Use of fine grained GRPC as π & μ detectors for heavy ion target exp.

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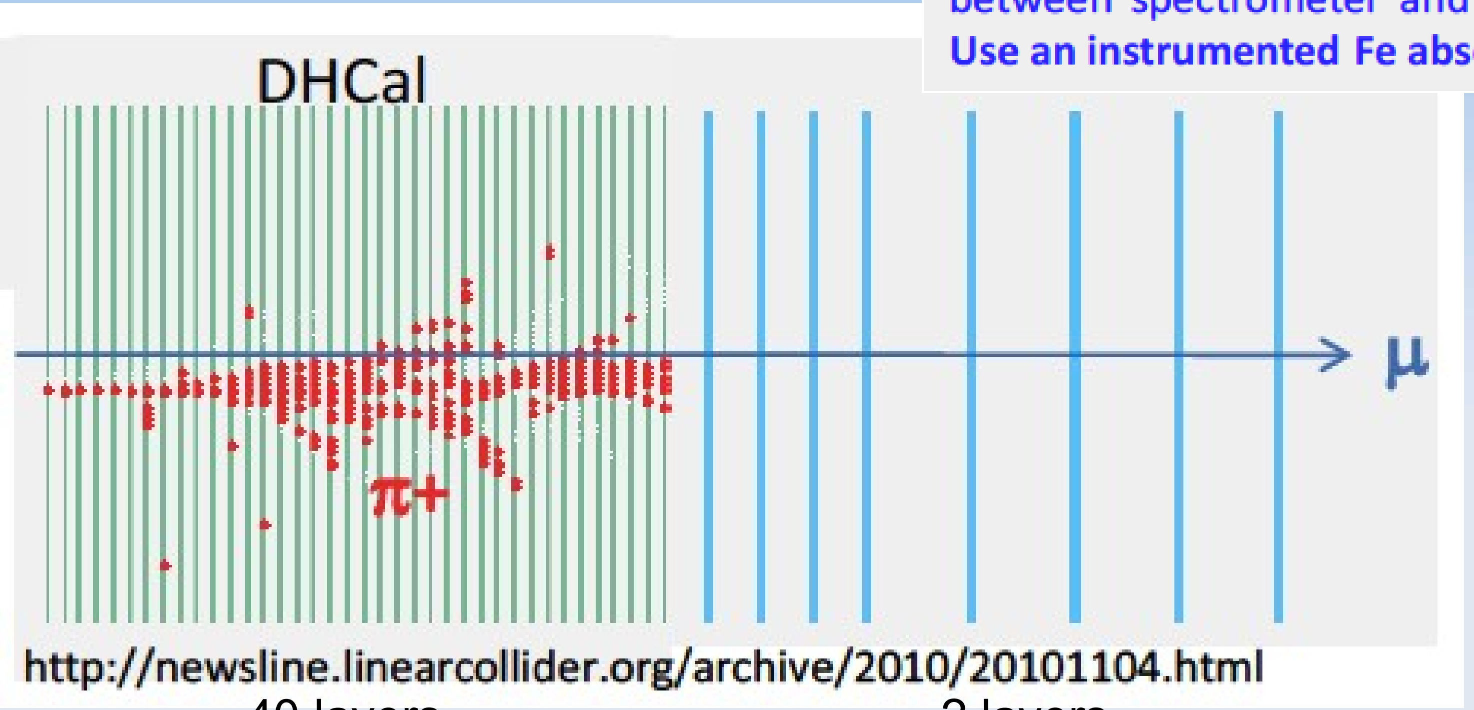
Fixed target for heavy ions at cern
IPNO Workshop
07/07/2011

Questions

Need to match muon track position between spectrometer and trigger : Use an instrumented Fe absorber



40 layers
1 m of Iron

? layers
? m of Iron

- Use of Gas detectors
  - fine for μ, OK for SHDCAL (rates ?)
- Optimal transverse granularity in μ tracker
- Optimal longitudinal sampling in μ tracker
- Triggering

