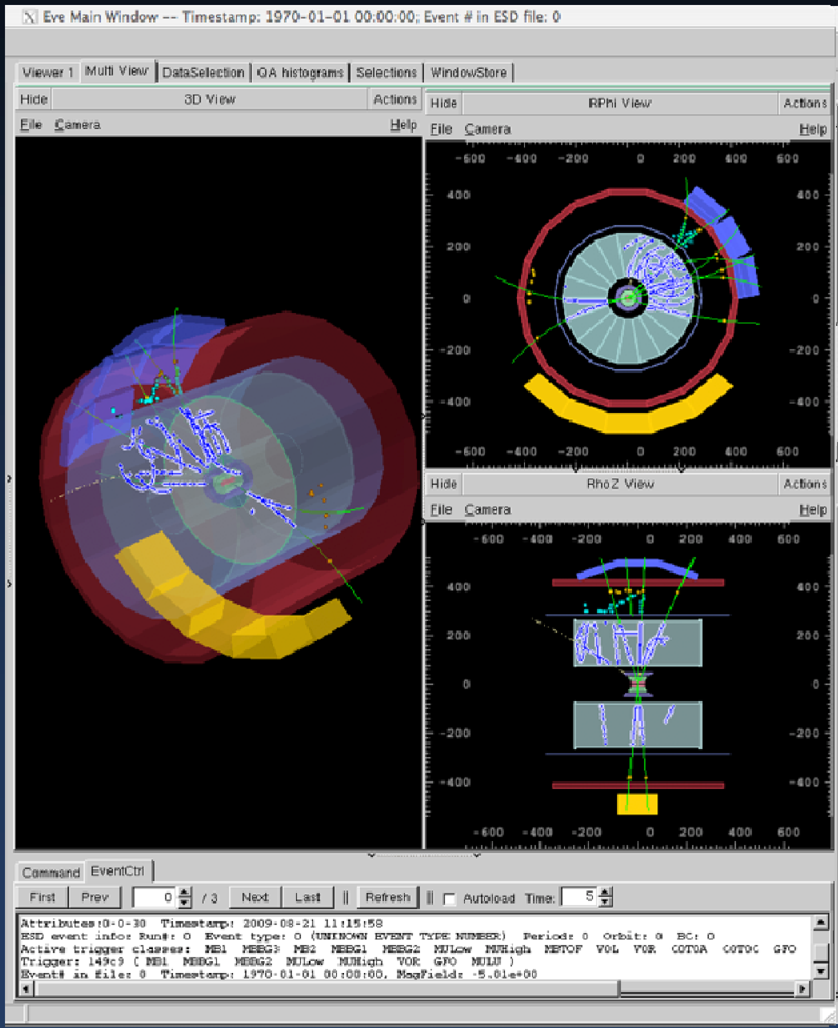
- Establish a framework which will ease work and information exchange.
- Several tools on the market. ➔Use a homogeneous, powerful and and widespread
- Frameworks which have come to our attention:
  - 4th concept - IlCRoot - ILC evolved from: AliRoot - Alice - LHC

    Based on widespread CERN software root with so-called Virtual Monte Carlo interface.
  - allows the use root using **Geant3/4** and **Fluka**
  - (e.g.: Pandora-Pythia, Whizard, Sherpa, CompHEP, GuineaPig to generate events)
- Done so far:
  - Set up of AliRoot an ILCRoot with on a few systems
  - Good connection to:

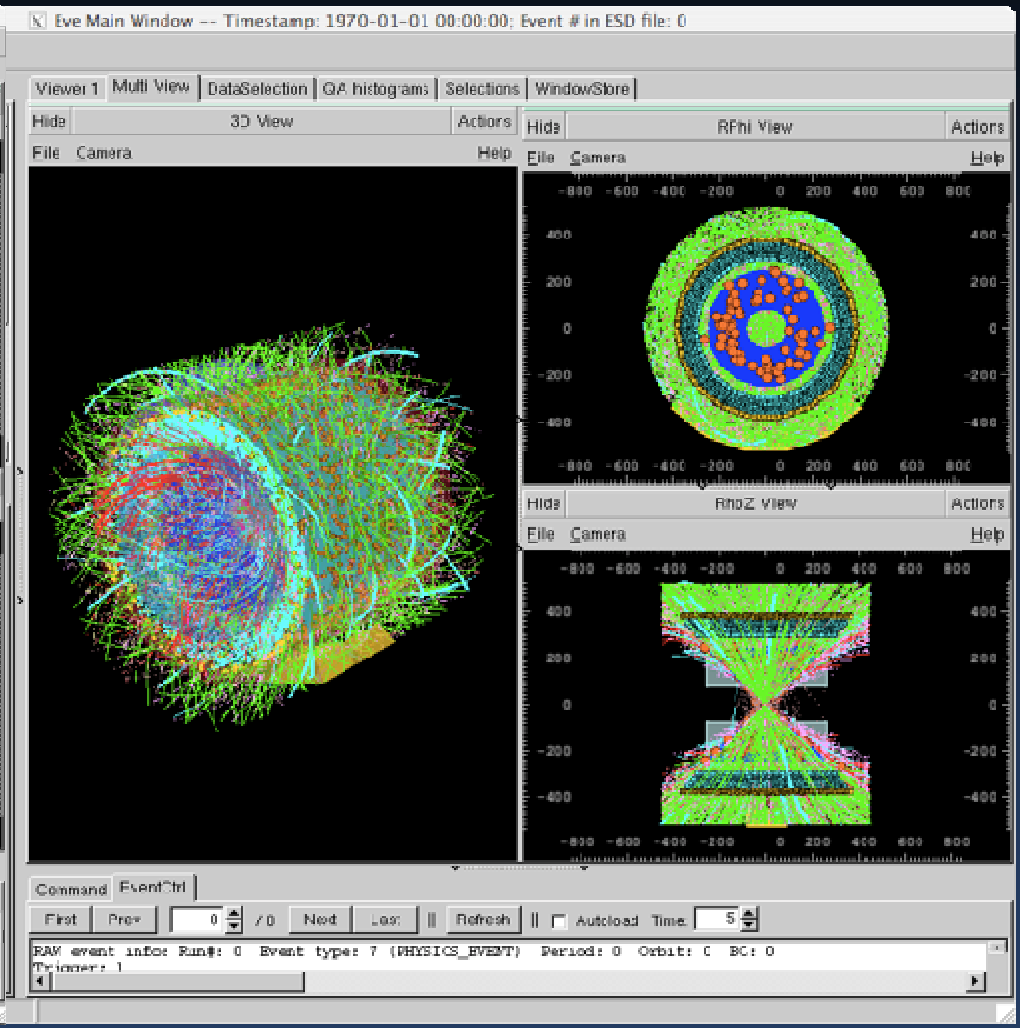
    “4th concept” IlcRoot: C.Gatto/ developer V. di Benedetto;

