LHeC Detector Working Group Kick-Off Summary

Alessandro Polini
Peter Kostka
Rainer Wallny

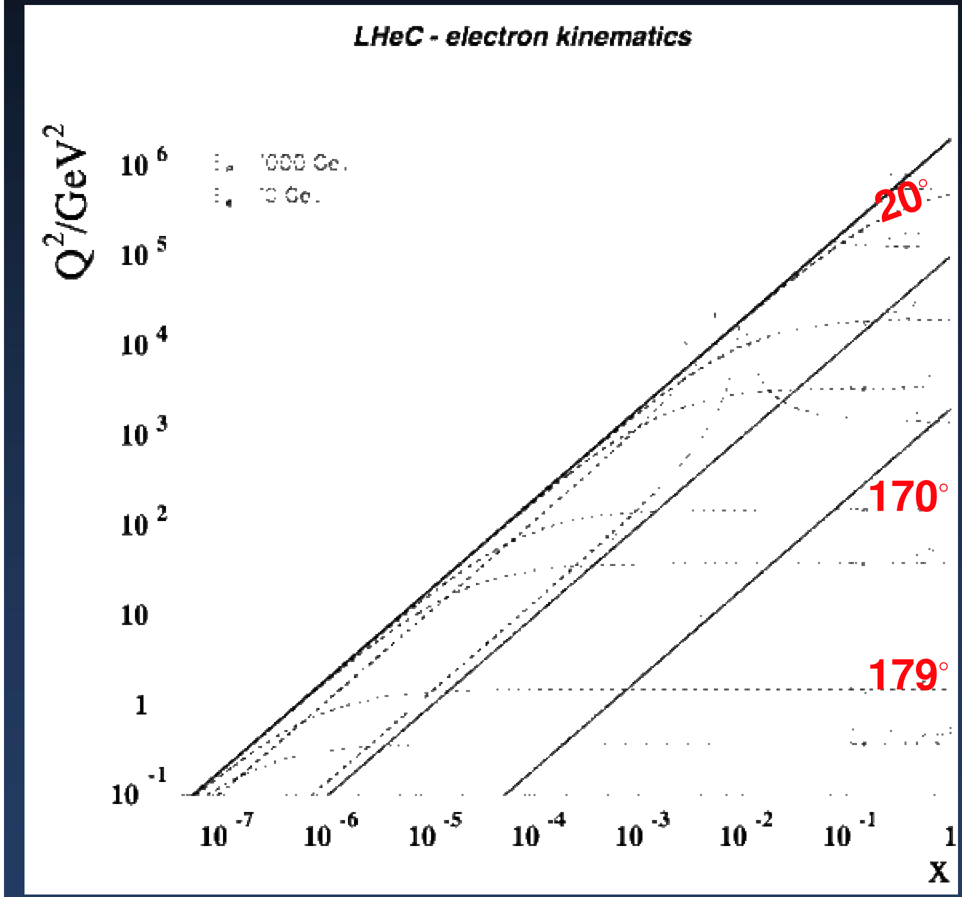
First LHeC Workshop, Divonne

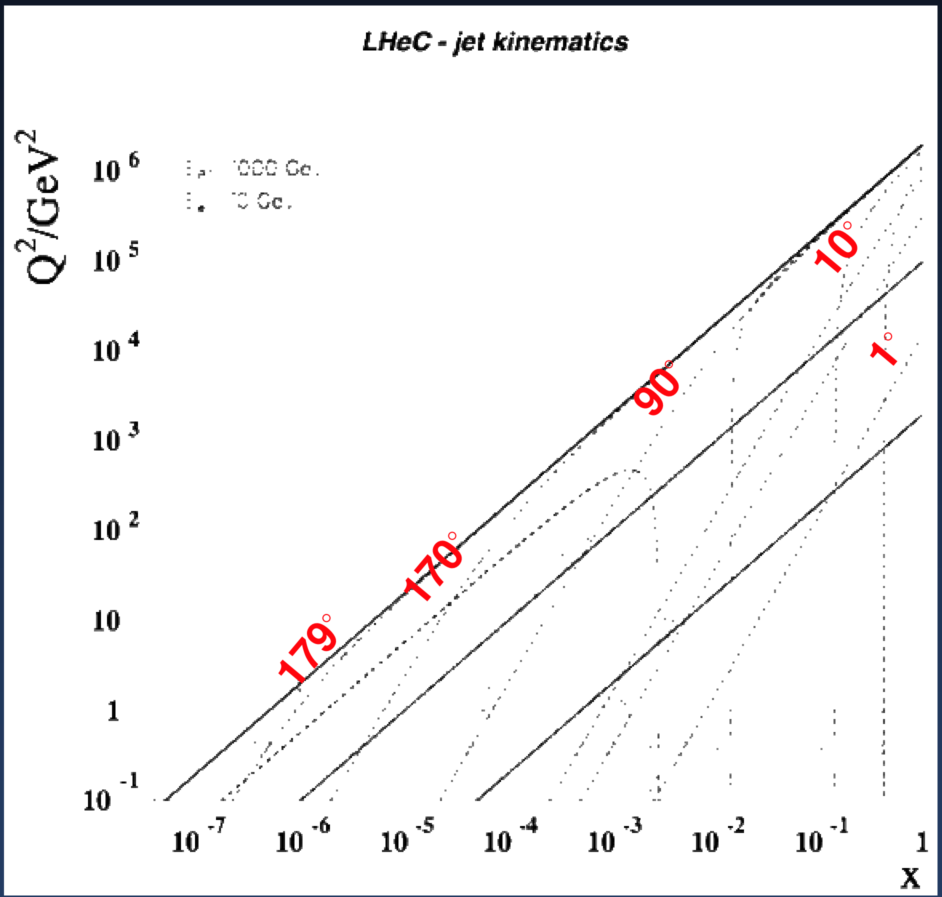
Boundary Conditions

- Ideally, high luminosity, full (4π) detector acceptance and low background conditions

- More realistic:
  - High luminosity, as required for the physics program
  - Good detector acceptance in forward and rear direction
  - Acceptable background conditions