CALICE GRPC SDHCAL

Highly Granular GRPC Semi-Digital HCAL

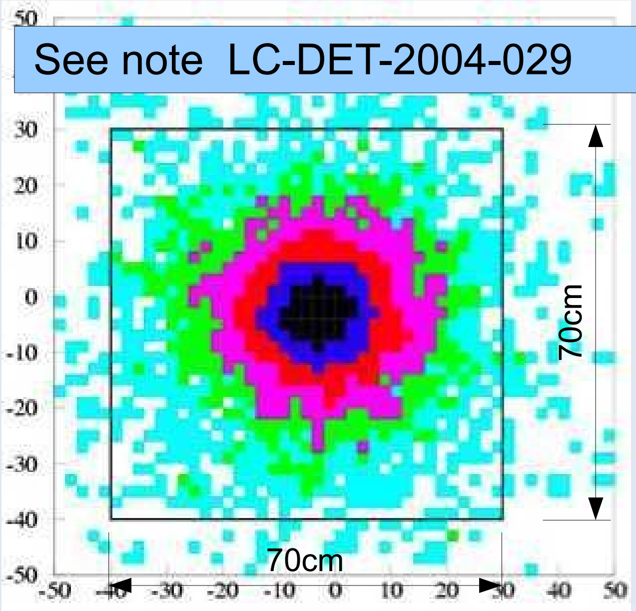
Particle Flow Based
- 1×1 cm² × 48 layers
- Imaging calorimety
  - Tracking in calorimeter
  - Energy loss recovery

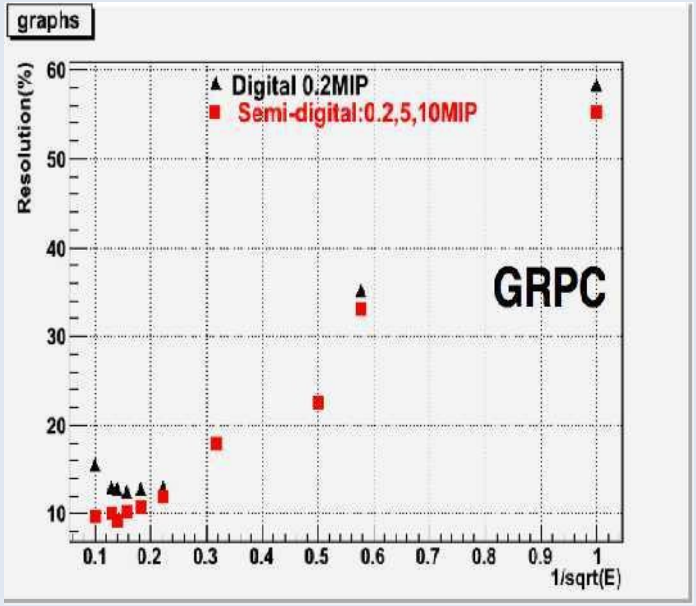
Gaseous calorimetry
- Lower sensitivity to *n*
  - Narrow showers (99% of 100 GeV π in 70×70cm²)
  - Less fluctuations (wrt H containing con

GRPC's
- Cheap
- Simple
- Reliable
- Large uniform surface (calibration of 70M ch.)