    “Alice” AliRoot, F. Carminati.
  - Several simulations, detector geometries etc. already exists
  - Import of our contained model-detector geometry in the environments
  - First results (see A. Kilic→ LHeC simulation with Geant4)
- Dedicated manpower for software maintenance needed

Simulation Environment (I)

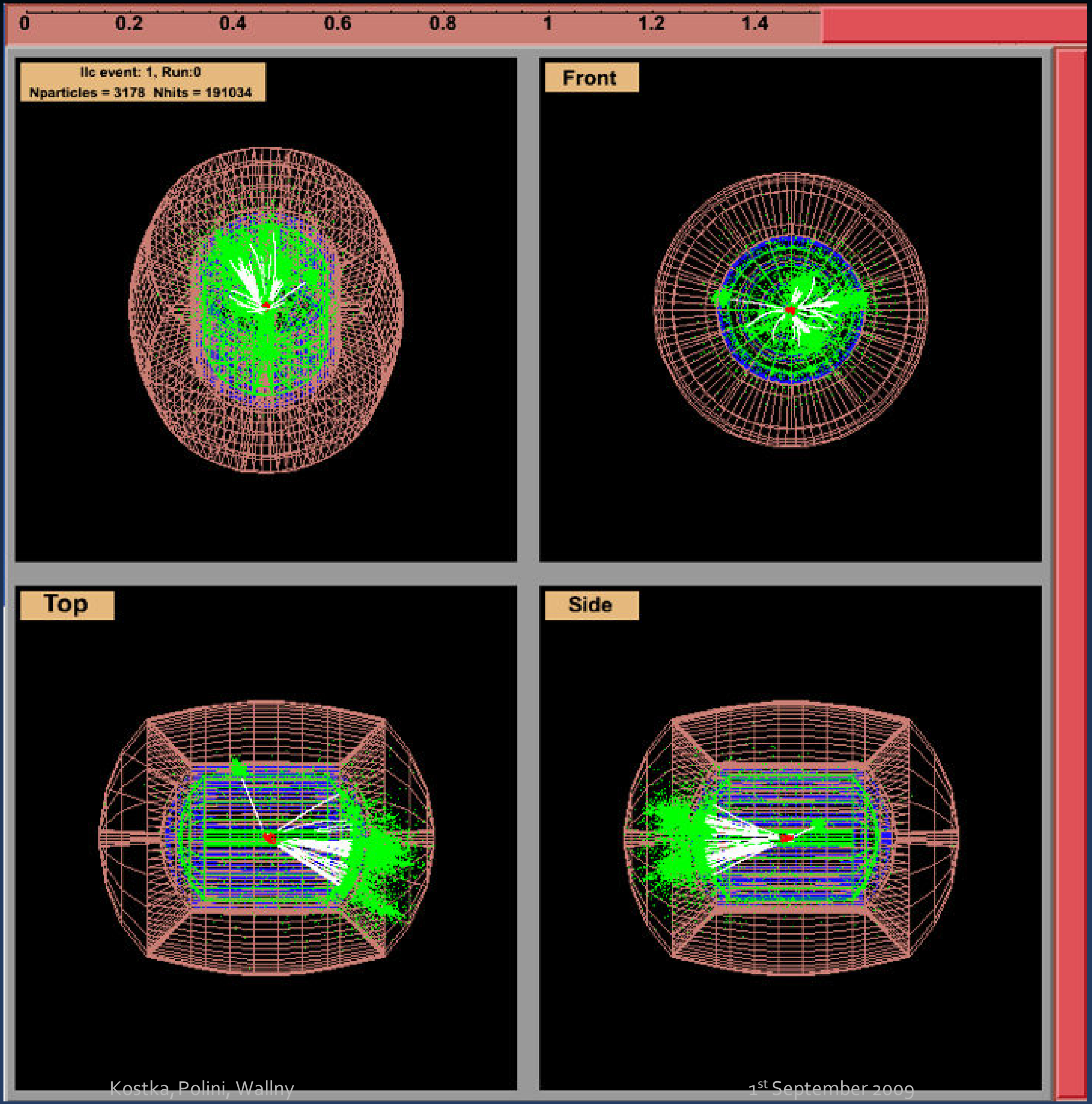


P-p Alice



Pb-Pb Alice

Simulation Environment (II)