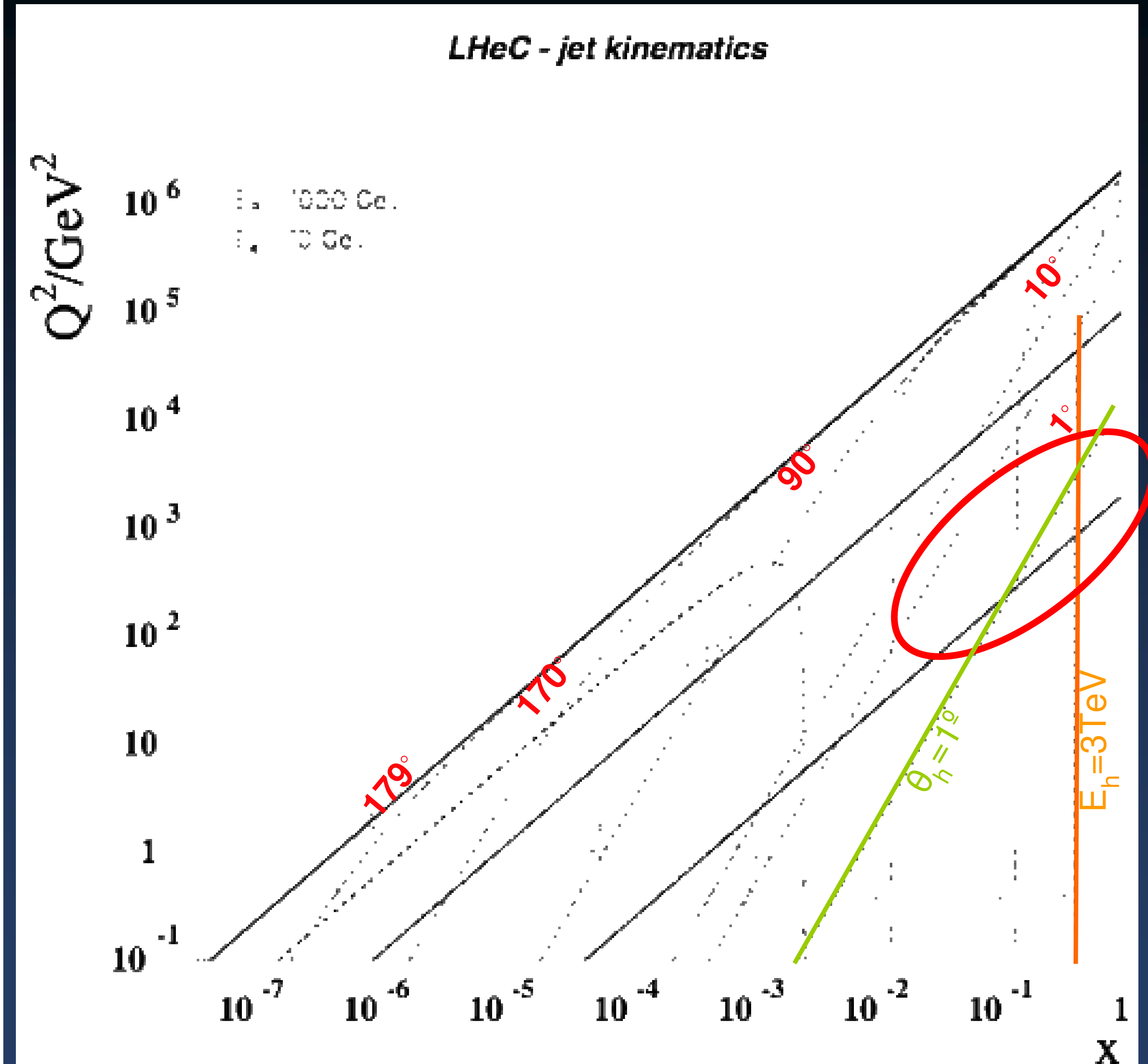
LHeC Kinematics





Thanks U. Klein

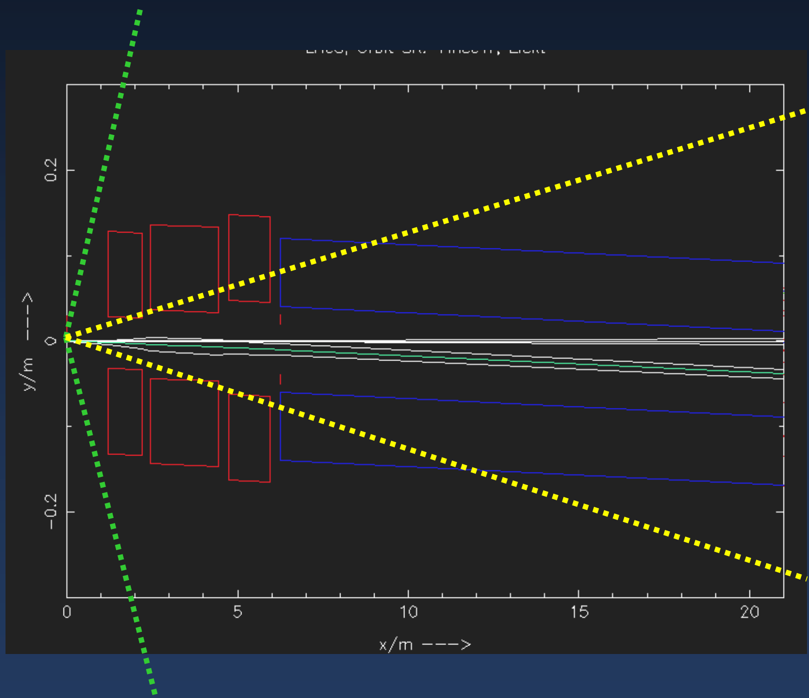
The Detector Challenge

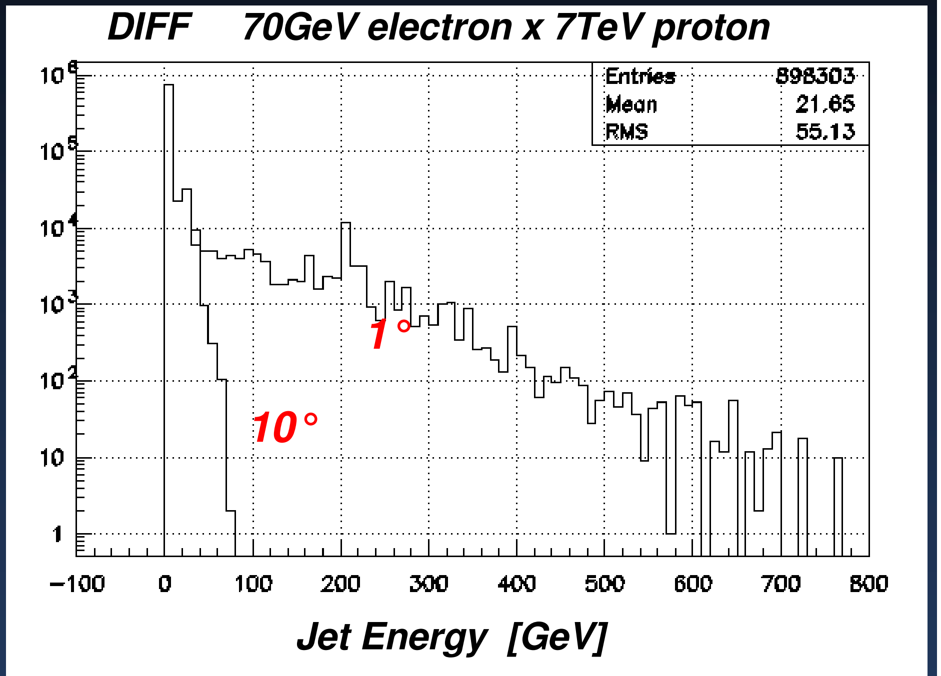


TeV jets at very fwd angles to be resolved

Detector Acceptance

From IR WG:
two options discussed at the moment:
10°   /   1°





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

compact magnet design required:

10° = 21 cm outer radius of Q1E quadrupole

1° = requires an alternative lattice , optics and luminosity

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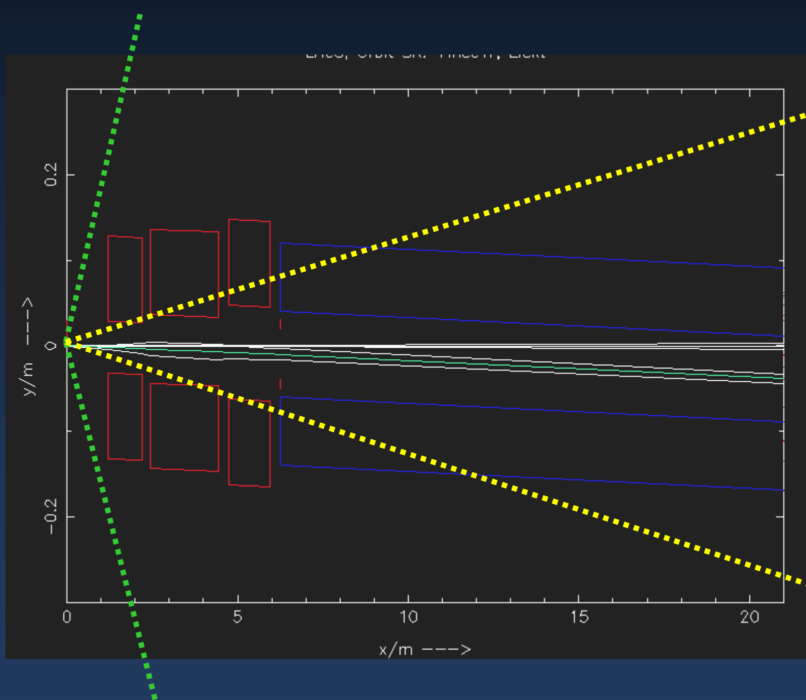