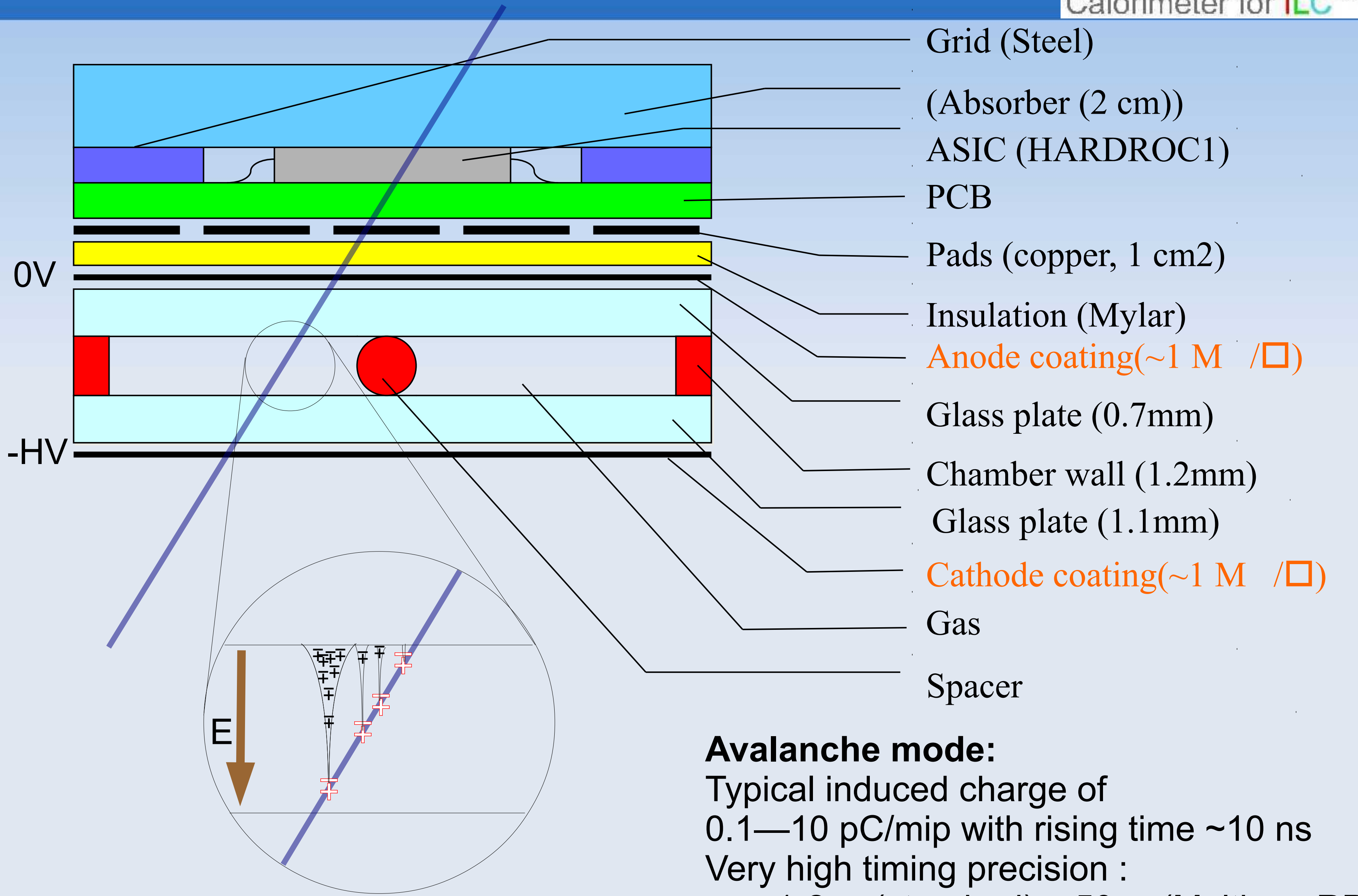
2 bits per cell
- Simplified electronics
  - reduced cost
  - less heat
- Improvement of energy rec. at High E.

