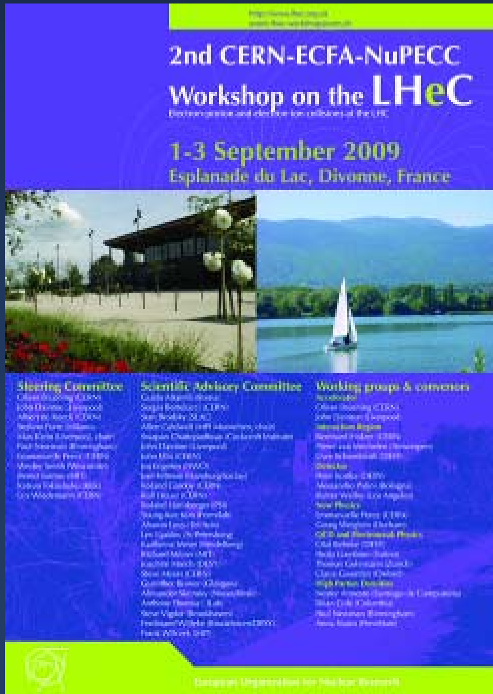
LHeC Detector Working Group: Summary

Peter Kostka
Alessandro Polini
Rainer Wallny

Outline

- Detector requirements
- Updated detector design
- Open Questions



CDR - Topics to be covered

- Detector Concept
  - Dimensions and General Requirements (accuracy, acceptance, beam pipe)
  - Coil
  - Calorimeters
  - Tracking
    (including options as GOSSIP vs. full Silicon)
  - Options for the Inner Detector Region
  - Detector Simulation and Performance

Detector Session

- Joint sessions with ACC/IRF and IRF/HPD
- Dedicated session:

Contribution List | Time Table

Wednesday, 02 September 2009

14:00

[50] Detector Requirements low x
by Paul NEWMAN
(Ausone: 14:00 - 14:30)

[54] MagCal Concept
by Tim GREENSHAW
(Ausone: 14:30 - 14:50)

[51] Si Gas Detector for Tracking
by Henry VAN DER GRAAF
(Ausone: 14:50 - 15:30)

15:00

[52] High Energy Calorimeters for ILCLIC
by Christian GREFE
(Ausone: 15:30 - 16:00)

Contribution List | Time Table

Wednesday, 02 September 2009

16:00

[53] Simulation of Detector in GEANT4
by Adnan KILIC
(Artists: 16:30 - 16:45)

[73] Introduction to Current Detector
by Peter KOSTKA
(Artists: 16:45 - 17:15)

17:00

[55] Discussion of Detector Layout
(Artists: 17:15 - 18:00)

Requirements from Physics

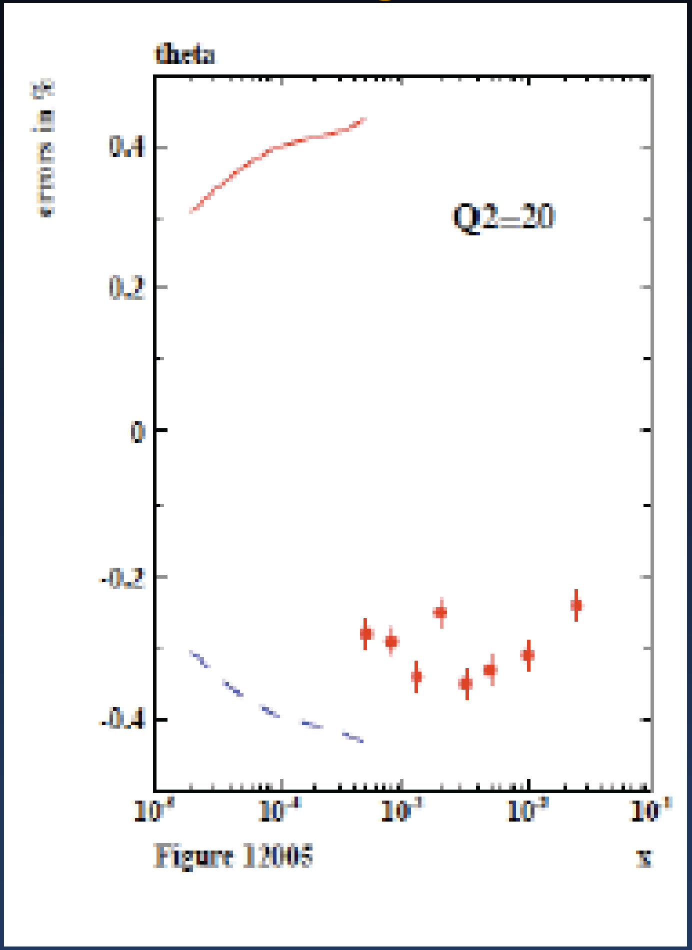
- High resolution tracking system
  - excellent primary vertex resolution
  - resolution of secondary vertices down to small angles in forward direction for high x heavy flavour physics and searches
  - precise pt measurement matching to calorimeter signals, calibrated and aligned to 1 mrad accuracy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

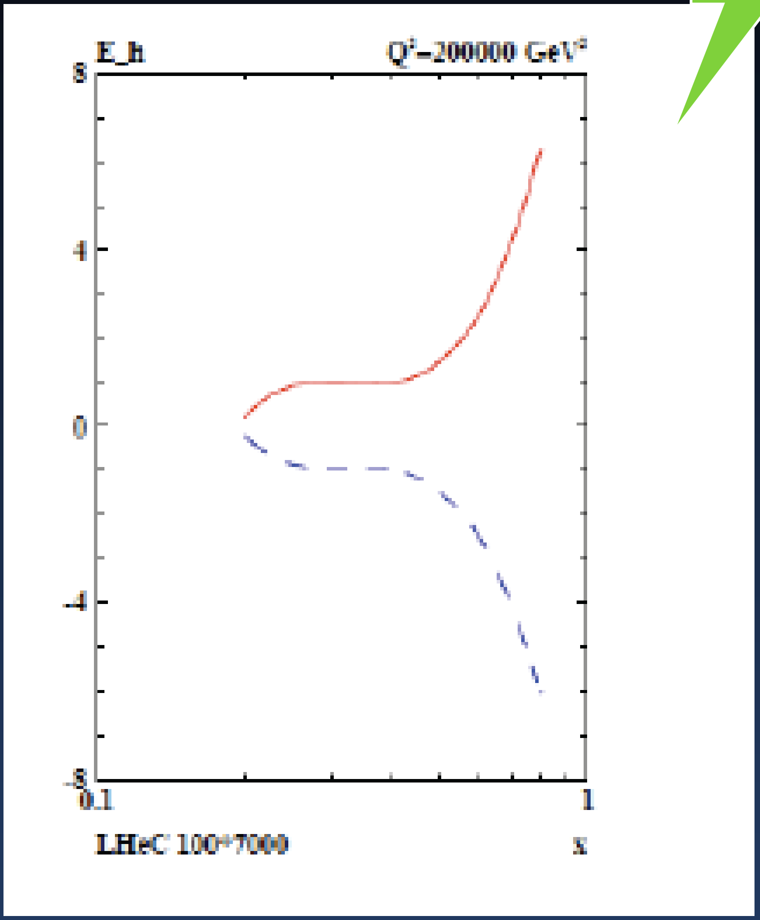
    Tagging of γ's and backward scattered electrons - precise measurement of luminosity and photo-production physics
  - hadronic part 30%/$\sqrt{E}$ calibrated with pT_e / pT_h to 1% accuracy

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

Physics Motivation (I)