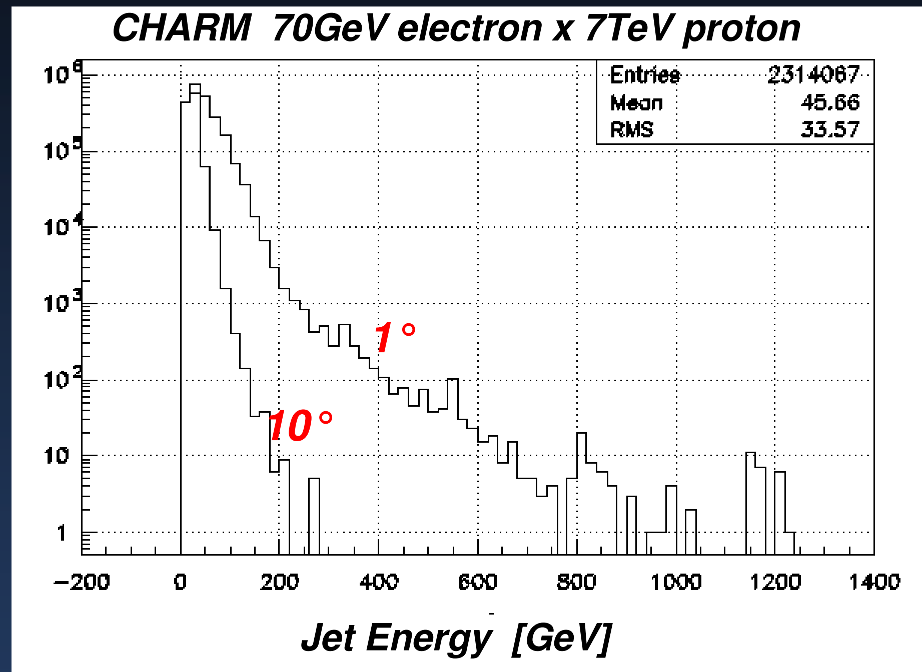

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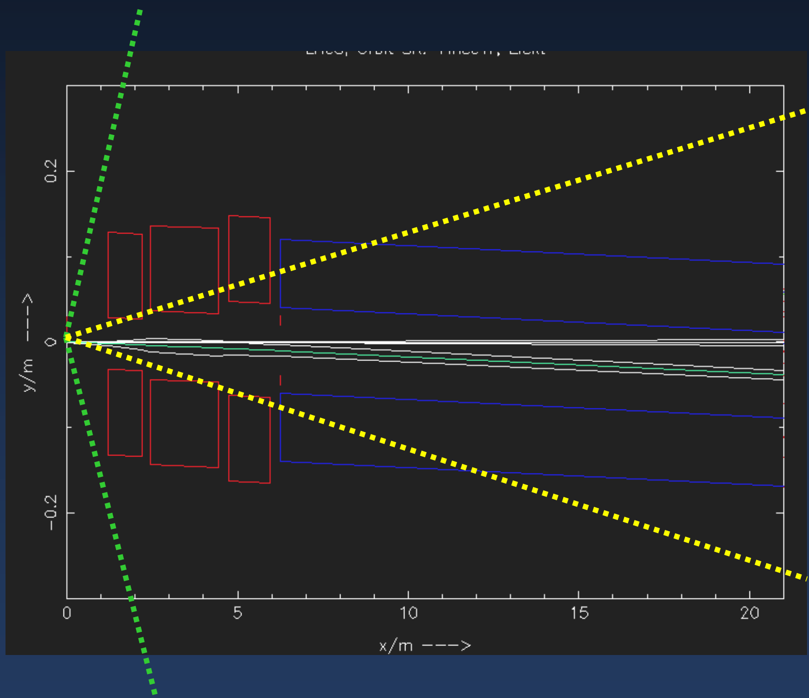

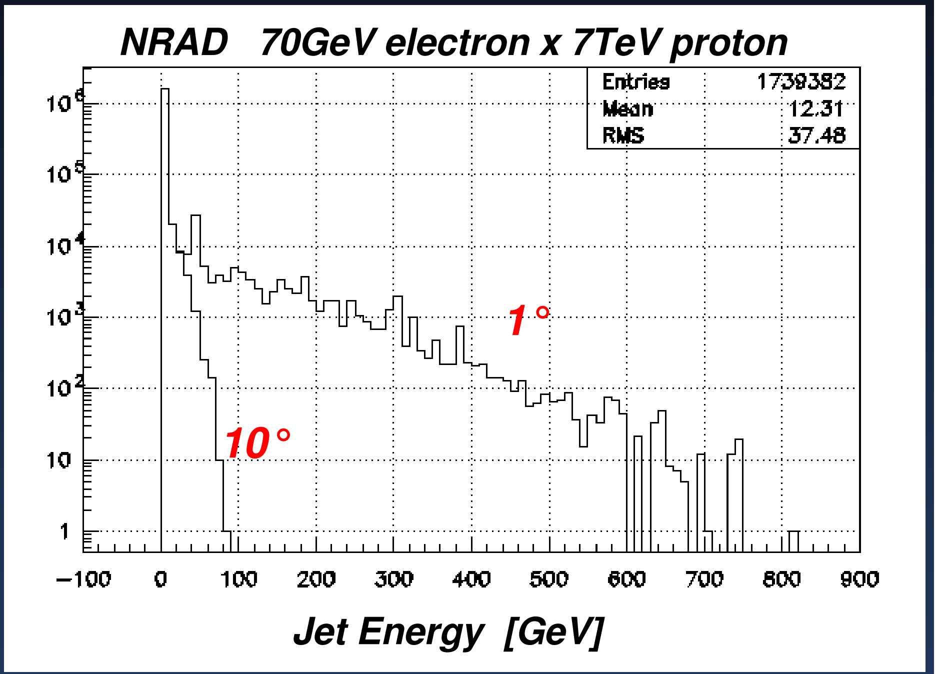

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How should the LHeC Detector look like ?

- There are TeV leptons and jets to measure -
final state objects as for LHC
LHC optimized on mass resolution $H \to ZZ \to 4$ leptons
- 50-100 GeV/c pt tracks / $\Delta p/p_{LHC} \approx 0.2 .. 0.4$ p (TeV)

- → expect size of LHeC detector to be comparable to LHC detectors (forward region)

- Tracking/Solenoid/Size:
  - $\Delta p/p \approx p \cdot \sigma_{hit} / (BL^2 \cdot \sqrt{N})$ B - magn.field, L - track length, σ_{hit} - hit resolution, N - number of trk-points

- EndCAP-Cal. em/had - particle flow concept (CALICE - ILC, see F.Simon)
Option: Barrel Calorimeter - LAr (H1, ATLAS ...)

Luminosity vs. Acceptance

- Luminosity and acceptance very much depend on physics program

- From IR/ACC WGs we have heard:
  - high luminosity. Can be done with reduced acceptance
  - Low Q^2 physics (high parton densities, diffraction, …) requires good forward and rear coverage 1 – 179°. Can be done with reduced luminosity (no low beta magnets)

- $L = x \cdot 10^{33}$ cm^{-2} s^{-1}, $10^{\circ} < \theta < 170^{\circ}$
  - go for that - lets work out that in detail - in mind:
    - optimised low beta quadrupoles
    - experiment magnets in forwd/backwd region supporting the machine optics requirement (may be)
    - instrumented low beta magnets (T.Greenshaw)

Agenda

DETECTOR SESSION Tuesday morning		
9:00h	PK,AP,RW	Introduction
9:15h	Norbert Wermes	Silicon Pixel Detectors for Tracking
10:00h	Michael Moll	RD50 and silicon hardness
10:30h		-coffee-
11:00h	Wesley Smith	Present and Future Collider Triggers
11:30h	Alex Cerri	Trigger and online displaced vertexing (CDF SVT)
12:00h	Andris Skuja	CMS Hadron Calorimeter
12:30h		-lunch-
COMMON SESSION DET/ACC/IR Tuesday afternoon		
14:00h	Tim Greenshaw	Instrumented Magnets
14:30h	Herman ten Kate	Magnet options for LHeC detector
DETECTOR SESSION Tuesday afternoon		
17:00h	Els Koffeman	Gossip gaseous pixel R&D
17:30h	Frank Simon	Calice calorimeters for the ILC
18:00h		Open Discussion

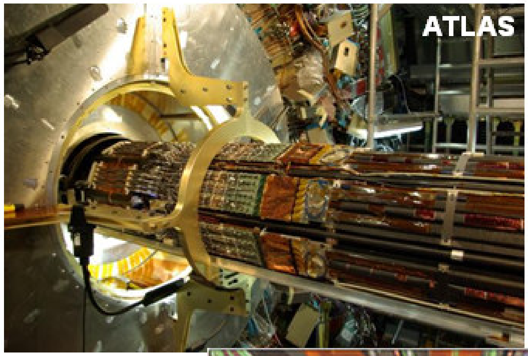
Silicon Pixel Detector – Innermost Layer

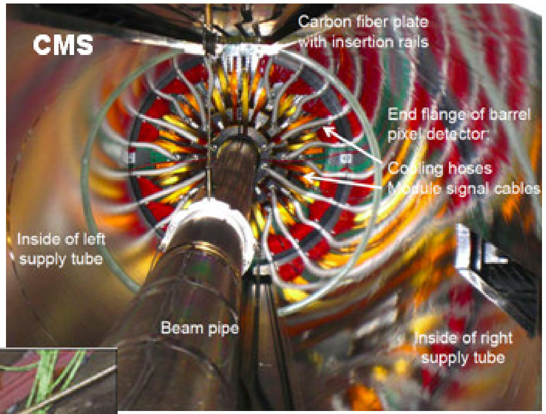
Silicon Pixel Detectors for Tracking

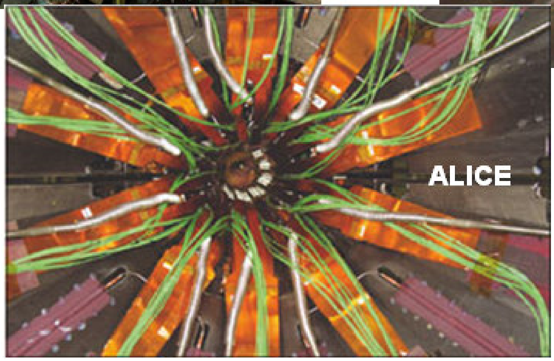
N. Wermes
Bonn University

LHeC Workshop, September 2008

The "PAST": large area pixel detectors at the LHC







all based on

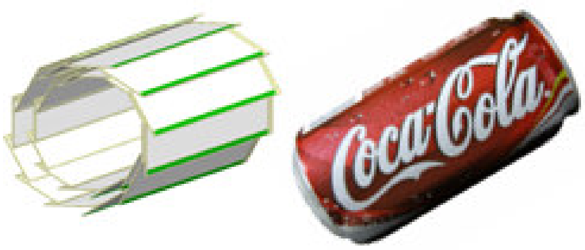
"Hybrid Pixel Detectors"

Silicon Pixel Detector (cont'd)