e±p Event GUI

IlcRoot

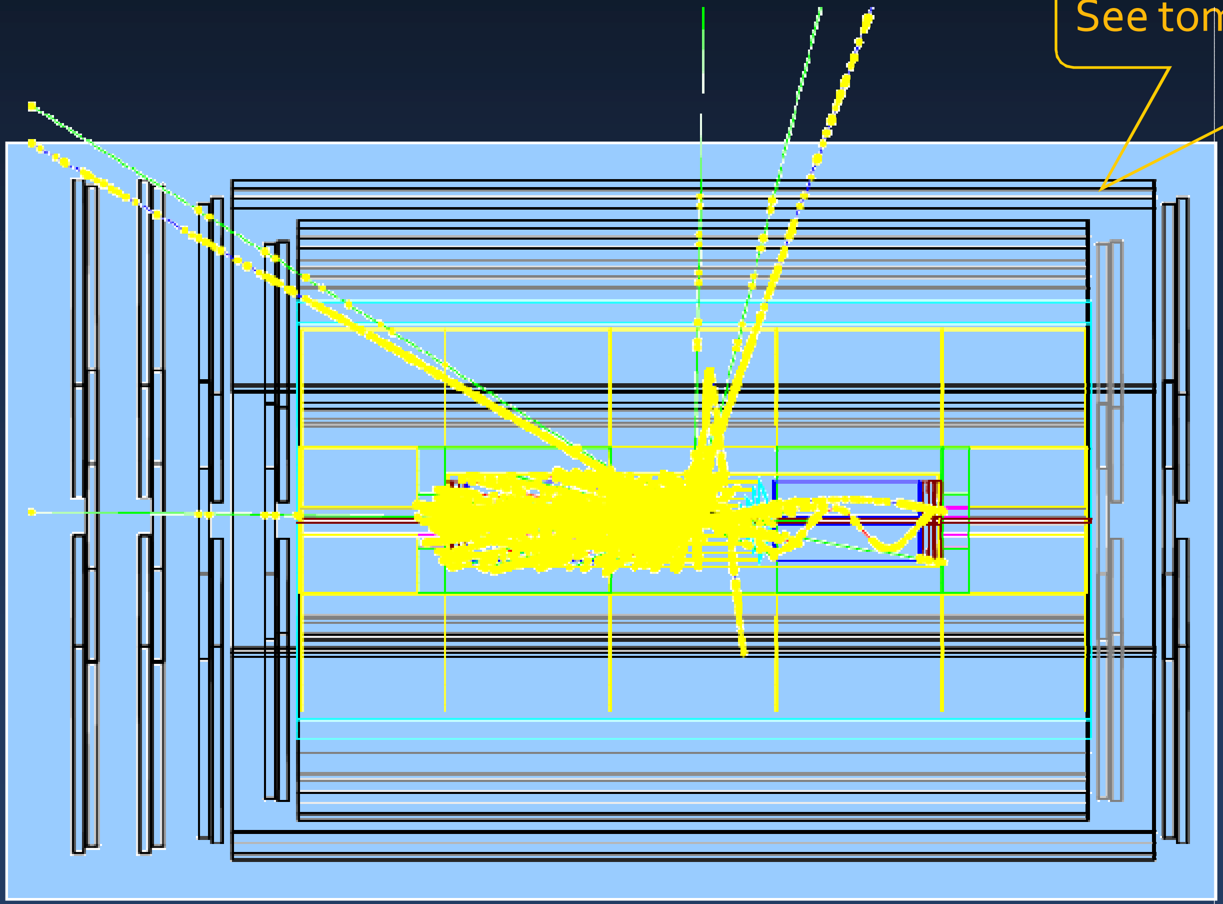
4th Concept

Detector

NC higgs event - produced using Madgraph and Pythia, beam energy 140 GeV electrons 7000 GeV protons (U.Klein - Liverpool)

LHeC detector 1st simulation

- Root TGeom model + Geant 4



See tomorrow's talk by A. Kilic

Our appreciation to our Colleagues from several Turkish Universities and Research Institution for having joined the LHeC detector WG

Starting point for discussions

- Optimize IR and ACC boundaries
- Establish detector concepts:

  we made a set of choices, none of these are final, but aim to provide one full design iteration for Physics Working Groups for feedback
- Simulation environment, its use and maintenance are essential.

- Work Packages definition and their coverage
- To do list for CDR

➔ to be detailed in detector session tomorrow 16:30

Summary

Status

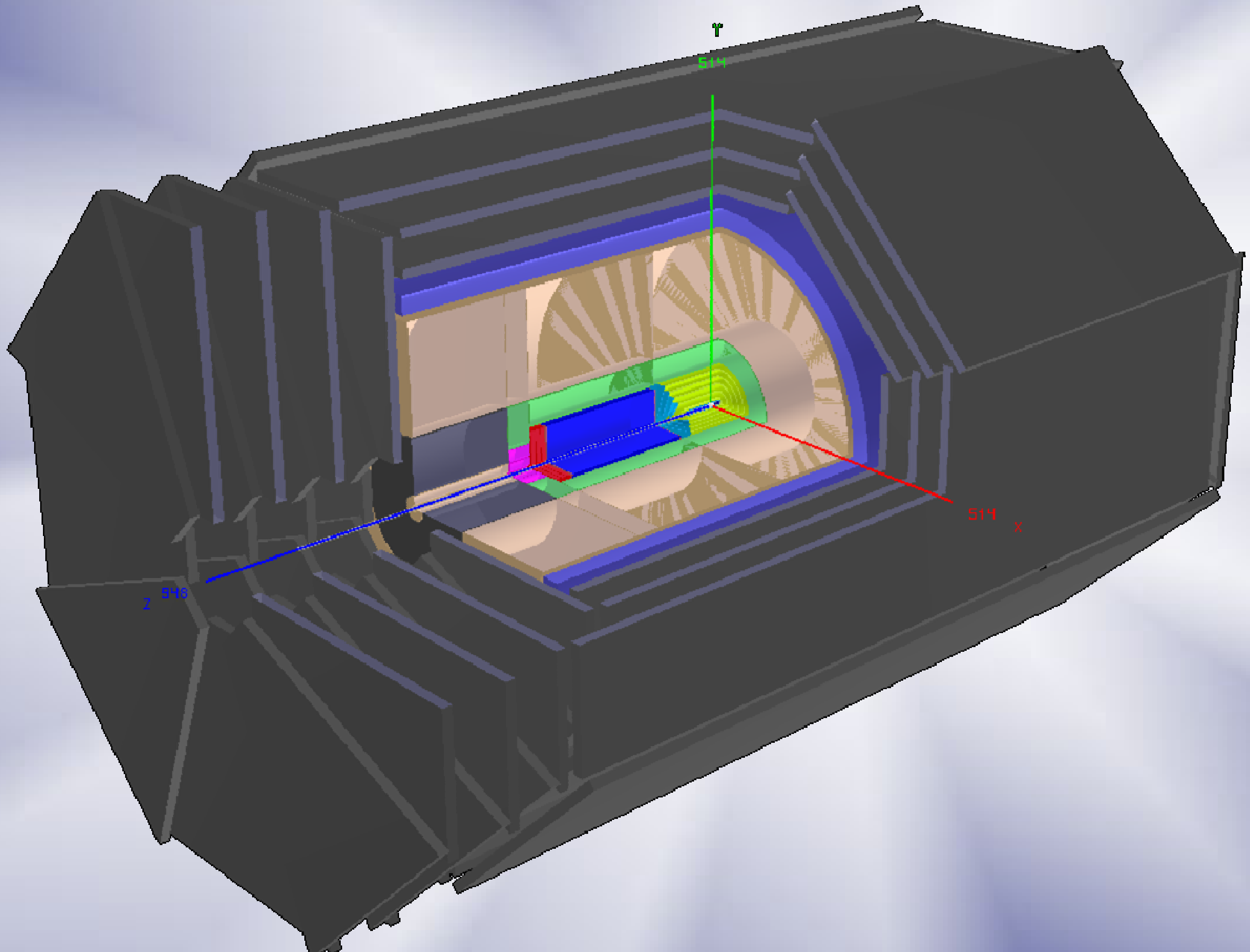
- A first design of a detector for LHeC presented
- Modular structure detector
- 2 configurations Low Q^2 and high luminosity-high Q^2
- Fwd/bwd plug modules: precision tracking or strong focusing magnets.
- Time constraints allows to follow developments from SLHC/ILC:
- Promising detector technologies available

Plans

- Description of the interaction region magnets, beampipe
- Detector description and simulations of detector details (+ very forward)
- This requires choosing an appropriate framework for simulation - essential decision. AliRoot-ILCRoot appear to be good candidates.
- Collaboration to existing projects is mandatory as resources and manpower are low.

➔ Interested people are very welcome. Design still very preliminary and open to new ideas.