Max Klein





$\Delta\ \theta$ ~0.1 mrad => 0.5% @ low Q2

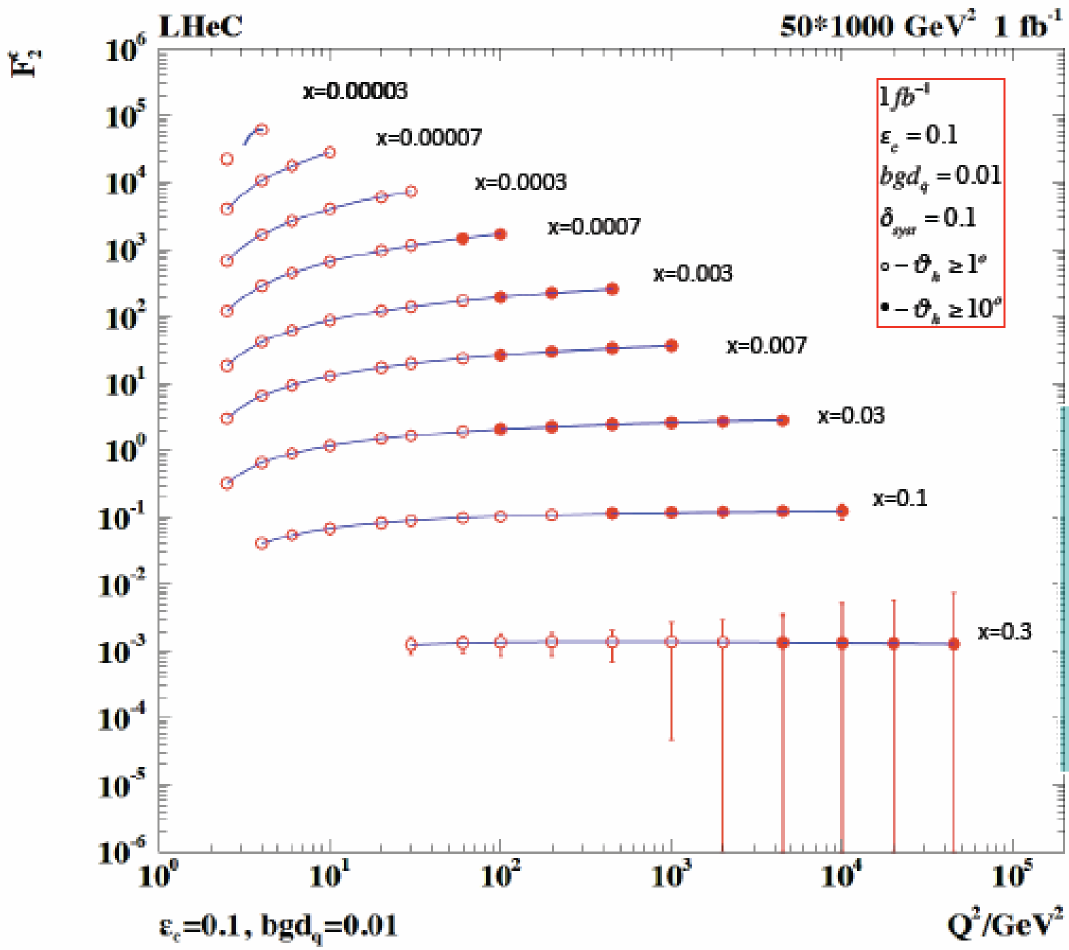
$\Delta\ E_h/E_h$ =1% => 5% @ x=0.8

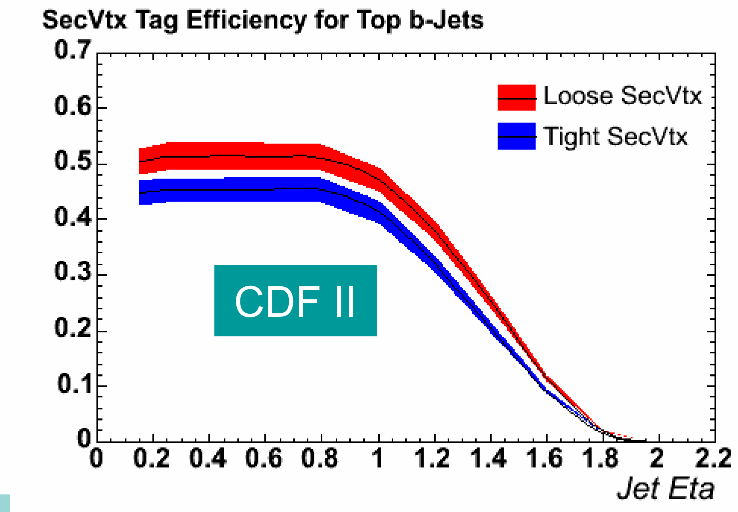
Two times better than H1 and full fwd/bwd coverage to θ= 1º

Max Klein

Physics Motivation (II)

Try to see charm at large x





Even in the most favourable beam energy setting, a search for intrinsic charm at x >=0.1 would require charm tagging down to few degrees…

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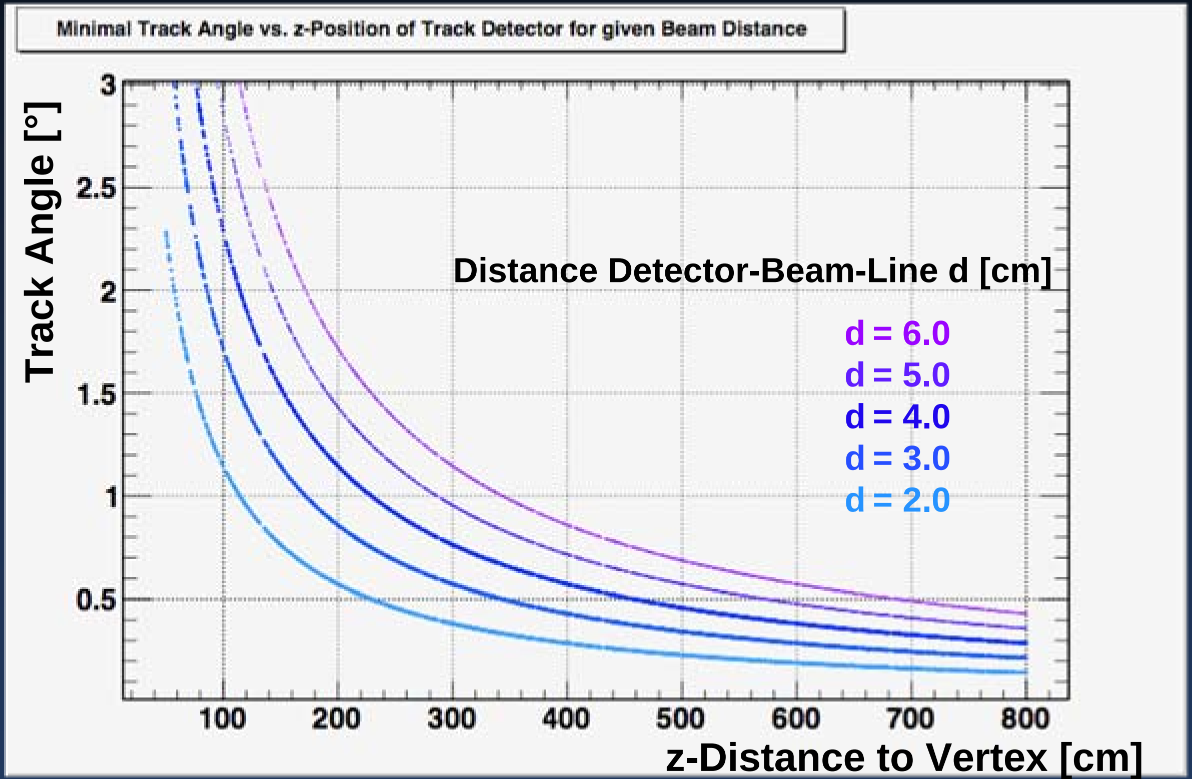
Requesting stringent Heavy Flavor tagging capabilities