See note LC-DET-2004-029





Glass Resistive Plate Chamber

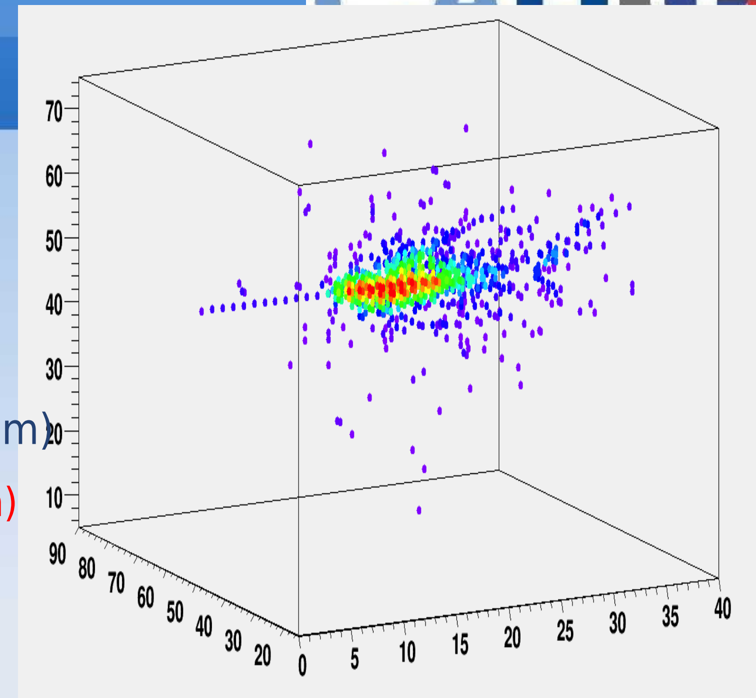


Avalanche mode:
Typical induced charge of
0.1—10 pC/mip with rising time ~10 ns
Very high timing precision :
1-2ns (standard)→ 50ps (Multigap RPCs)