- Looking forward to fruitful collaboration and attractive developments aiming at the Conceptual Design Report



Thank you

Backup slides

Open Questions

- IR/ACC
- Detector technologies
- Tracking: Detector Choice: Gossip, H.Van De Graaf
  Operation near the beam pipe, resolution/efficiency - which S/N is required?
  Stability, R/O modes/electronics - trigger, tracker, TRD
  Alternatives have to be discussed in spite of rapid development for e.g. SLHC / SuperBelle tracking.
  At the moment (first test's) most lightweight detector delivering track segments and TRD/trigger capable.
- ILC/CLIC Calorimeters
  Energy Flow - necessary?
  Alternatives for dense jet resolution, pion/e ident, gamma/e at high energy, neutron, deuteron, proton tag e-nucleon requirements to be defined - TOF system, Zero Degree Calo ...
- Magnetic field
- Instrumented Magnets
- Detector Simulation:
- Fast implementation (expert resources) necessary)
  - detector performance studies, development of algorithms for reconstruction and physics analysis of the data
  - detector geometries - root format - MySQL interface (finally)
  - event display in Ali-Ilc-Fair-MPD-Root is based on the EVE (Event Visualization Environment)
  - grid ... for performance -> 150 event simulation = several hours on Laptop
  - define/use data import interface formats
- Manpower

  immediately: Need expert support for setup and maintenance of a Detector Simulation environment.
  all special detector fields - expert knowledge wanted
- ILC/CLIC LHC SLHC common detector simulation effort - feasible?
- ...

How should the LHeC Detector look like ? (present draft)

Radius (cm)	Subdetector	Comment
2.9–4.6/3.47-6.05	2 layer ellipt. V_{pix}	δ(IP) < 10 μm
7.5–61	5 layer Si-Gas barrel	covering ~ xxx m^2
5–61	4 cone Si-Gas barrel	covering ~ xxx m^2
5–60	fwd/bwd TPC	covering ~ xxx m^3
5–60	fwd/bwd *3*2 planes Si-Gas	covering ~ xxx m^2
70–110	ECAL (material!!)	25-30 Xo
112-289	HCAL (material!!)	6-10 λ_I
300–330	Coil	3.5 T
340–700	Fe/muon	

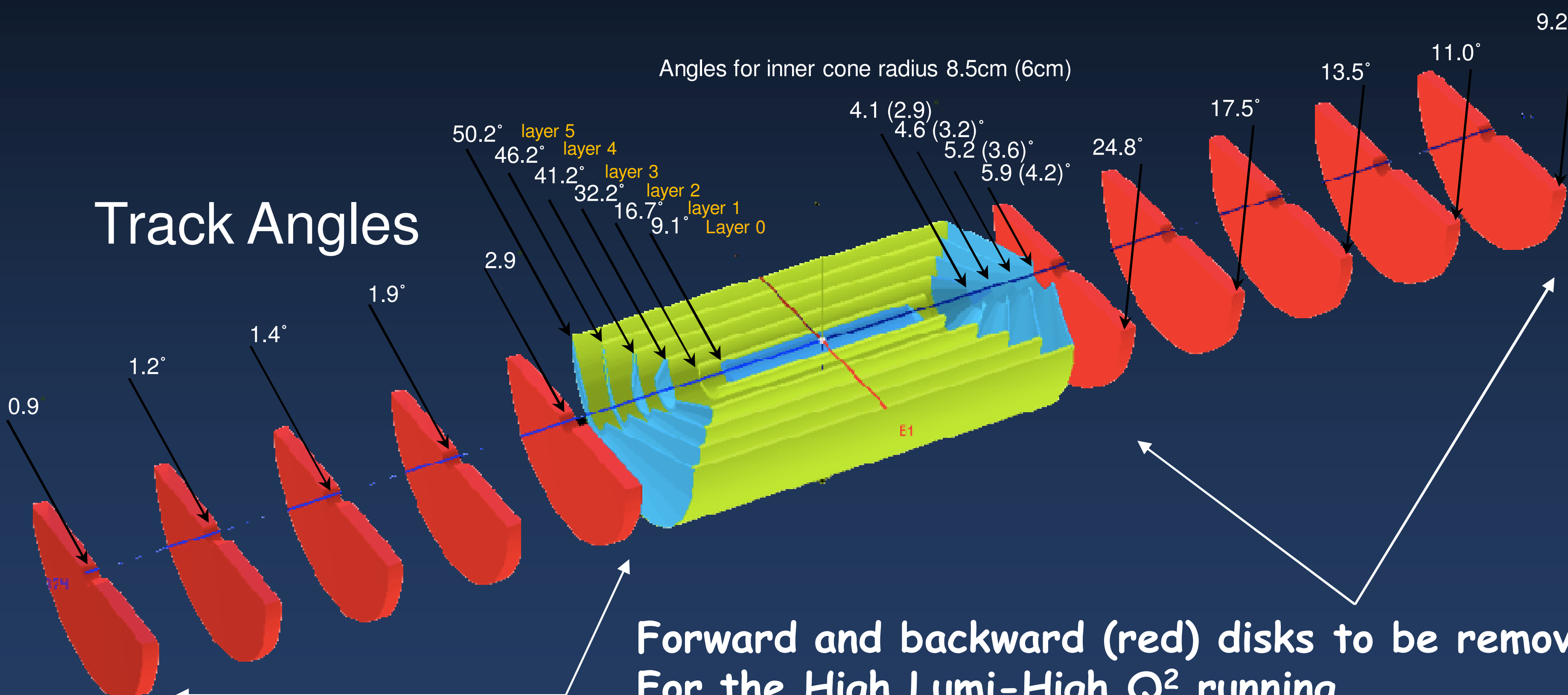
Tracking: alternative design (to be optimised)

One option: GAS-Si Tracker - GOSSIP Type NIKHEF

Gas On Slimmed Silicon Pixels (or Strixels/Pads)

Container Model

Track Angles



Forward and backward (red) disks to be removed
For the High Lumi-High Q^2 running.

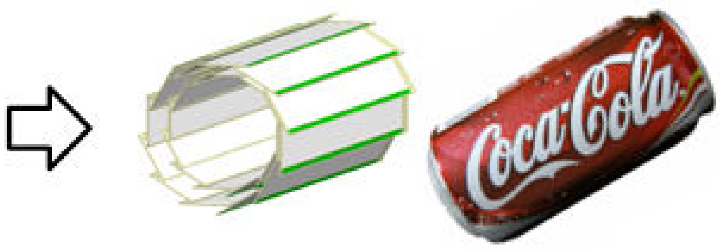
Alternative technologies: Pixels, IMAPS, DEPFET etc.*)
see Divonne 2008 workshop