Beam Pipe Considerations

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

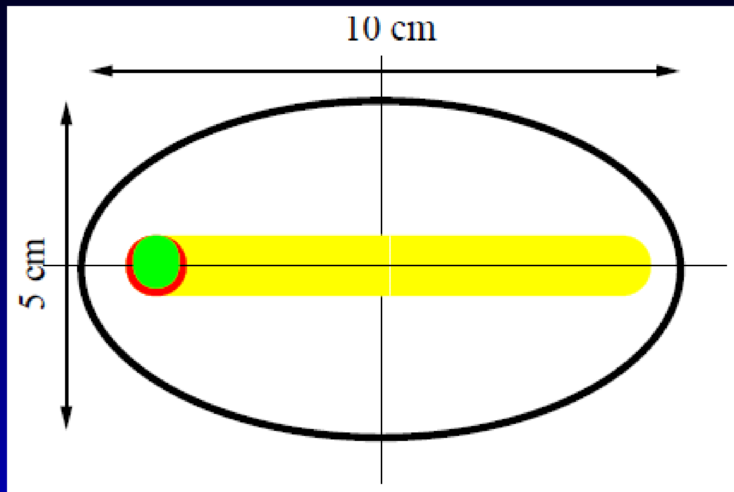
Strong implications in terms of costs and acceptance



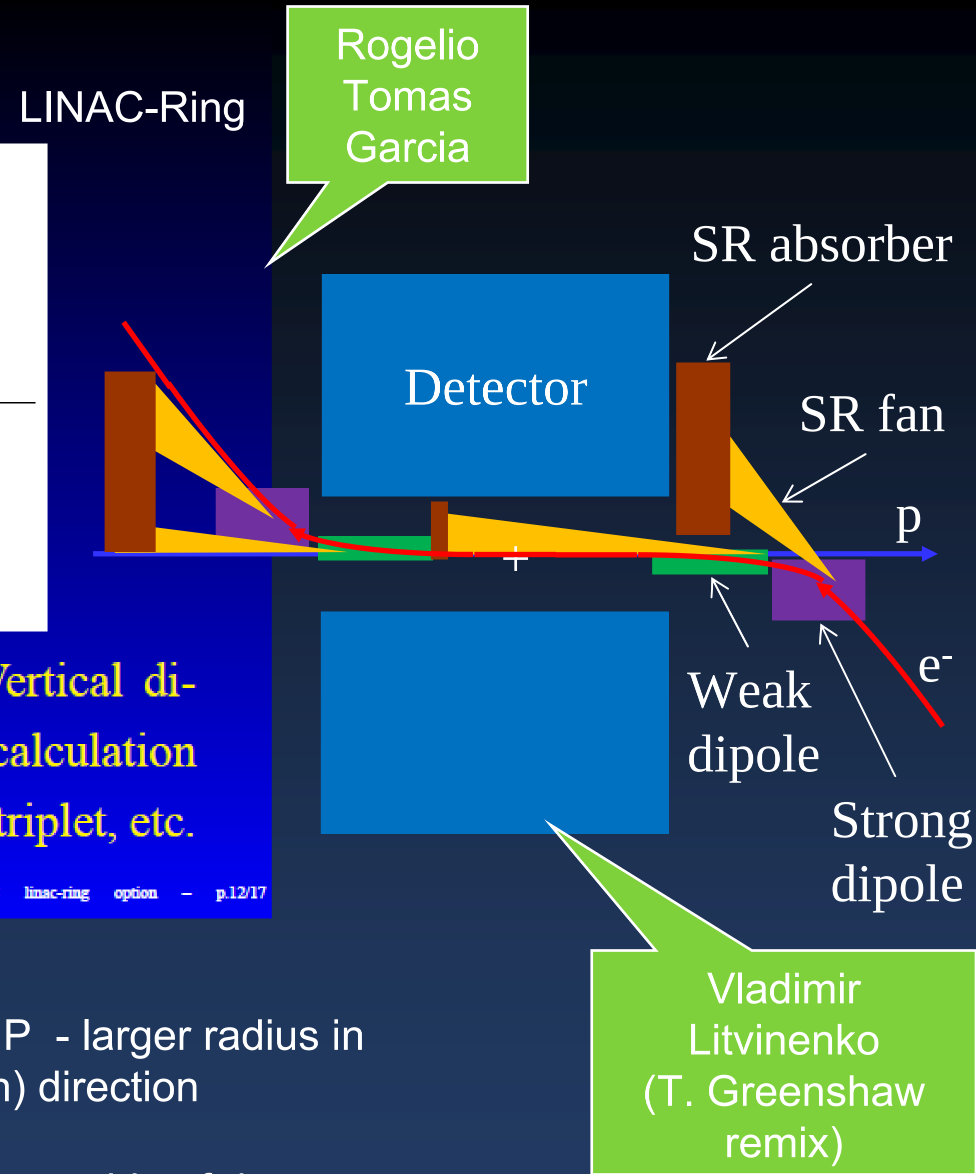
Present design: elliptical Be beam pipe from SLHC for now: r_y=2.50 cm (radius of SLHC design) and r_x=3.07 cm (scaled from HERA experience)

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

IP beam-pipe for 100GeV e^-



Horizontal dimension is defined by SR. Vertical dimension is a guess by P. Kostka. Precise calculation needs to include solenoid, radiation from e- triplet, etc.



- We assumed beam pipe diameter 6cm @ IP - larger radius in backward region smaller in forward (proton) direction possible
- eRHIC solution: hard bend of electron beam outside of detector sync rad fan bypasses active areas

- **needs optimization/feedback detector WG ⇔ IR region ⇔ Accelerator Group**

Detector Requirements (I)

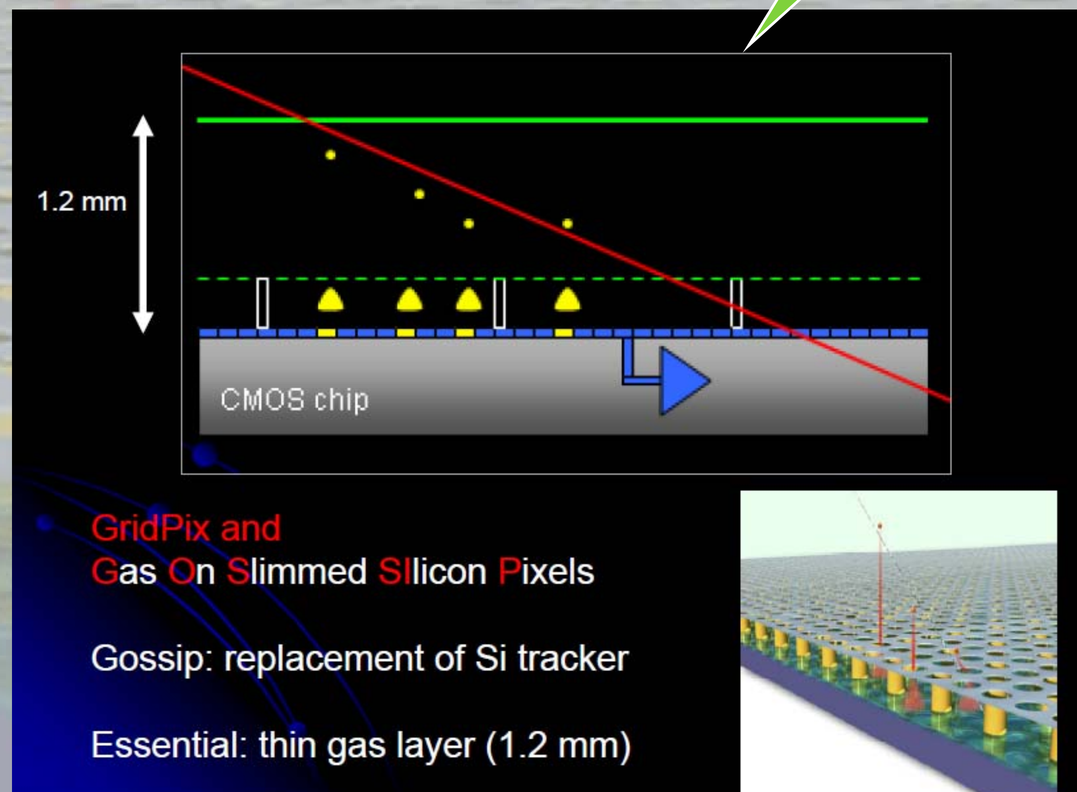
- Tracking
  - lowest mass tracker - essential for $\gamma/e^{\pm}$ ident (specifically bwd)
  - TPC
    TPC near the beam line - TPC background tolerant / BG tolerable? outer radii only?
    Discussion during this meeting - TPC replaced by low weight high resolution Si-Detectors ("conventional" or SiGas)
  - high resolution track definition in front of forward calo
  - tracking trigger in front of fwd/bwd calo
  - Early π^0 ident - vertex detector/trigger

Precision Tracking: Si-Gas Tracker – GOSSIP

Gas on Slimmed Silicon Pixels

- 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 – 3D tracking
- Gas choice: radiator : Transition Radiation Tracker - e/π identification
- Diffusion and drift velocity limits position measurement currently to ~<<20μm

Henry van der Graaf



Detector Requirements (II)

Calorimeter

- Minimize longitudinal and lateral energy leakage
- Fwd/bwd Particle Flow Detector to achieve desired mass resolution ; $\gamma/e^{\pm}$; π^0 ; …
  This technique combines the tracking/calorimetry information in an optimal way in order to get the best possible jet-energy resolution.
  Or Dream (dual readout) - event to event correction
- Both electromagnetic and hadron calorimetry inside the solenoid coil; minimum material inside EmCal;
- Prototyping, test at high energy!