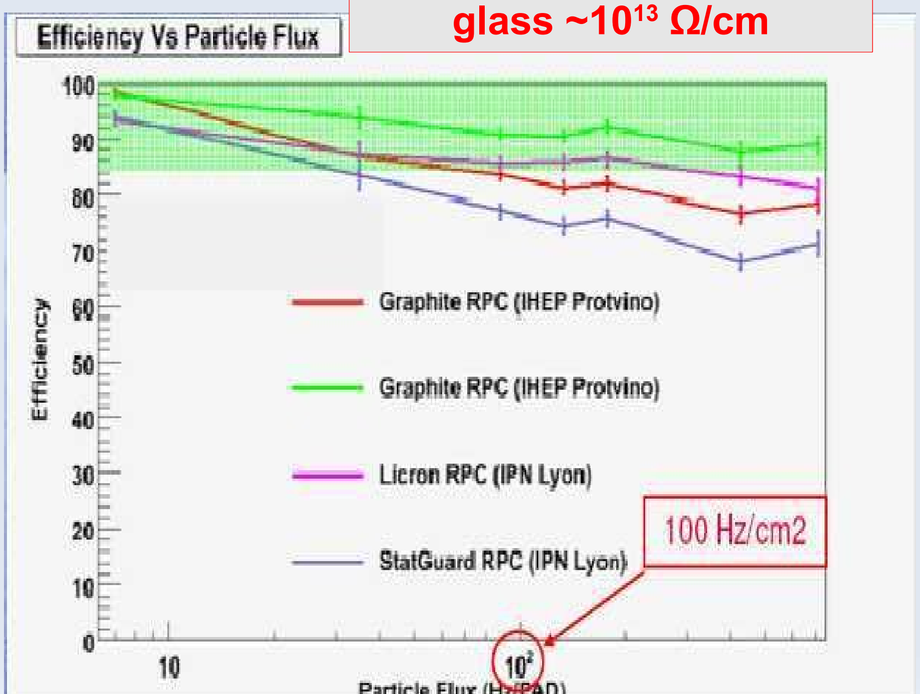
Used in Atlas muons system

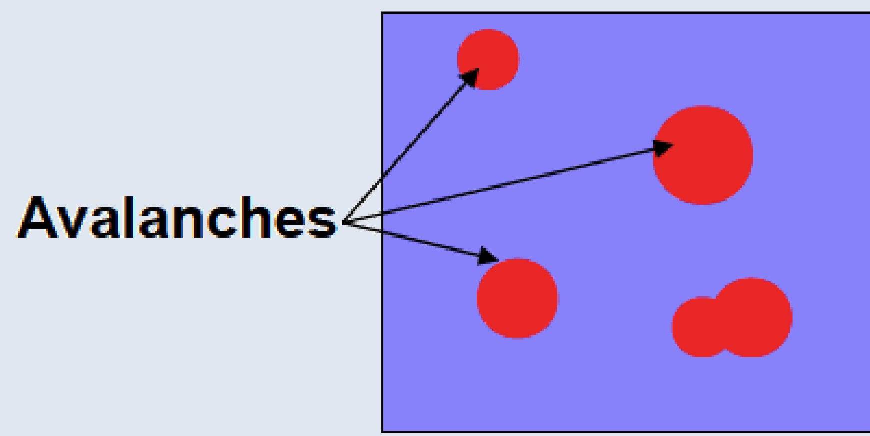
Space & time

- Avalanches typical size ~ few mm^2
- ~95-97% efficiency to mip
- Multiplicity ↗ 1.5 at cell boundary
- Rate limitatio1 ~ 100 Hz/cm^2 with standard Glass ($10^{13}\Omega$/cm)
  - OK @ ≥30 kHz/cm^2 with low resistivity glass (~10^{10} Ω/cm)
  - Alternatives: µMegas or GEMs (in early phase & more expensive)