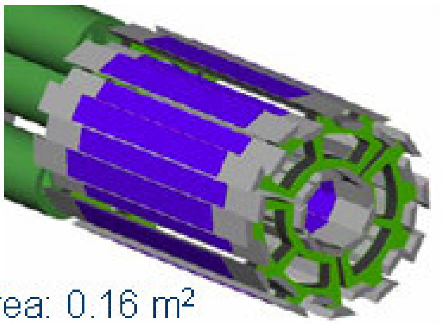
(Semi-) Monolithic Pixels Overview

- 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 m²



- 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 m²

- 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

Radiation Hardness –RD50

1st LHeC Workshop, Divonne les Bains, France, September 1-3, 2008

Recent RD50 Developments on Radiation Tolerant Silicon Sensors

Michael Moll (CERN-PH-DT)

OUTLINE

- Motivation, RD50 work program
- Radiation Damage in Silicon Sensors (1 slide)
- Silicon Materials (MCZ, EPI, FZ) (2 slides)
- Recent results and future plans on
  - Pad detectors (diode structures)
  - Strip detectors (segmented structures)
  - 3D detectors
- Summary

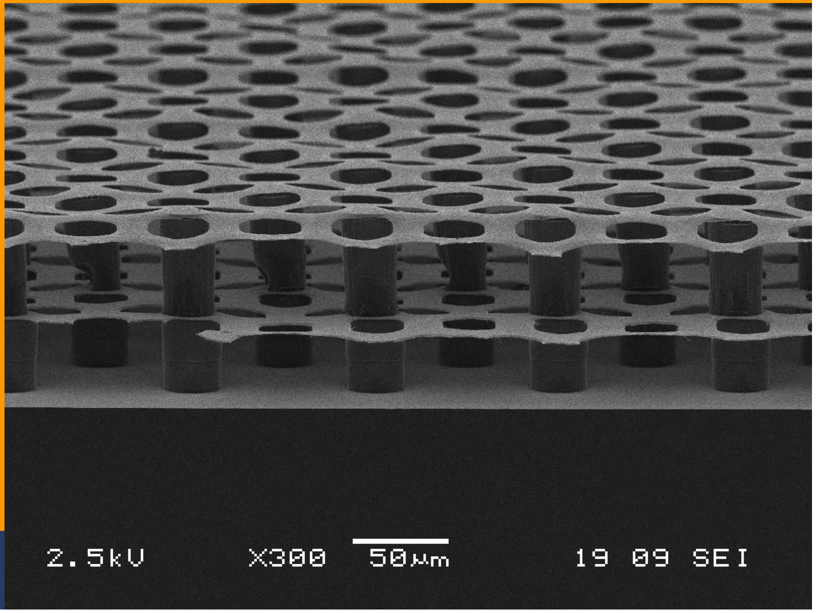
Precision Tracking: GOSSIP Gas on Slimmed Silicon Pixels E.Koffemann - NIKHEF et.al.

- Radiation hard - standard CMOS (90nm process)
- Large volume detector affordable
- Time measurement - digital TPC
- Radiator : transition radiation tracker - particle ID
- Spark protection
  - Highly resistive layer (amorphous silicon and silicon nitride)
  - Twingrid
- Ageing
  - 60Co irradiation encouraging
  - Low fields compared to wire chambers
  - Process not fully understood
- Diffusion and drift velocity
  - Limits position measurement ~30μm

Gas in a tracking detector

- Amplification of primary electrons in gas
  - No bias current
  - Low capacitance (10 fF) per pixel
- No radiation damage of sensor
  - Operation at room (or any other) temperature
- low sensitivity for neutron and X-ray background
- δ-rays can be recognized
- High ion & electron mobility: fast signals, high count rates are possible

- Discharges/sparks: readout system should be spark proof
- Ageing: must be solved and must be understood / under control
- Diffusion: limits max. drift length or position resolution



Gas in a tracking detector

- Amplification of primary electrons in gas
  - No bias current
  - Low capacitance (10 fF) per pixel
- No radiation damage of sensor
  - Operation at room (or any other) temperature
- low sensitivity for neutron and X-ray background
- δ-rays can be recognized
- High ion & electron mobility: fast signals, high count rates are possible

This may result in a design with:

1. Less power consumption
2. Less cooling
3. Reduced complexity (wafer processing instead of bumping)
4. Less material

Gas in a tracking detector

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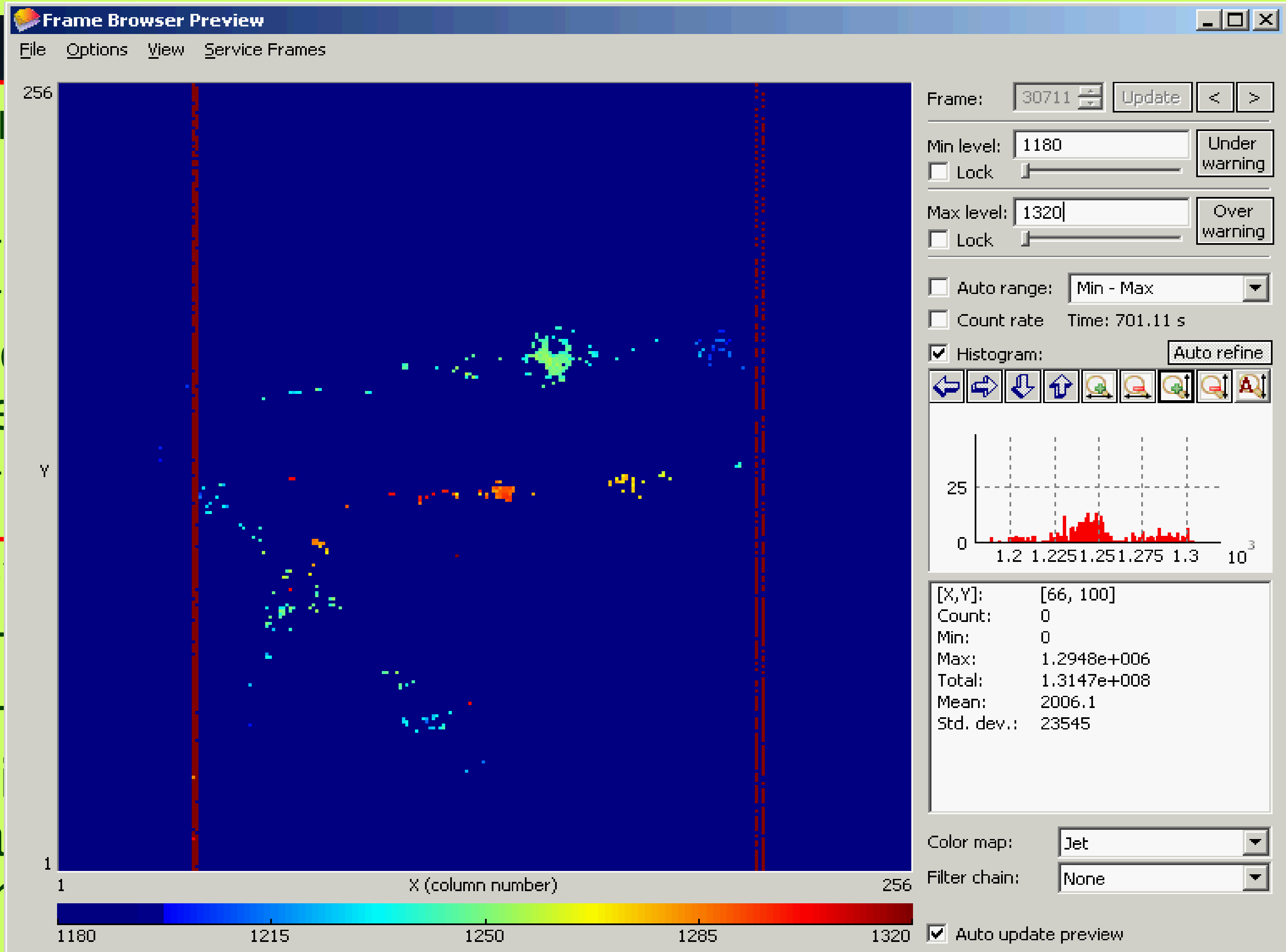
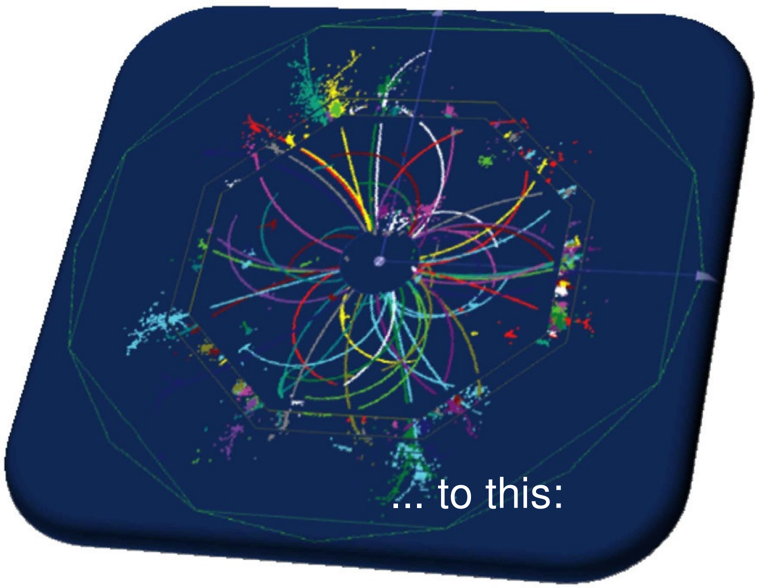