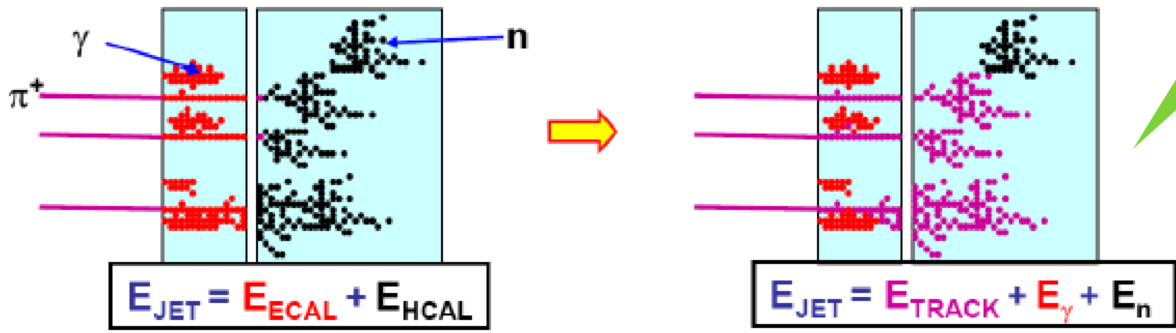
Magnetic Field

- 3.5 Tesla solenoidal field

Particle Flow

Christian Grefe

- Use tracking information to improve jet energy reconstruction
- Need to associate tracks with clusters
- Ideally only neutral cluster energy is taken from calorimeter



- "Confusion" is main source of errors
  - Need to separate neutral and charged clusters (B + radius)
  - Need highly granular calorimeter to see cluster structure

$$\text{Confusion} \propto B^{-0.3} R^{-1.0}$$

A hardware and software challenge

Tungsten = compact HCAL to minimize solenoid radius

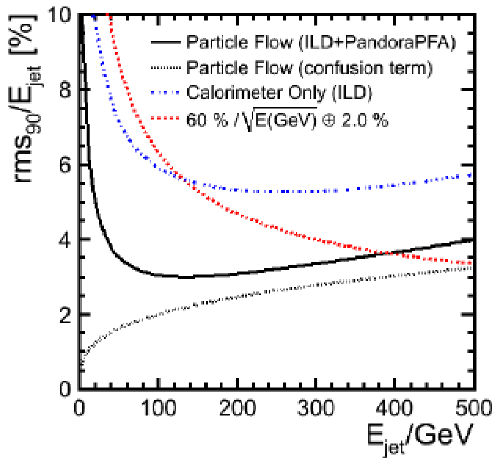
PFA Performance

- Empiric formula for PFA performance

$$\frac{\sigma_E}{E} = \frac{21}{\sqrt{E}} \oplus 0.7 \oplus 0.004E \oplus 2.1\left(\frac{E}{100}\right)^{+0.3} \%$$

Resolution | Tracking | Leakage | Confusion

- Comparing PFA and pure calorimetry:
  - PFA "wins" for E_{jet} < 400 GeV
  - There is room for improvement of the algorithm
  - Can chose reconstruction depending on event



- http://indico.cern.ch/contributionDisplay.py?contribId=268&sessionId=2&confId=30383
- http://indico.cern.ch/materialDisplay.py?contribId=1&materialId=slides&confId=56735

Mark Thomson

Barrel Region

Christian Grefe

Default ILD: B = 3.5 T, 6 λ HCal

E_{JET}	$\sigma_E/E = \alpha/\sqrt{E_{jj}}$ $\lvert\cos\theta\rvert<0.7$	σ_E/E_j
45 GeV	25.2 %	3.7 %
100 GeV	29.2 %	2.9 %
180 GeV	40.3 %	3.0 %
250 GeV	49.3 %	3.1 %
375 GeV	81.4 %	3.6 %
500 GeV	91.6 %	4.1 %

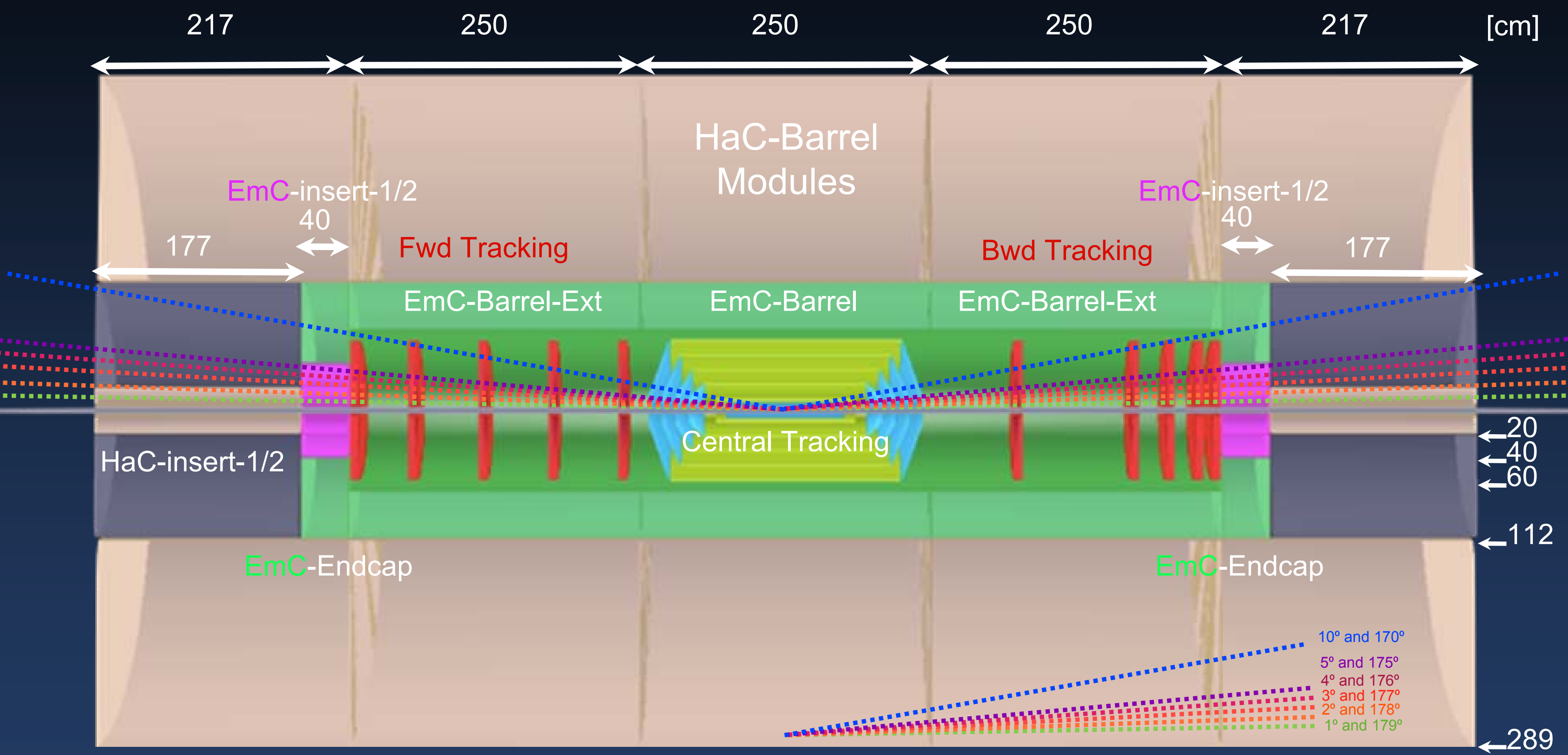
- Good option for barrel HCAL
  - need input from physics groups about mass and/or energy resolution
- PFA performance in fwd region unproven
- => consider conventional or "DREAM" fwd calorimeter