Silicon Pixel Detector

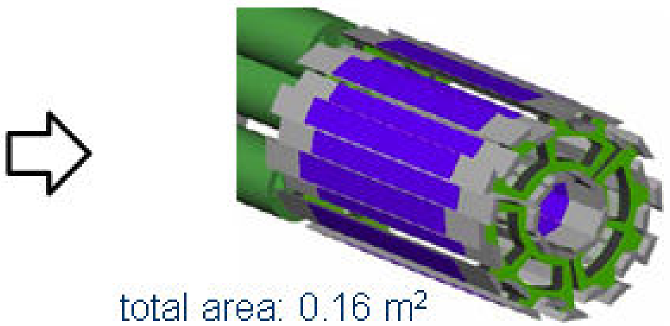
(Semi-) Monolithic Pixels Overview

- DEPFET Pixels
  - one transistor in pixel bulk
  - Q-collection in fully depleted bulk
  - R&D (for ILC) since > 10 years
  - recently (2008): a 2 layer detector for superBelle

total area: 0.014 m^2



- Monolithic Active Pixels (MAPS-epi)
  - Q collection in thin epi-layer
  - need tricks for full CMOS
  - R&D (for ILC) since ~ 10 years
  - 2 (or 3) layer detector for STAR@RHIC

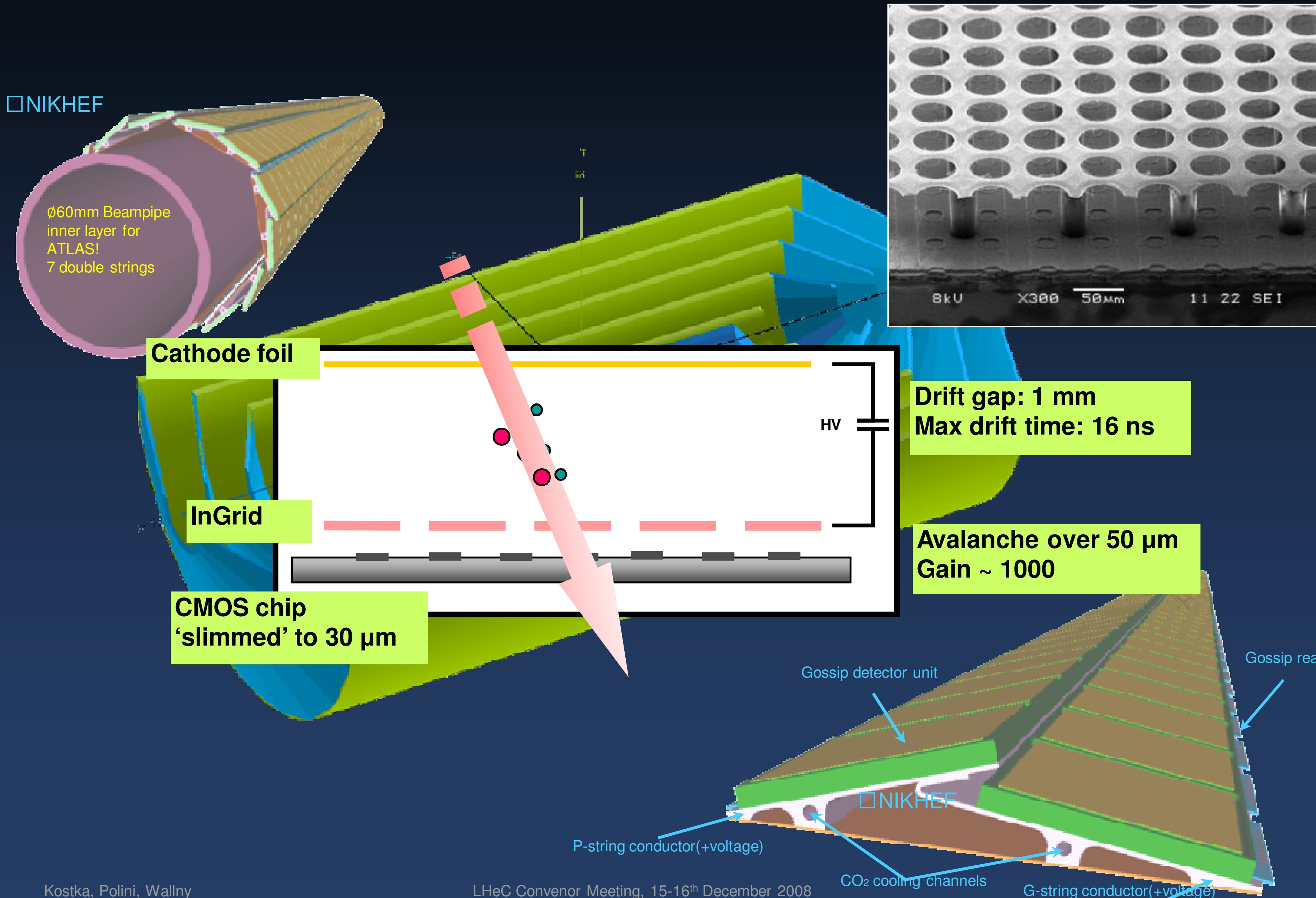


total area: 0.16 m^2

- Monolithic Active Pixels (MAPS-SoI)
  - **full CMOS in active area**
  - Q - collection in **fully depleted** bulk
  - R&D started 2006