Reference: classical float glass ~10^{13} Ω/cm

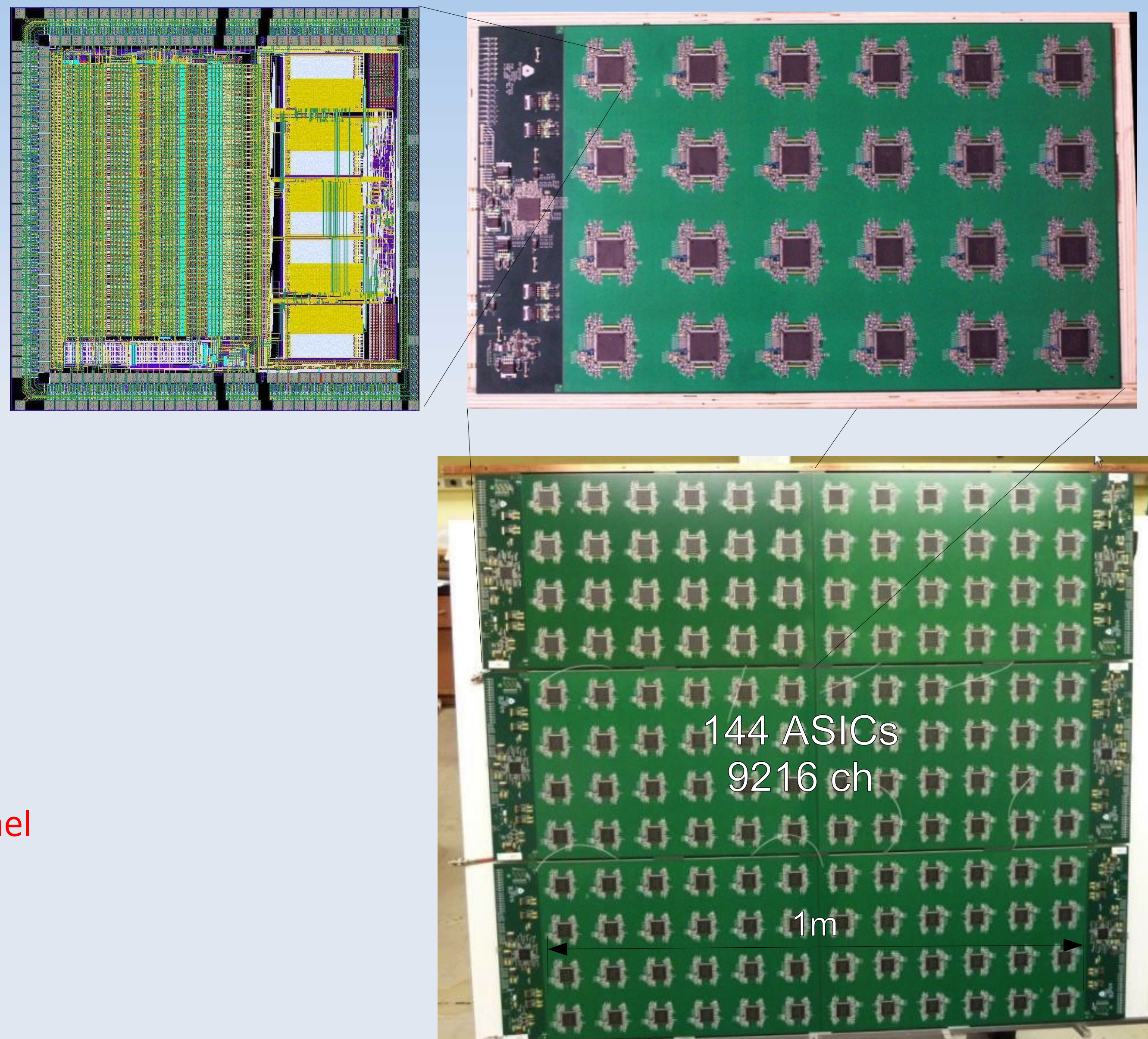