… the detector

… an updated draft

The Detector - Low Q^2 Setup

(to be optimised)



- **TPC replaced with Si-Gas double planes (concern about low angle tracks)**

Low-x

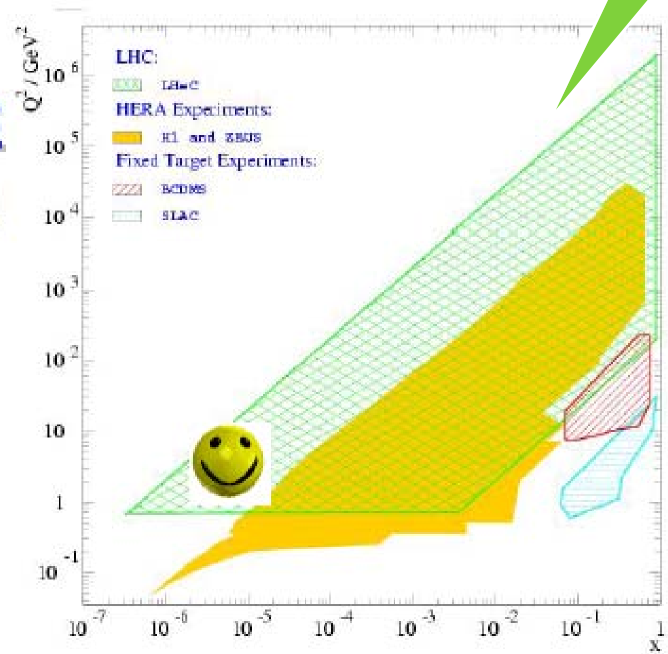
Paul Newman

Discussion Points on Detector Requirements for low x / high parton density physics

Paul Newman (Birmingham)

with Nestor Armesto, Brian Cole, Anna Stasto and the low x working group

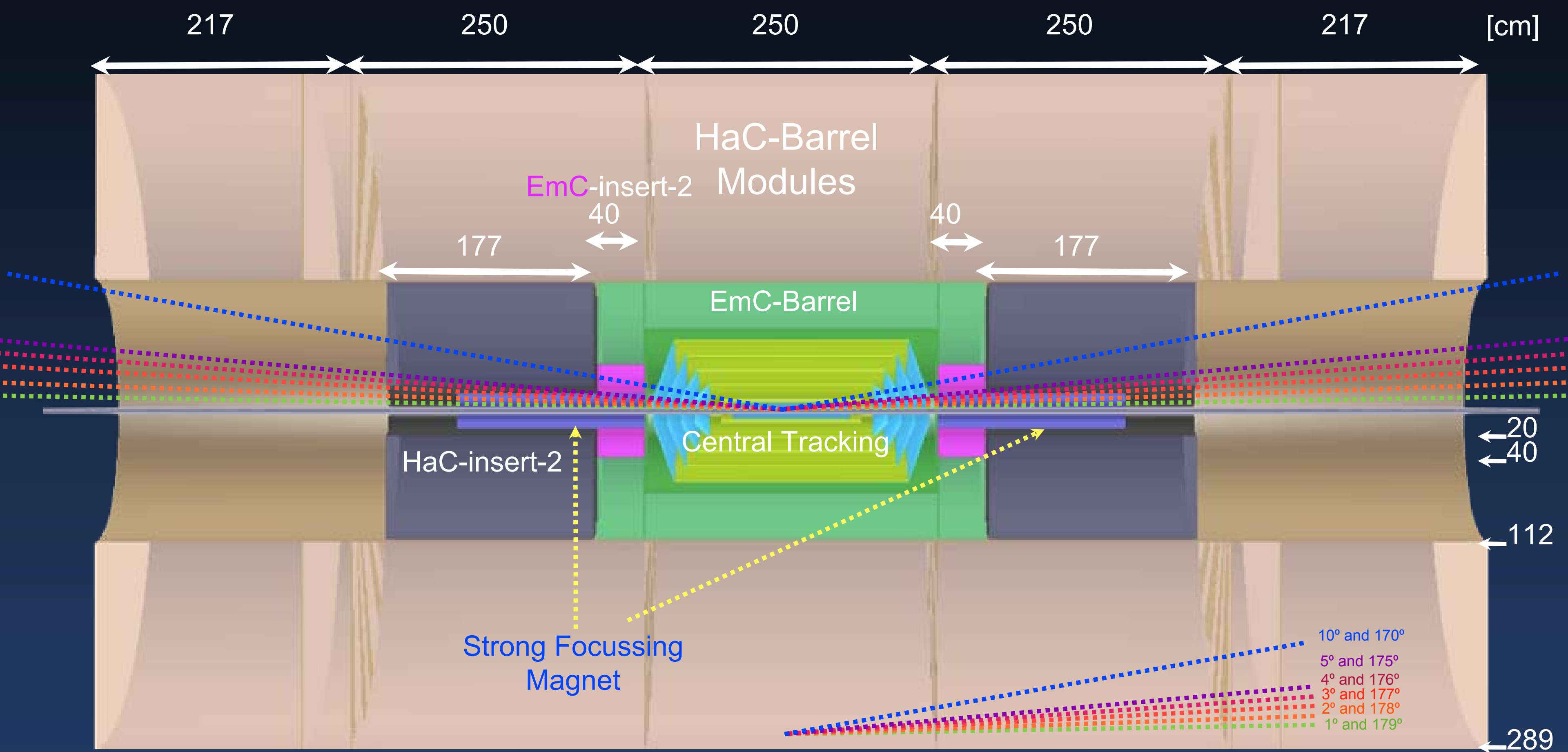
LHeC @ Divonne 2/9/2009



1) Generalities
2) Inclusive scattering
3) Vector mesons
4) Inclusive diffraction
5) Beam-line detection (e, p, n)
6) Forward jets

The High Q^2 Setup

(to be optimised)



L1 Low Q^2 SetUp → High Q^2 SetUp

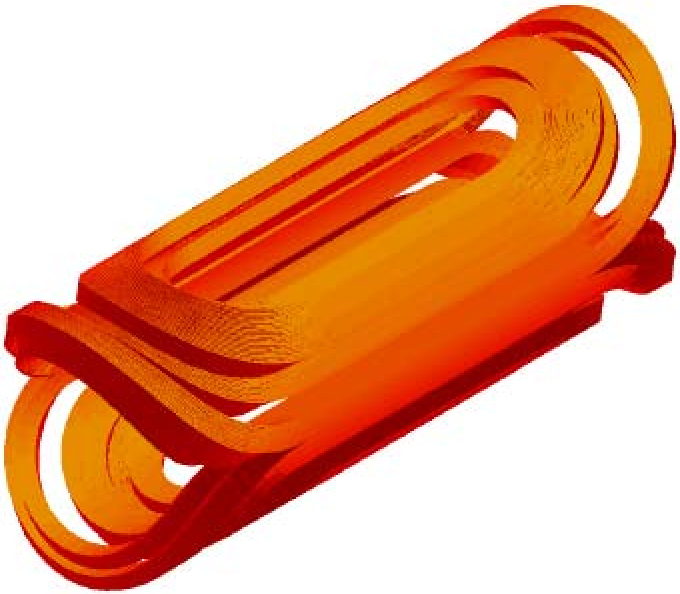
- Fwd/Bwd Tracking & EmC-Extensions, HaC-Insert-1 removed
-Calo-Inserts in position
-Strong Focussing Magnet installed