CALICE: A new Type of Calorimetry

F.Simon - MPI Munich



Motivation: unprecedented jet energy resolution
for precision physics

Particle Flow

- 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
- Requires highly granular calorimeters to allow geometrical separation of particles

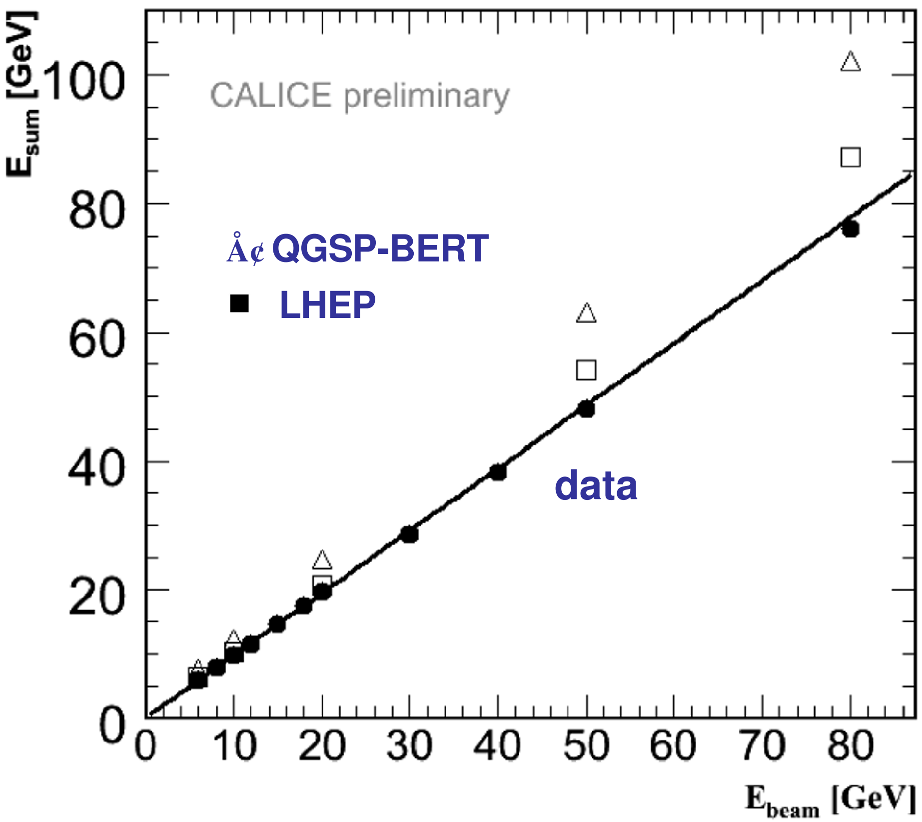
CALICE: Technology

- All calorimeters designed for Particle Flow
  - high granularity: unprecedented longitudinal and transverse segmentation

- Compact devices to accommodate large channel count
  - integrated electronics on detector where possible:
    - ASICs mounted on active material
    - photon sensors directly on scintillator tiles

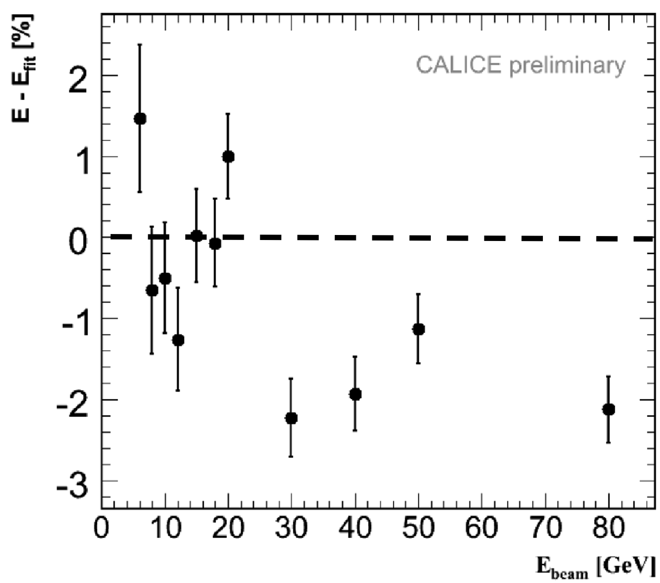
- Investigation of different technologies:
  - silicon vs scintillators
  - scintillators vs gaseous detectors
  - analog vs digital

AHCAL Performance: Linearity



- Surprisingly linear response to hadrons
- detector systematics to be quantified

residuals to linear fit
from 6 - 20 GeV

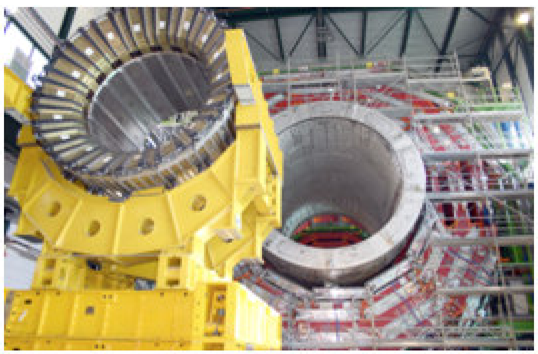


Experience from CMS

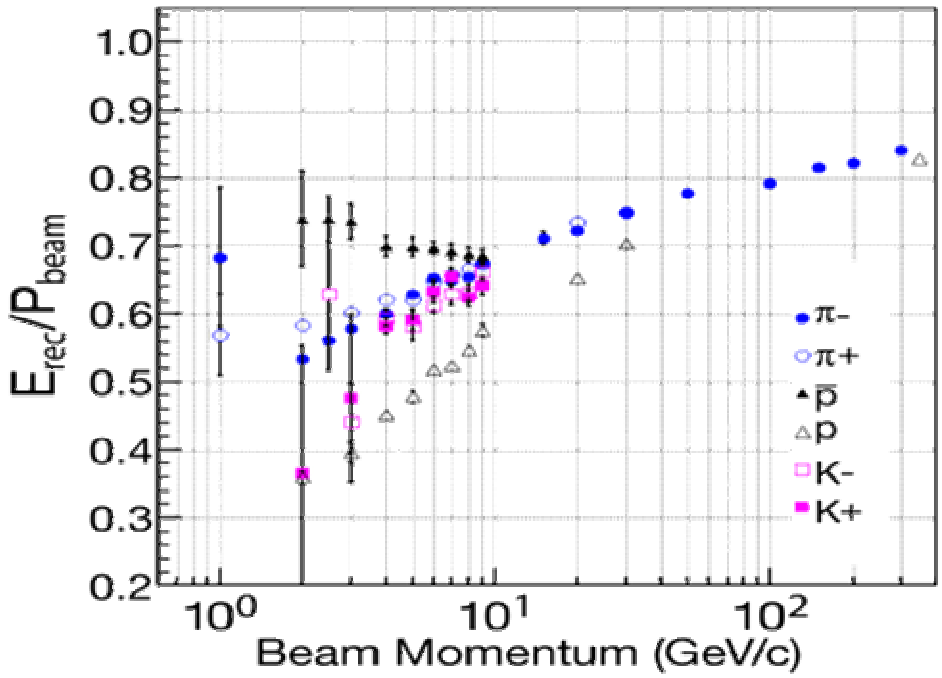
An Overview of the CMS Hadron Calorimeter

Andris Skuja
(University of Maryland)
on behalf of CMS HCAL Collaboration

LeHC '08,
Sept 1-3, Divonne, France



Combined Calorimeter (EB+HB+HO) Response



HB: 3x3 towers
EB: 7x7 crystals
HO. 3x2 towers

Energy Scale:
EB: 50 GeV electron
HB: 50 GeV electron

At 5 GeV:
pion resp. ~62 %
proton resp. ~47%
antiproton resp ~70%

Trigger & DAQ Summary:
LHC Case

Level 1 Trigger

- Select 100 kHz interactions from 1 GHz (10 GHz at SLHC)
- Processing is synchronous & pipelined
- Decision latency is 3 μs (x~2 at SLHC)
- Algorithms run on local, coarse data
  - Cal & Muon at LHC (& tracking at SLHC)
  - Use of ASICs & FPGAs (mostly FPGAs at SLHC)

Higher Level Triggers

- Depending on experiment, done in one or two steps
- If two steps, first is hardware region of interest
- Then run software/algorithms as close to offline as possible on dedicated farm of PCs