I will show selection of current efforts

GAS-Si Tracker

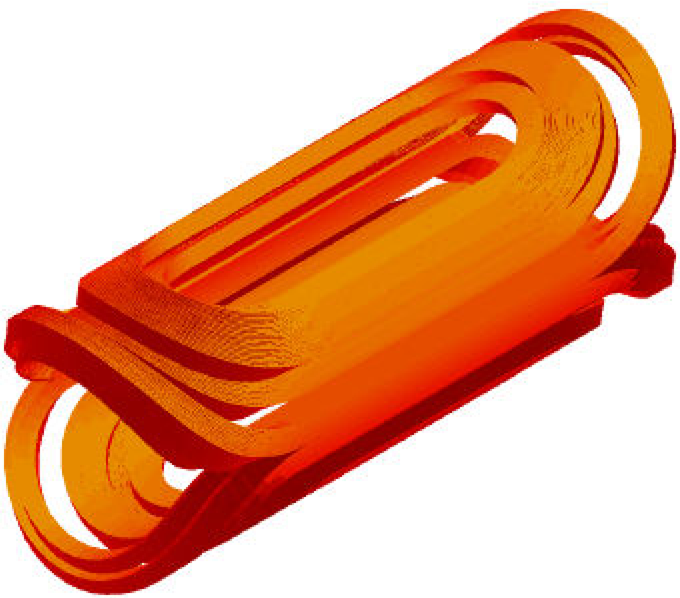


Instrumented Magnets

Superconducting magcal – take one

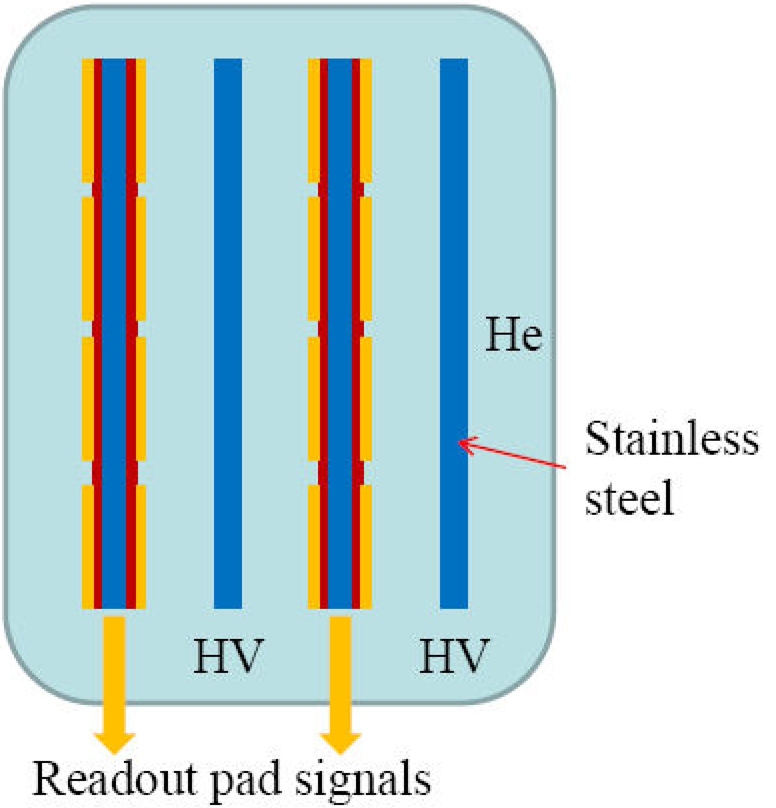
Tim Greenshaw

- Helium cooled SC magnet.
- Coils in He bath.



- Space for calorimeter using He as active component?

- Could add stainless steel plates as absorber with readout pads:



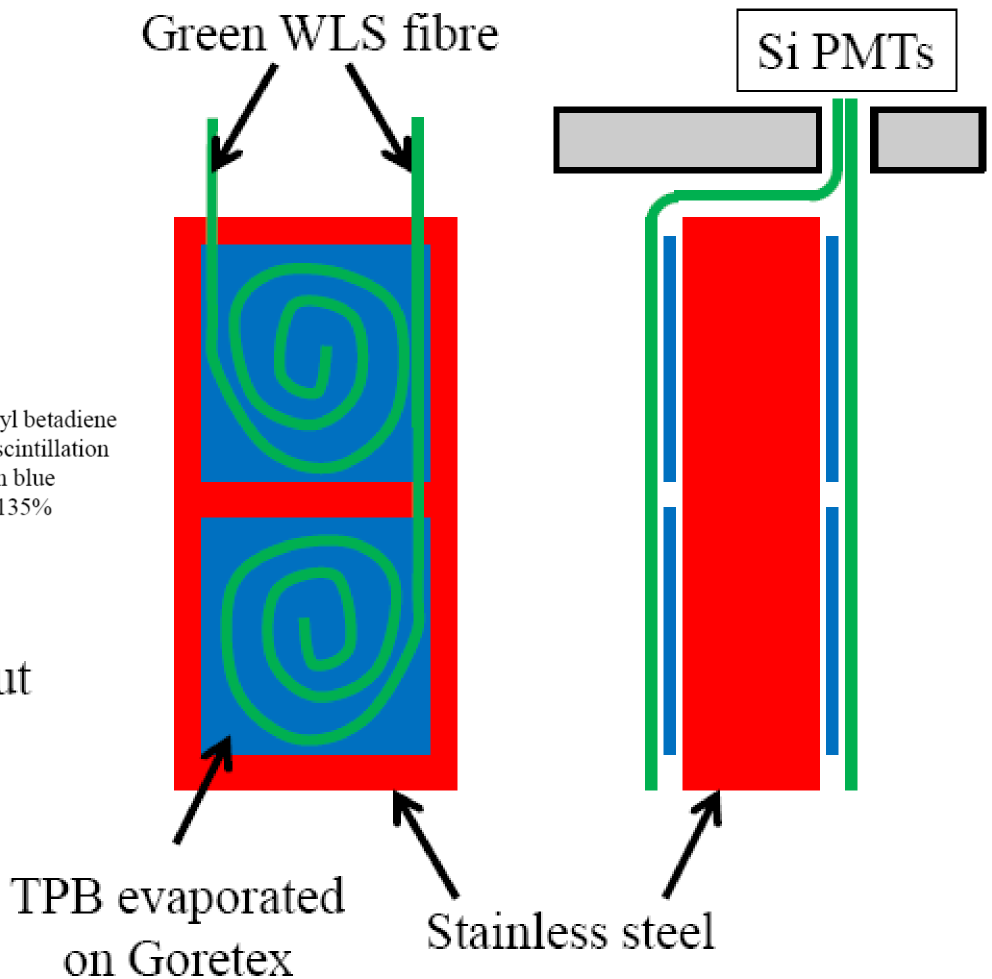
Instrumented Magnets (cont'd)