Instrumented Magnets

Tim Greenshaw

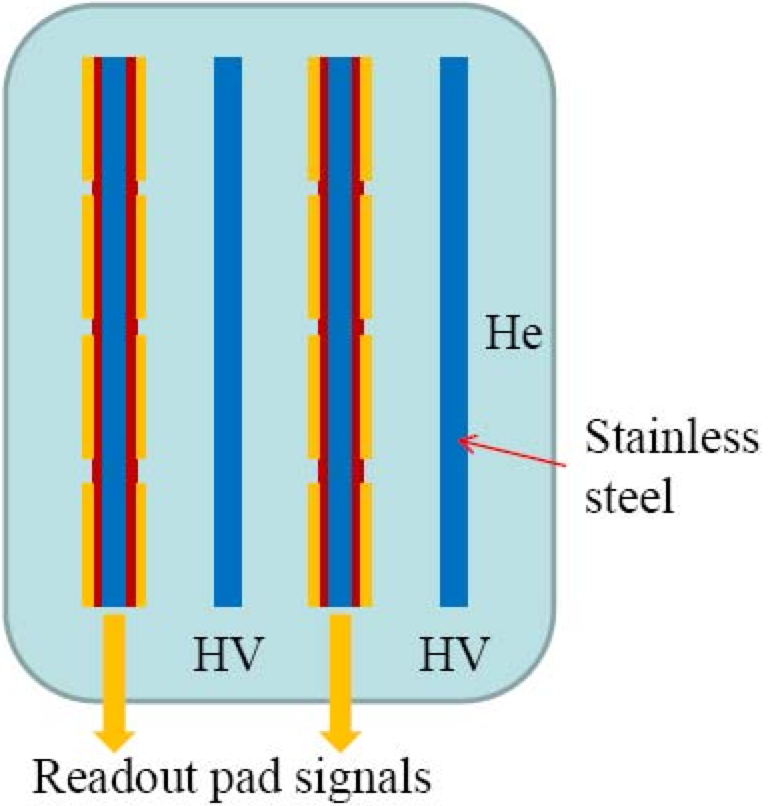
Superconducting magcal – take one

- 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:



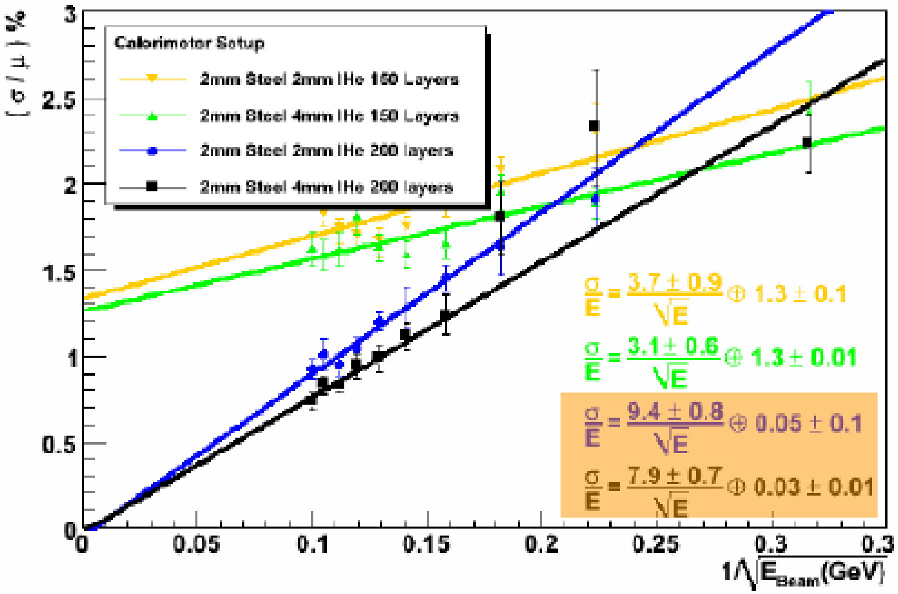
Tim Greenshaw

Geant 4 studies Birmingham

- Resolution, expect:

$$\frac{\sigma}{\mu} = \frac{\text{const.}}{\sqrt{E}}.$$

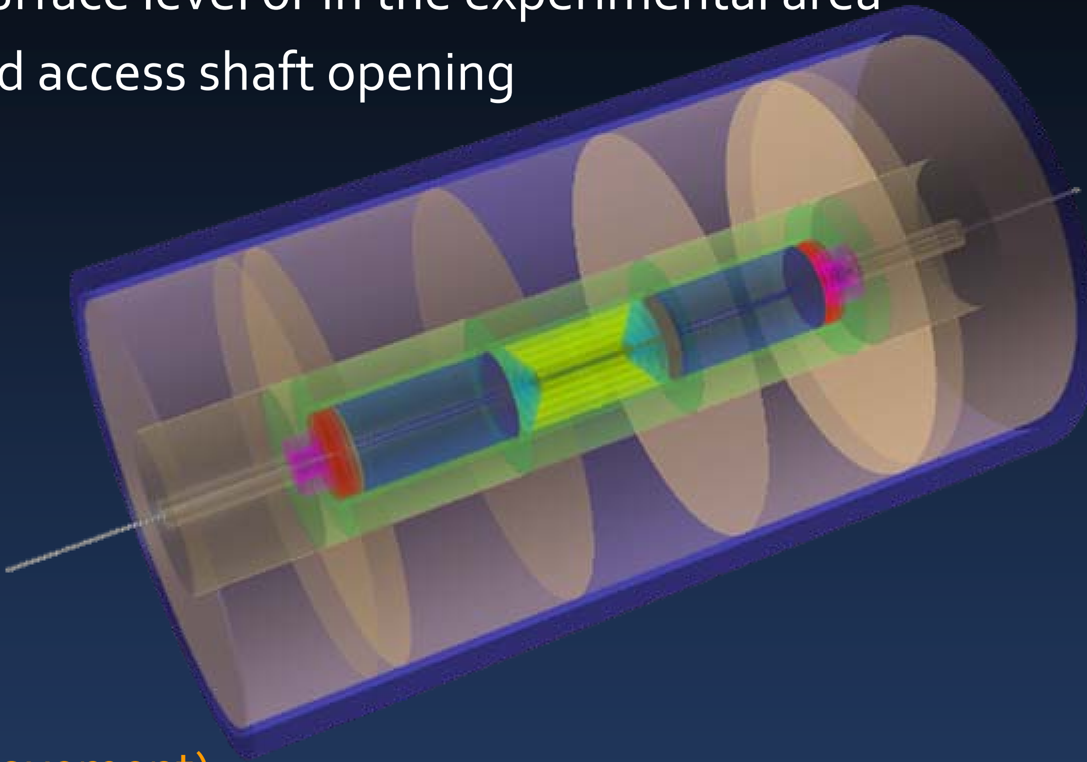
- Extract const. from slope of graph of σ/μ against 1/√E.



- Highest luminosity at collider requires magnets close to IP.
- These limit experimental acceptance unless they can provide (calorimetric) measurements.
- Stainless steel/LHe scintillation sandwich calorimeters look to be able to provide an energy resolution of ~ 10%/√E...
- ...but the showers in the calorimeters are broad and so they have to be reasonably large.

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 (resolution improvement)

Geometry constraints:

- Current beam pipe dimensions
- Requirement of 1^{o} tracking coverage
- Homogeneous B field in the tracking area

Overview - Core Detector

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	
5–61	4 cone Si-Gas barrel	
5–60	fwd/bwd × 5 × 2 planes Si-Gas	
70–110	ECAL	25-30 Xo
112-289	HCAL	6-10 λ_I
300–330	Coil	3.5 T - tracking
340–700	Fe/muon, ...	

Not covered:

very forward detectors, lumi measurement, what to do w/ 2^{nd} proton beam ...

may be important for e-nucleon running:
TOF system, Zero Degree Calo ... ?