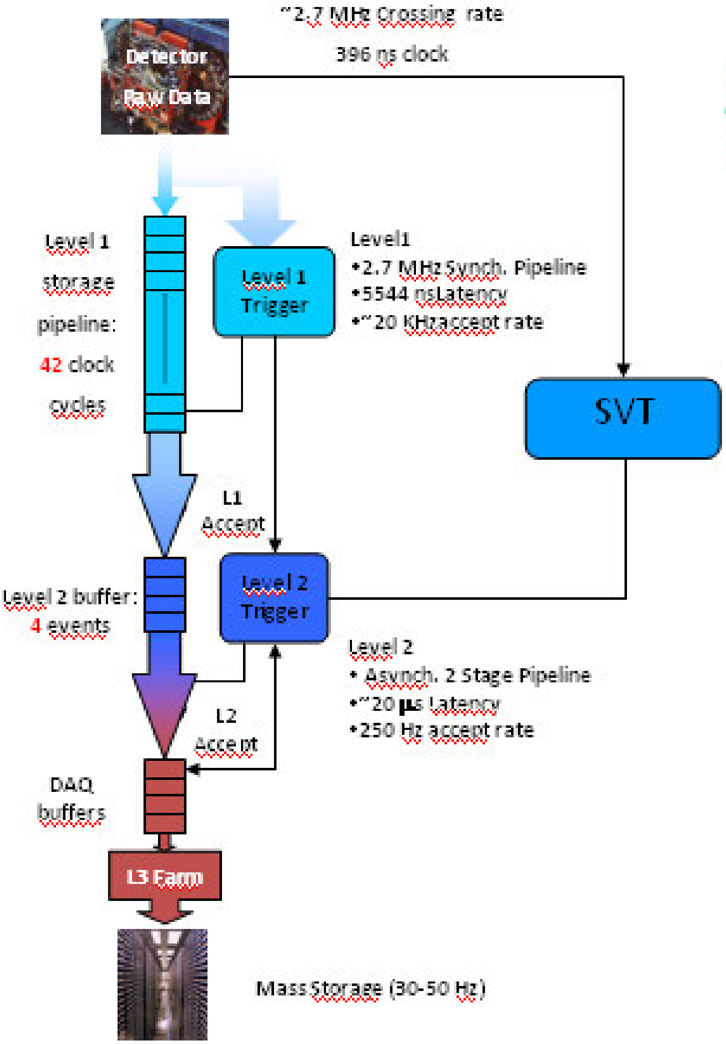
Trigger

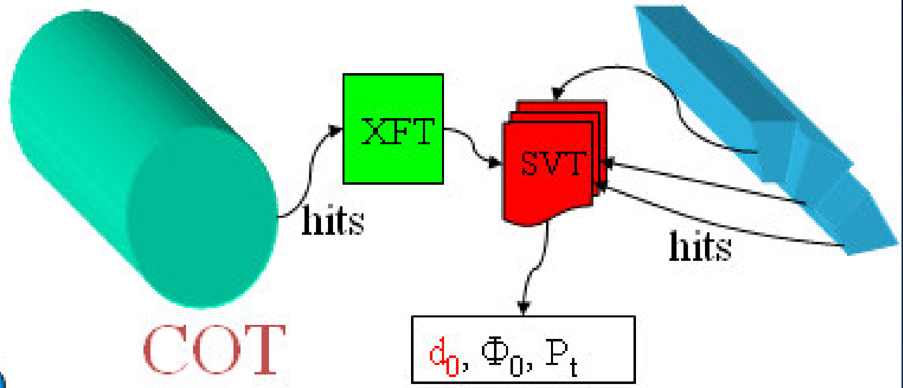
- The b-tagging in dense jet environment is a very demanding task
  - on higher level trigger or on level 1?
  - level 1 - implications for R/O electronic, data transfer, decision logic near to the tracker hardware
- Trigger and Displaced Vertexing the CDF Silicon Vertex Tracker - see talk by Alessandro Cerri (CERN)
  - SVT: hardware for high resolution tracking at early trigger stages
  - Use cases:
    - Need for fast pattern recognition on large amounts of data (of different detectors):
      - Fine detector segmentation
      - High-occupancy
    - Heavy flavor physics (b, c)
    - New physics coupled to 3rd family (e.g. H->bb, ττ etc.)
  - How to measure tracks in ~20 μs/event, when software takes typically ~1s (Associative Memory - predefined roads - BINGO)

Displaced Vertexing (cont’d)

SVT within the CDF DAQ

The CDF Trigger





Goals:

•Offline-like track parameters (IP in particular)

•In Real time, as early as possible within DAQ constraints

Keys to sufficient speed and accuracy:

•Combine L1 COT “tracks” (Pt,Φ) with Silicon detector information

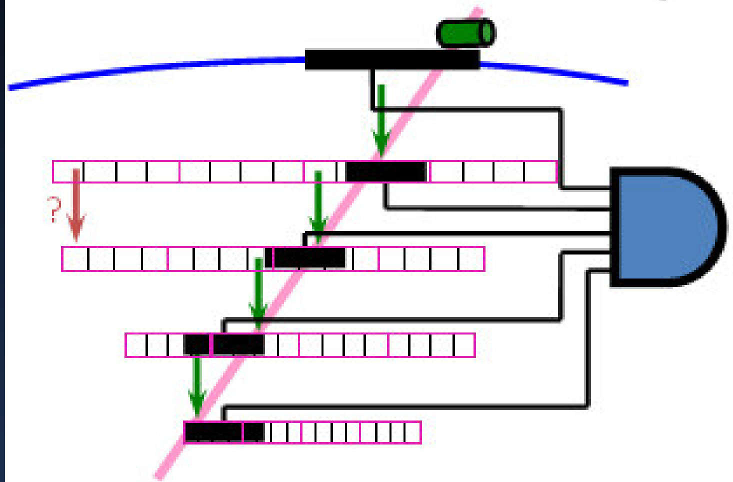
•Drop stereo information

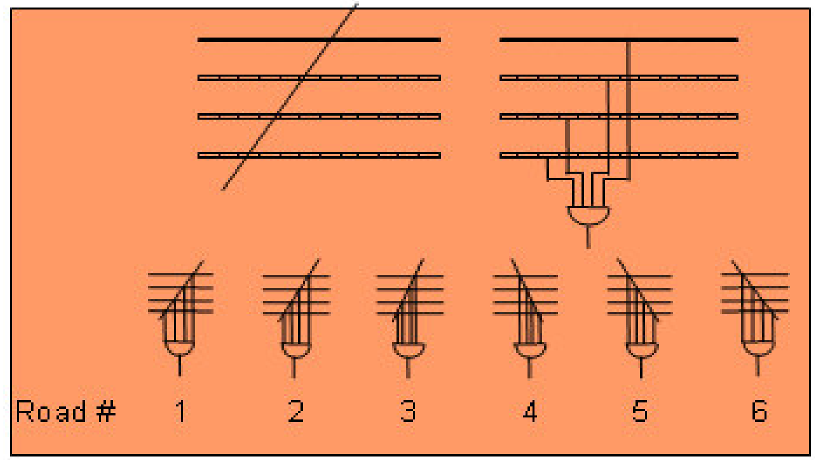
•Parallelize tasks in hardware

Alessandro Cerri

Displaced Vertexing

Streamlined pattern recognition



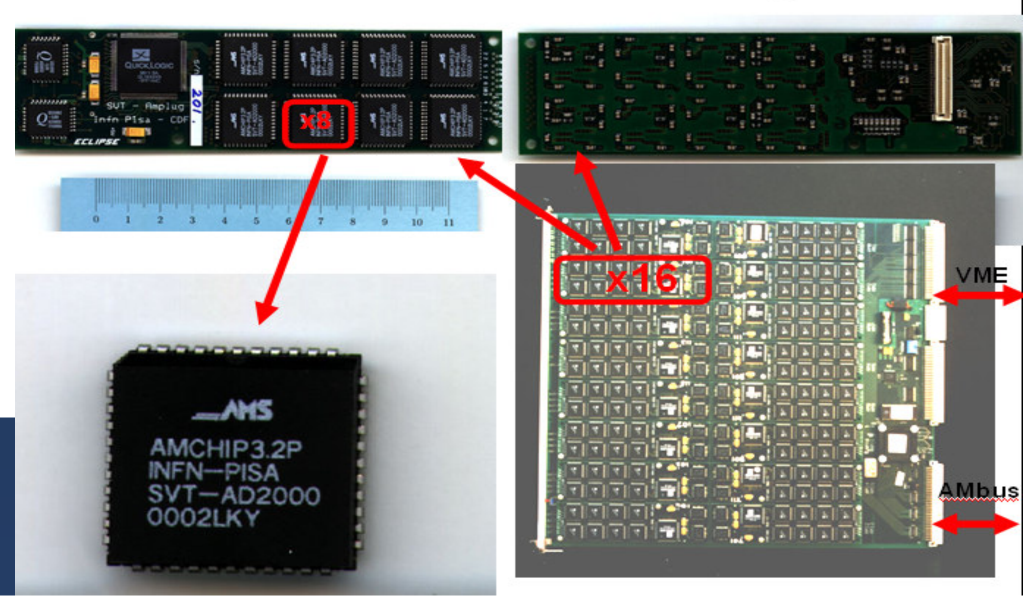


The way we find tracks is a cross between

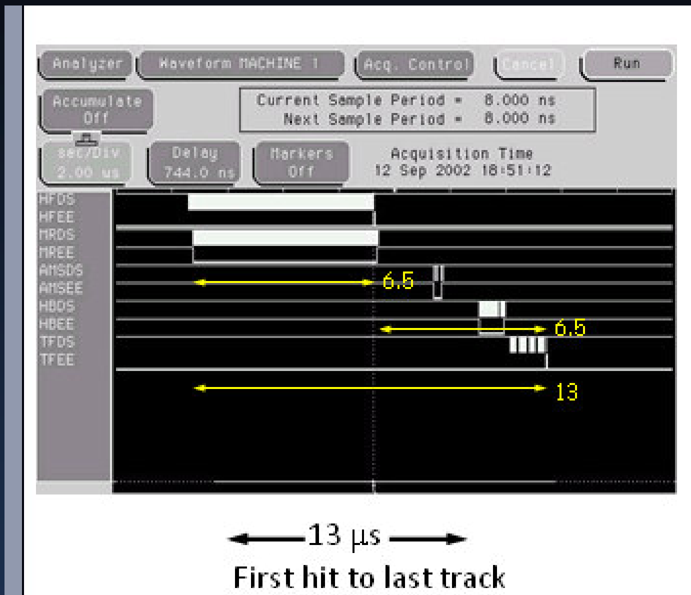
- searching predefined roads
- playing BINGO

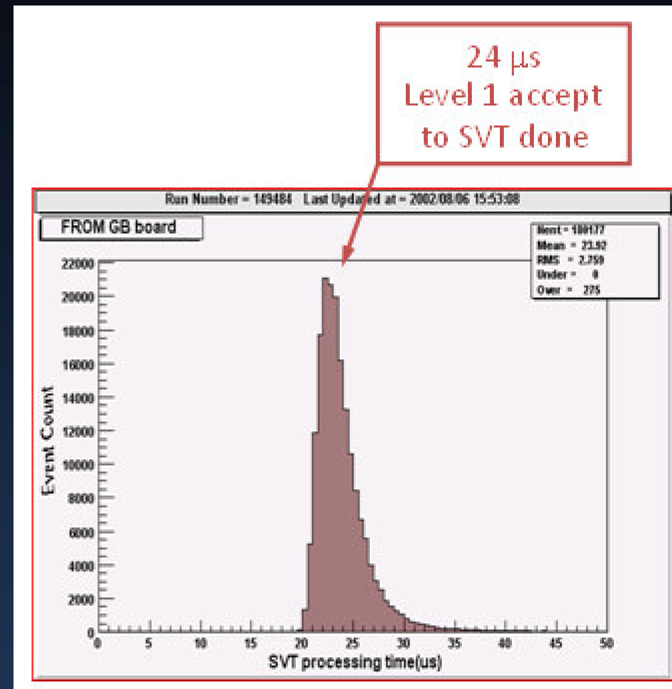
Time ~ $A*N_{hits} + B*N_{matchedroads}$

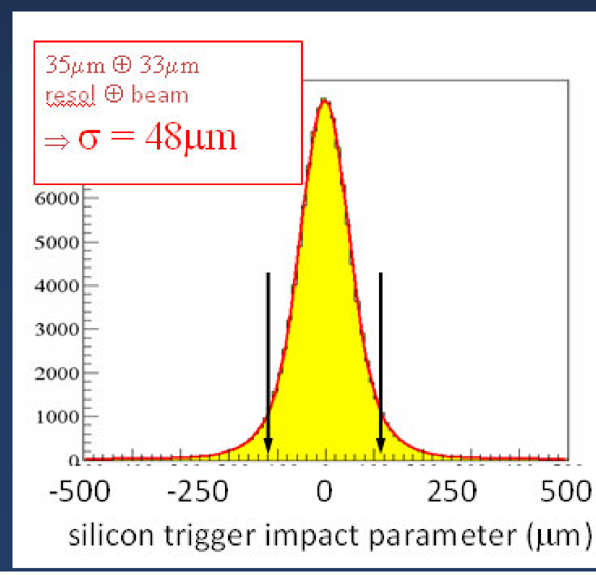
Associative memories: Our Bingo Cards

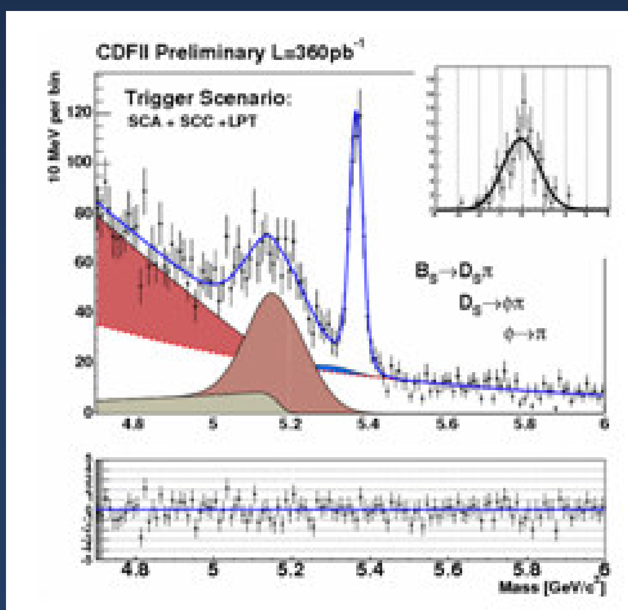


Displaced Vertexing (cont'd)







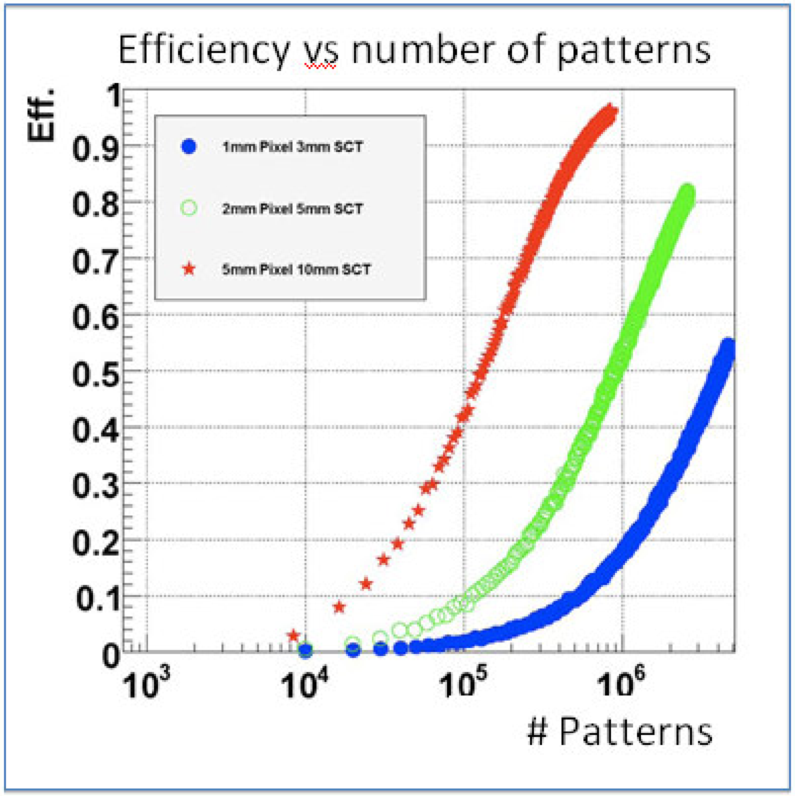


Displaced Vertexing (cont'd)

- SVT provides a very powerful real-time general-purpose "funnel"
  - Can handle mixed detectors
  - Pattern recognition core can be used in an hierarchical fashion to derive objects of increased complexity
- Critical design parameters:
  - Detector:
    - Geometry
    - Segmentation
    - Readout characteristics
  - Environment:
    - Occupancy
    - Physics case

Architecture scalable to LHeC

An example from the ATLAS /FTK proposals:

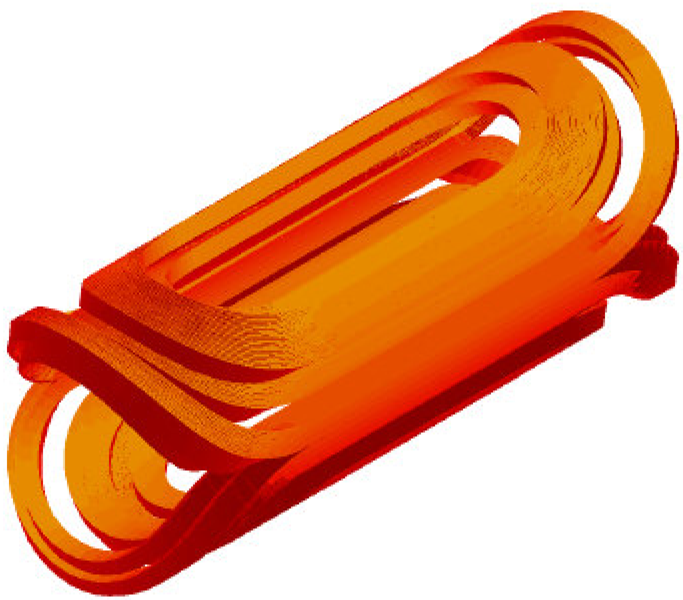


Instrumented Magnets

Superconducting magcal – take one

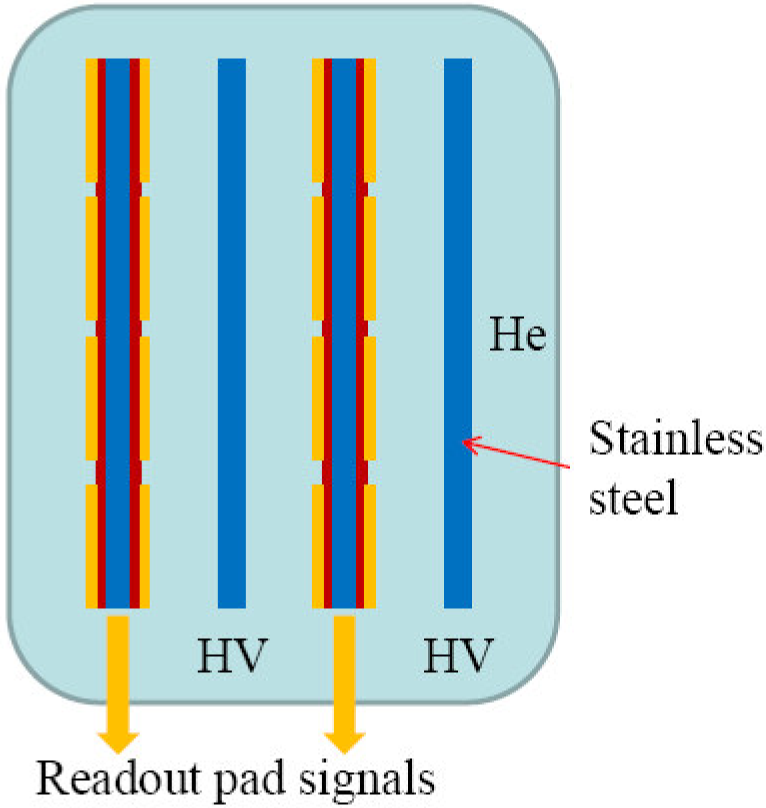
Tim Greenshaw

- 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:



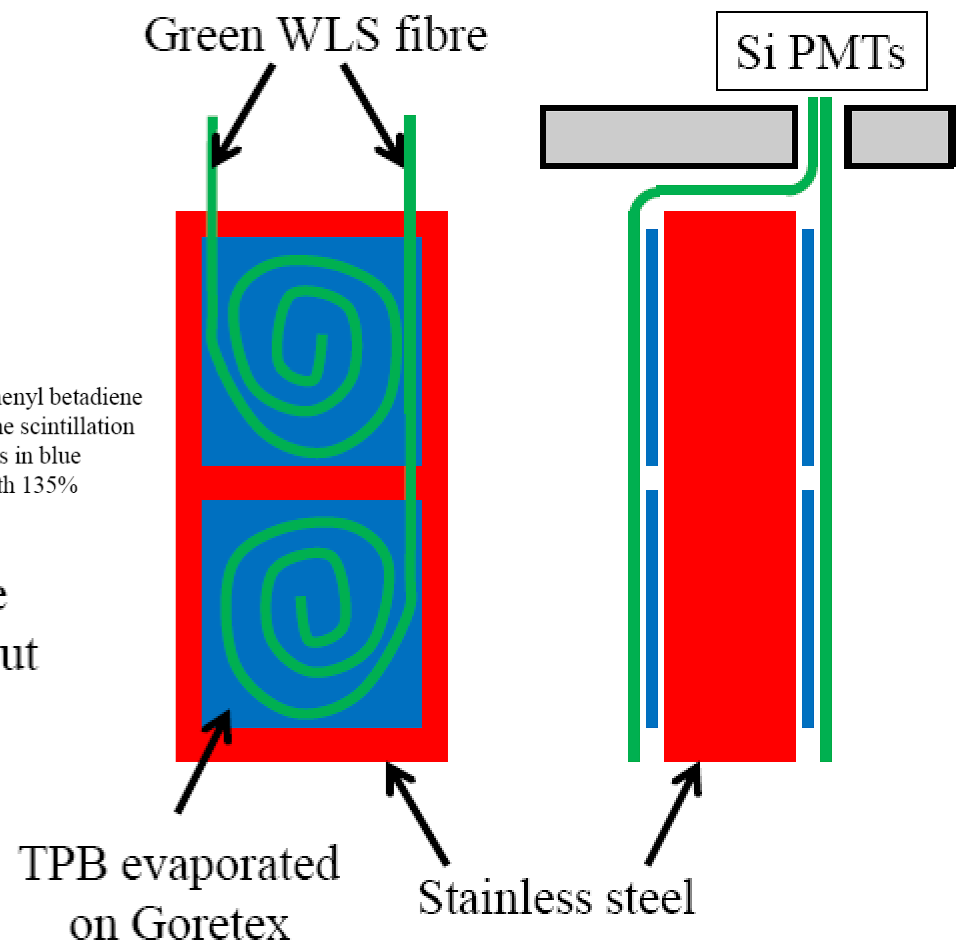
Instrumented Magnets (cont'd)

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.

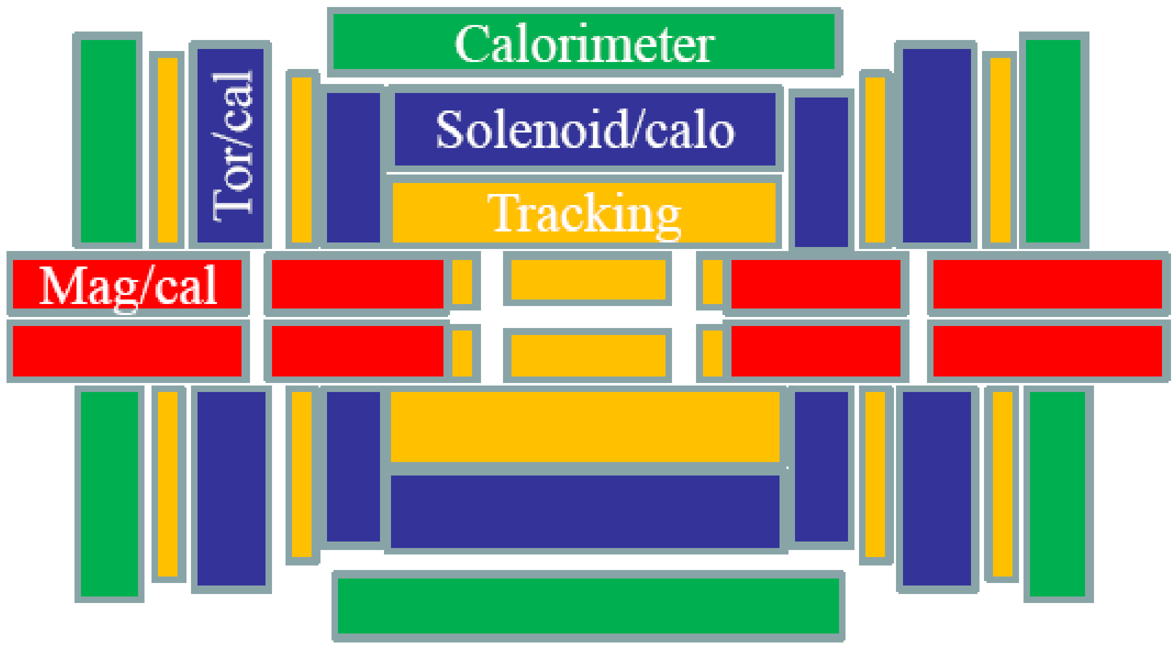


Instrumented Magnets (cont'd)

SC magcal – possible uses

Tim Greenshaw

- If it all works:
- Use magcal for machine magnets closest to IP?
- Also use for detector magnet(s) to minimise amount of dead material in front of calorimeter?
- Solenoid for central region plus toroids for forward region?



Open Discussion

Detector (1st draft):

- Barrel Solenoid Magnet:
- Barrel Liquid Argon Calorimeter
- Central-Forward-Backward TRT Gossip “particle ID” & tracking
- Central Forward-Backward Tracker
- Innermost layer of high Res Pixel (Monolithic CMOS)
- Forward Backward CALICE Type Calorimeters
- Instrumented low beta magnets

IR and Acc. Machine:

- Luminosity: O (10^{33}) cm^{-2} s^{-1}
- Acceptance: 1^o or 10^o forward/rear aperture
- Optics (quadrupole-dipole strong focusing)
- Synchrotron Radiation background
- Bypass proton beam