SC magcal – possible design

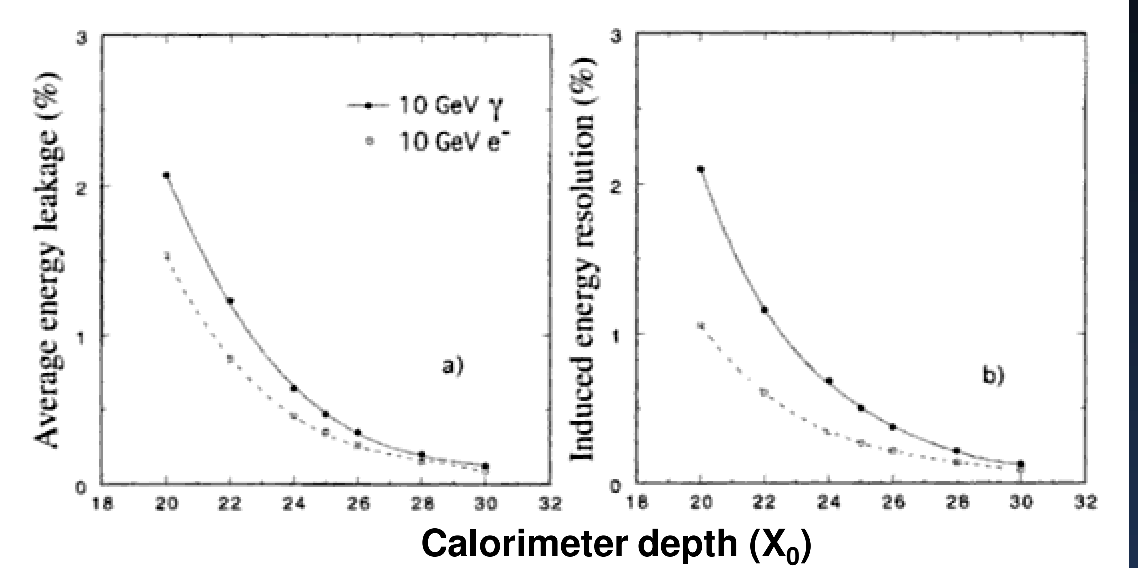
Tim Greenshaw

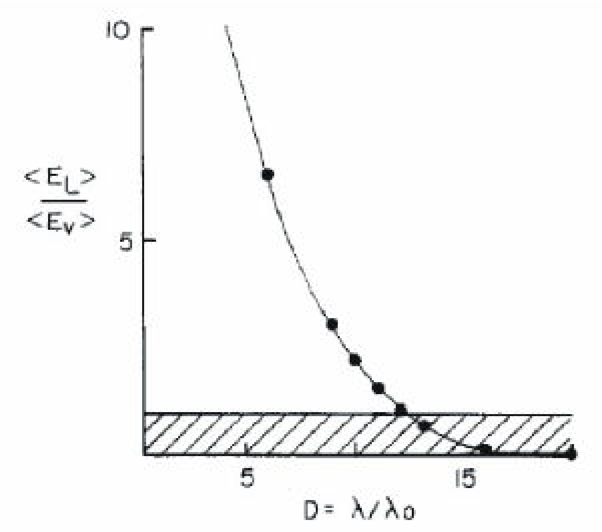
- Consider steel/LHe sandwich design.
- If have ~ 2 mm thick stainless steel plates with similar width gaps, then:
  - $X_0 \sim 2.2$ cm.
  - $r_M \sim 1.9$ cm.
  - $\lambda_I \sim 21$ cm.
- Above determine necessary size of calorimeter and size of readout cells.
- Possible cell construction illustrated opposite.

The fluor tetraphenyl betadiene (TPB) absorbs the scintillation light and re-emits in blue ($\lambda \sim 430$ nm) with 135% efficiency.

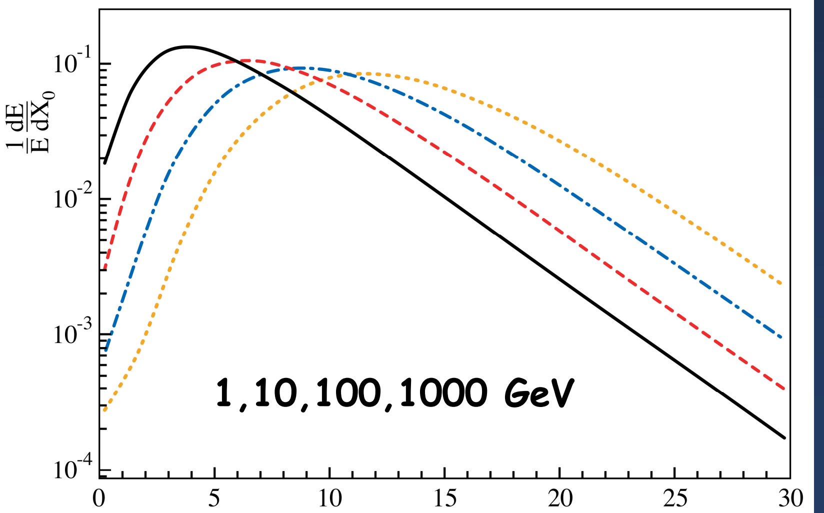


Calorimeter Essentials





Ratio of energy loss due to longitudinal leakage divided by loss due to neutrinos vs long thicknes in interaction lengths



Longitudinal profile

Dual Readout Calorimeters

The dual readout consists in reading independently (in a non-compensating cal.)

- a Cerenkov response only sensitive to relativistic shower components (mostly electrons)
- a Scintillation response sensitive to all dE/dx
- and correcting event by event and cell by cell the main (scintillation) response.

- Experienced first by the DREAM Collaboration

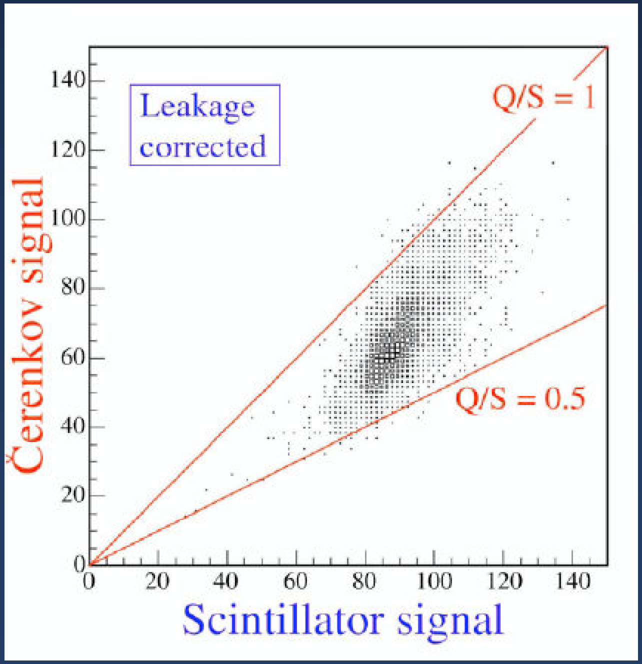
Two independent measurements: Q and S
Using e/h(Q) =4.7 e/h(S) =1.3 and :

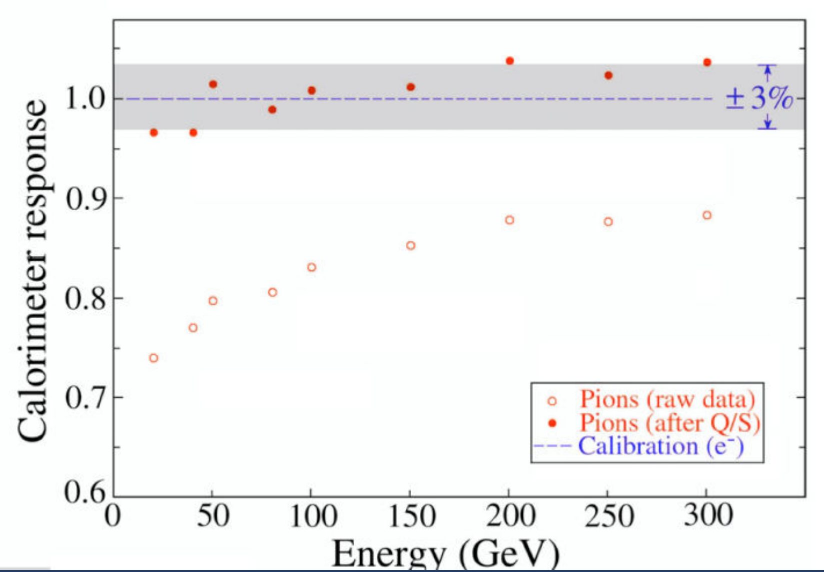
$$S = E\left[f_{em} + \frac{1}{(e/h)_S}(1 - f_{em})\right]$$

$$Q = E\left[f_{em} + \frac{1}{(e/h)_Q}(1 - f_{em})\right]$$

One can calculate fem and E event/event.