Detector Simulation

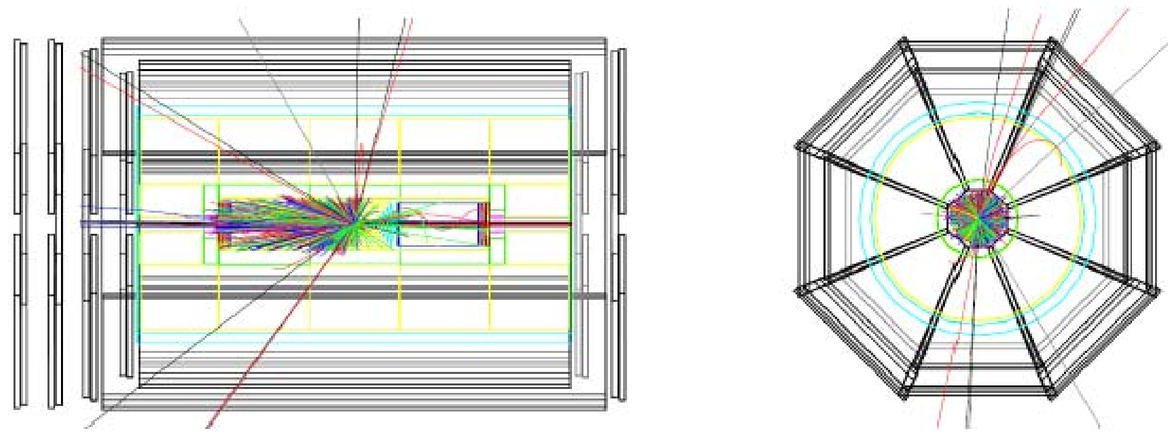
- Precise detector simulations are needed:
  - optimize full detector designs for physics performance on mission critical processes
  - optimize the designs of subsystems and subdetectors
  - compare proposed detector technologies with each other (in concert with test beam)
- The hardware selection aspect makes use of world wide efforts for the preparation of ILC and SLHC experiments

Simulation of Detector in Geant4

A. Kilic, F. Kocak and I. Tapan
Uludag University, Turkey

Adnan Kilic

Simulation

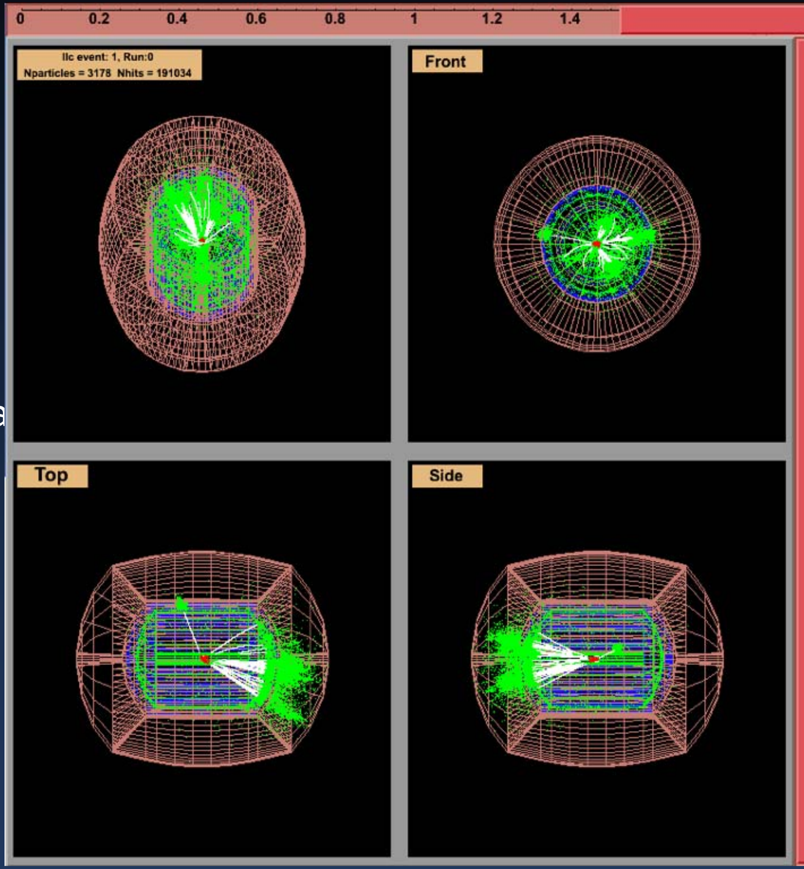


kaon- blue, kaon+ red, kaon0 black, kaon0S black, kaon0L black, kaon0 green,
e- blue,e+ red, pi+ red, pi- blue, mu+ red, mu- blue, nu_mu black, gamma green,neutron yell

First promising steps towards GEANT4 detector simulation for physics

Simulation Framework

- Several tools on the market
  ➔Use a homogeneous, powerful and widespread
- Frameworks which have come to our attention:
  - 4th concept - IlCRoot - ILC evolved from: AliRoot - Alice - LHC
    - Based on CERN software root with so-called Virtua Monte Carlo
  - 4 experiments using AliRoot based framework: Ali - Ilc - Fair - MPD -Root
  - Import of our contained model-detector geometry in the environments
  - Good contact to developers
- Dedicated manpower for software implementation needed



ep Higgs event in 4th detector

Summary

- Need to define beam pipe radii – feedback w/ accelerator and physics working groups (HF tagging needs)

- Need to agree benchmark physics analyses – negotiate different requirements on the detector

  - mass resolution needed

  - heavy flavor tagging needs

- Benchmark analyses need to be set up in simulation environment – need simulation experts

- We are trying to give our best estimation for first detector iteration - nothing is final yet, but should provide a reasonable start