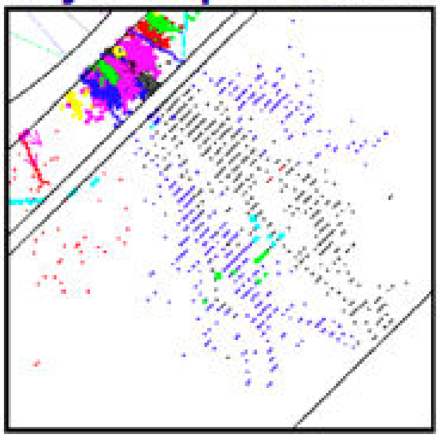
- **linearity is restored**
- **energy resolution is improved**





PFA Performance

★ **ILC:** demonstration that particle flow meets ILC goals + major in put into detector concept design **(ILD)**

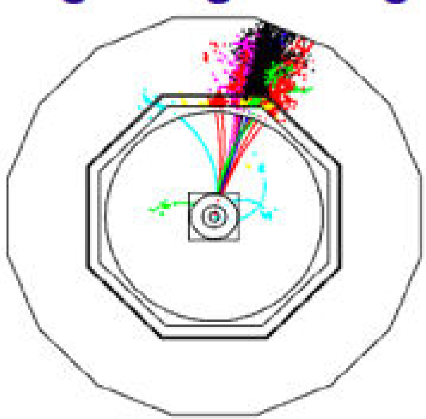


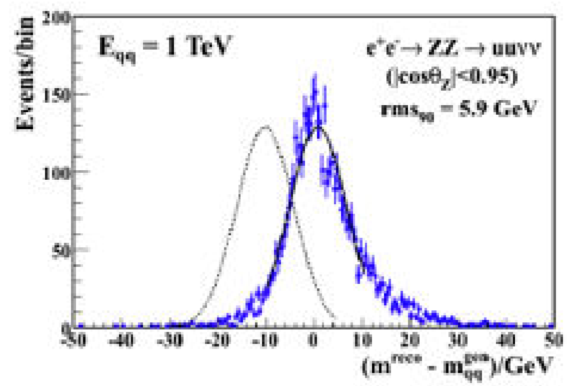
E_j	$\sigma(E_{jj})$	$\sigma(E_{jj})/\sqrt{E_{jj}}$	$\sigma(E_j)/E_j$
45 GeV	2.4 GeV	25 %	3.7 %
100 GeV	4.1 GeV	29 %	2.9 %
180 GeV	7.5 GeV	40 %	3.0 %
250 GeV	11.1 GeV	50 %	3.2 %

di-jet ($\sigma(E_{jj})$, $\sigma(E_{jj})/\sqrt{E_{jj}}$) jet ($\sigma(E_j)/E_j$)

★ **CLIC:** promising at high energies (not optimised)

1 TeV Z





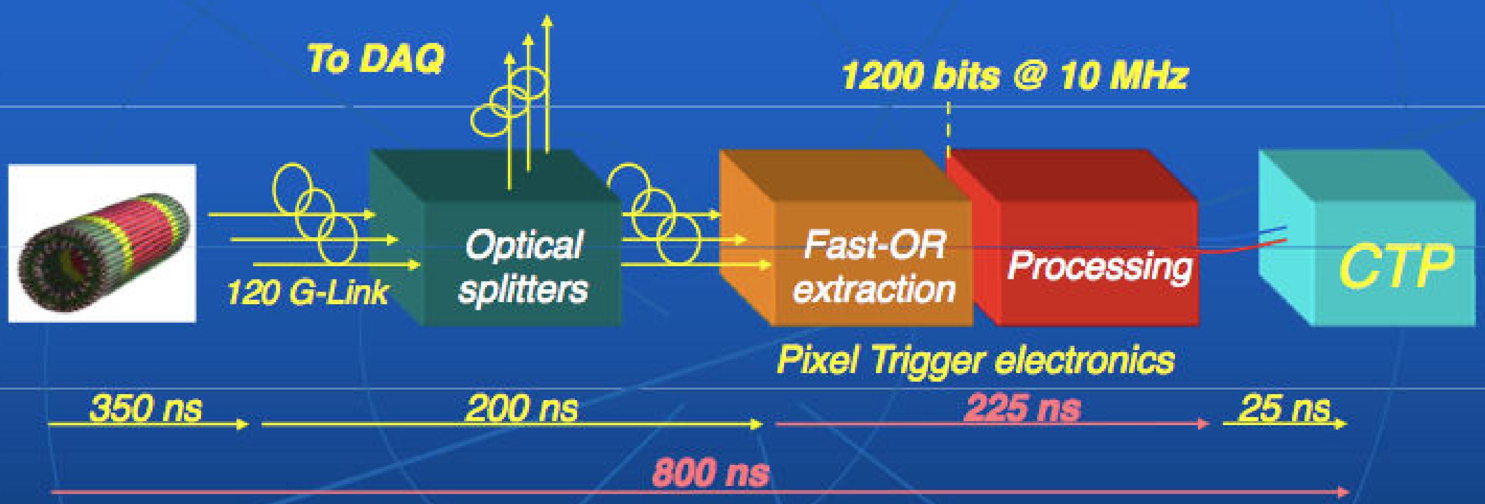
Innermost Tracker
Level 1 -Trigger: Pixel

- 2 inner layers: pixel detector (trigger detector)
  e · p: Minimum bias, High multiplicity studies, Topological selection (jets), Secondary vertex pre-ident, p_T pre-selection
  e · nucleon: Impact parameter pre-selection

- Material (in general for all detectors)
  - strong interplay between:
    resolution – secondaries – pattern/track algorithms - minimum material; 2 layers enough?
  - new powering concepts (serial, DC-DC), fast R/O
  - cooling strategy + support structure + pixel technology + electronics
  - goal: $X/X_0^{90^\circ} < 0.3\%$ - where placing the power electronics ?
  - radiation an issue: ? neq/cm^2 @ innermost layers
  - sensor alternatives: 3D-silicon, planar (n in p), diamond
  - FE electronics digital

Track Trigger: an existing LHC example

ALICE - Pixel Trigger System



- Overall latency: **800 ns**
- Space occupancy (1 crate)
- Bottleneck: data deserialization and Fast-OR extraction
  - Processing time < 25 ns

Strip readout (on-chip correlation/trigger)