- CDR detector design philosophy – 'conventional' technology + new options

Backup slides

Infrastructure

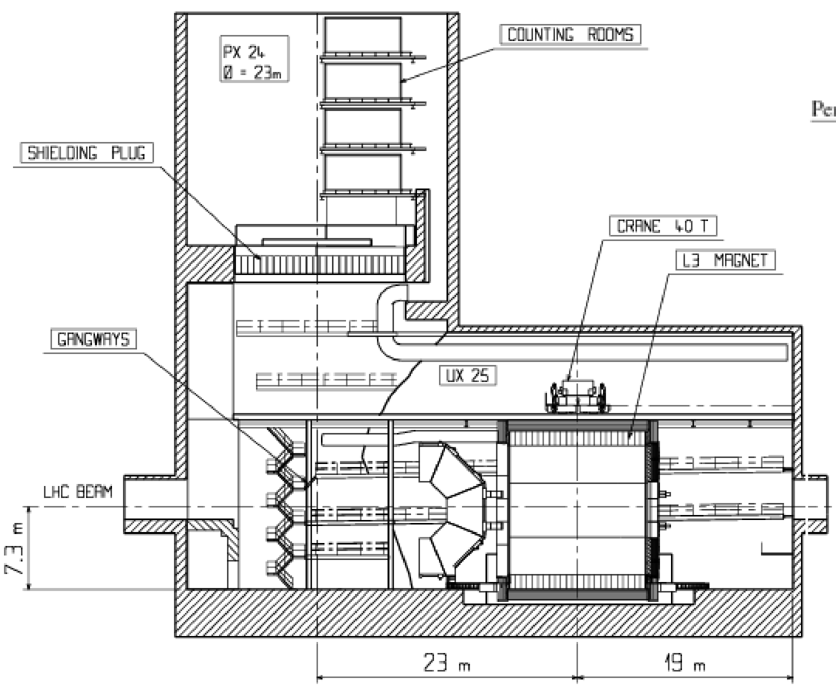
ALICE

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

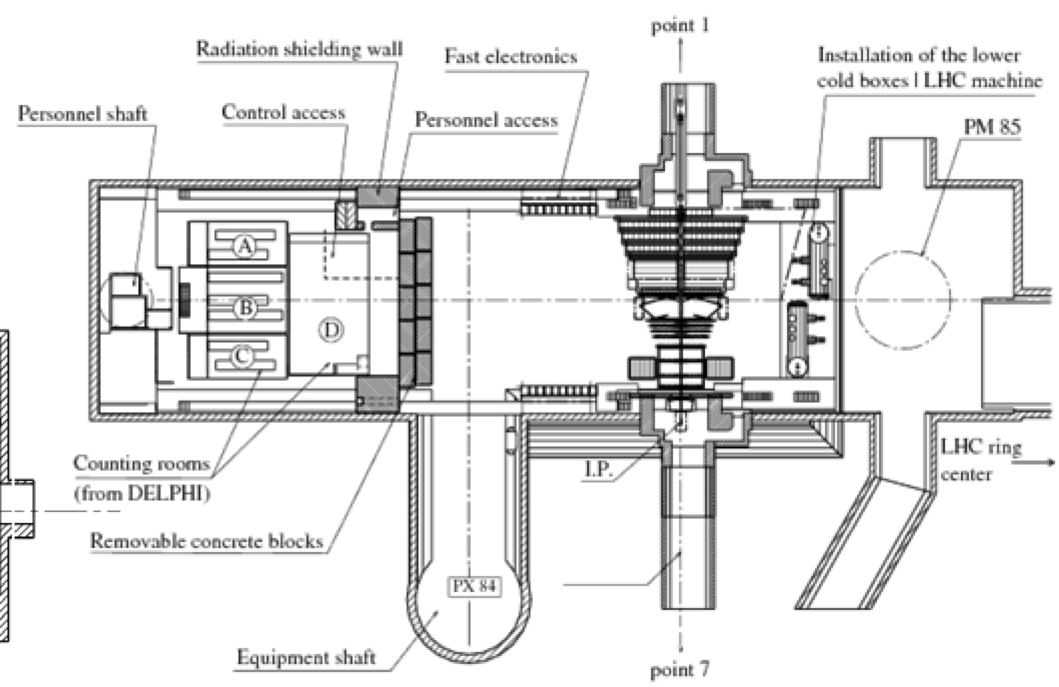
LHCb

- 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

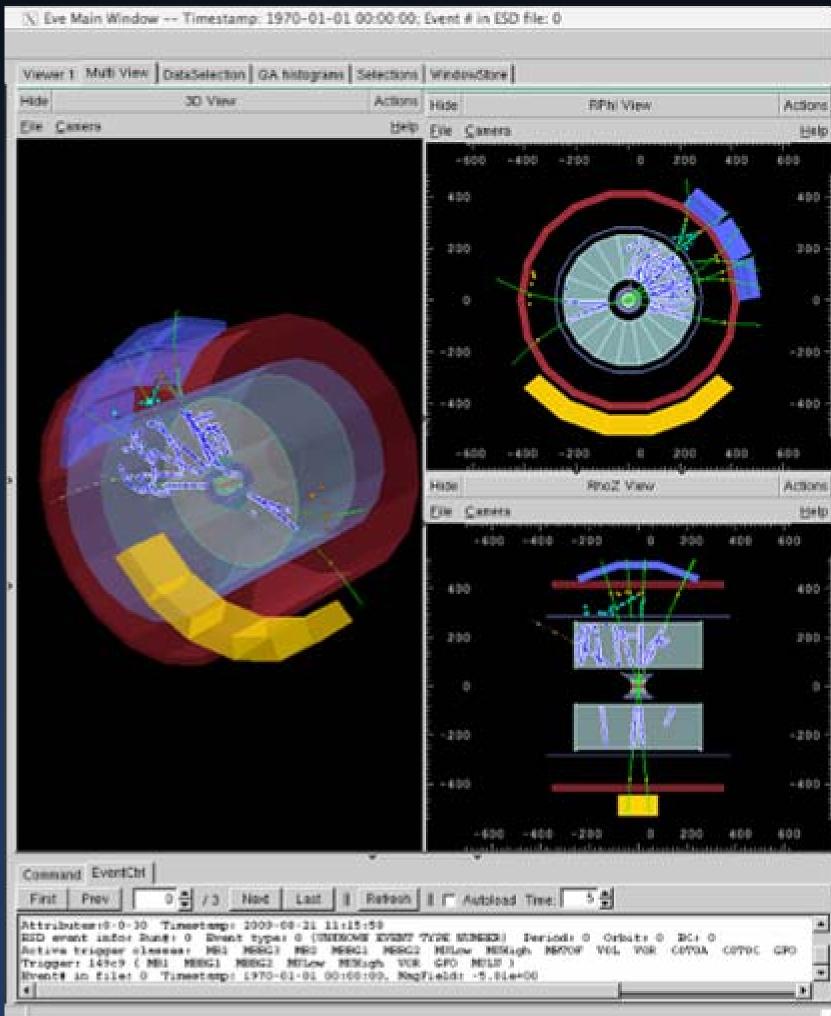
Point 2 (Alice)



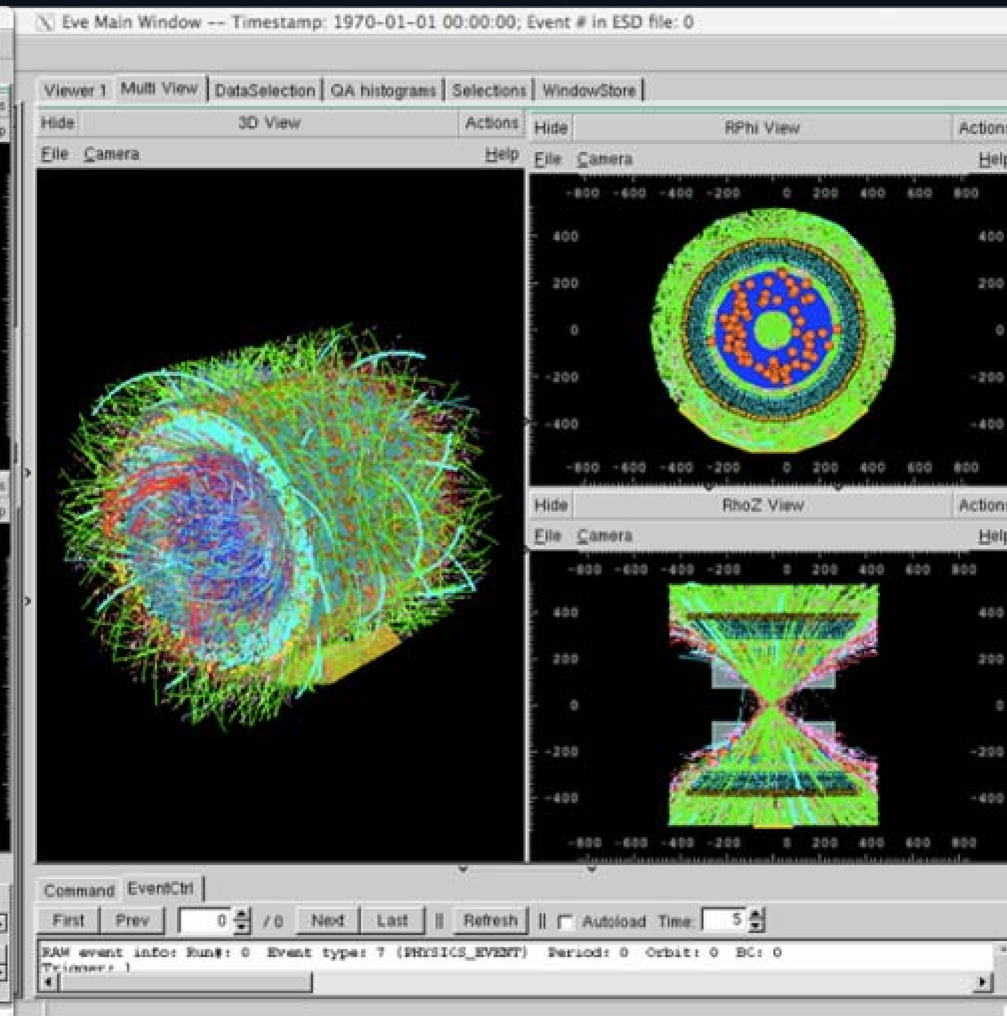
Point 8 (LHCb)



Simulation Environment (I)



P-p Alice



Pb-Pb Alice