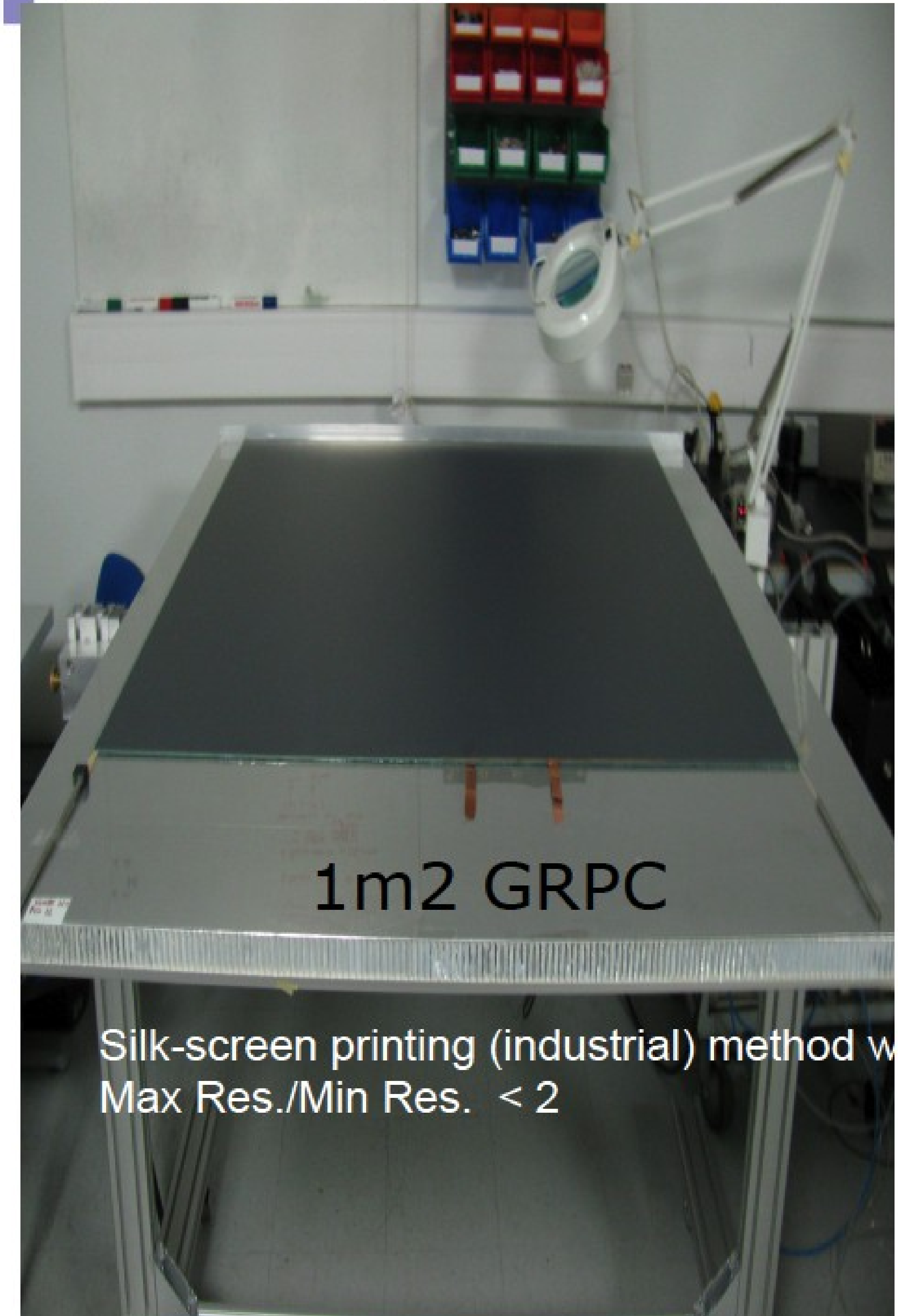


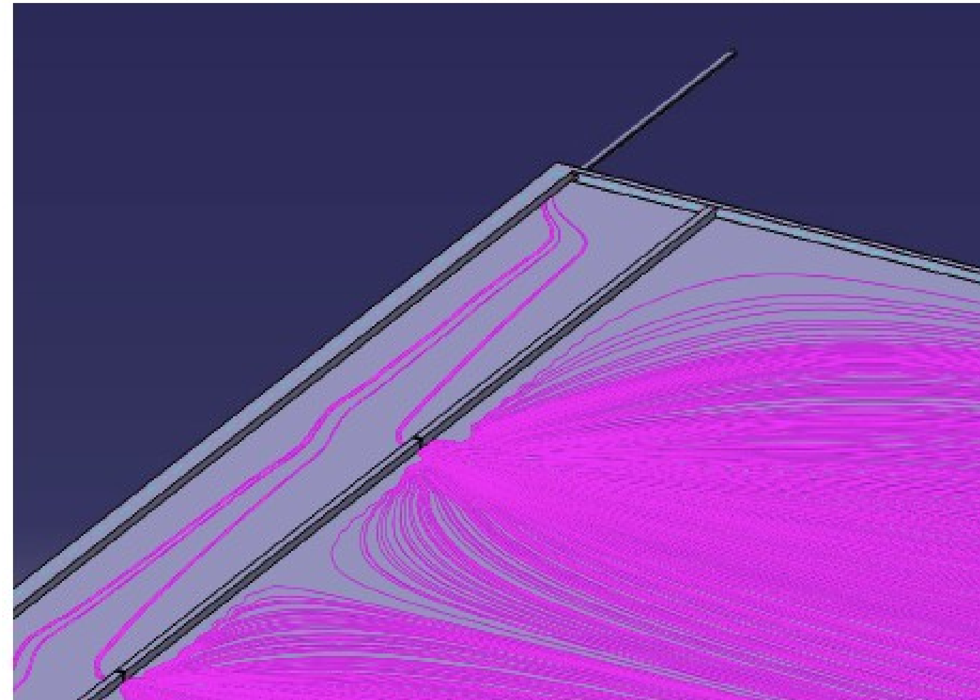
1 cm^2 pad

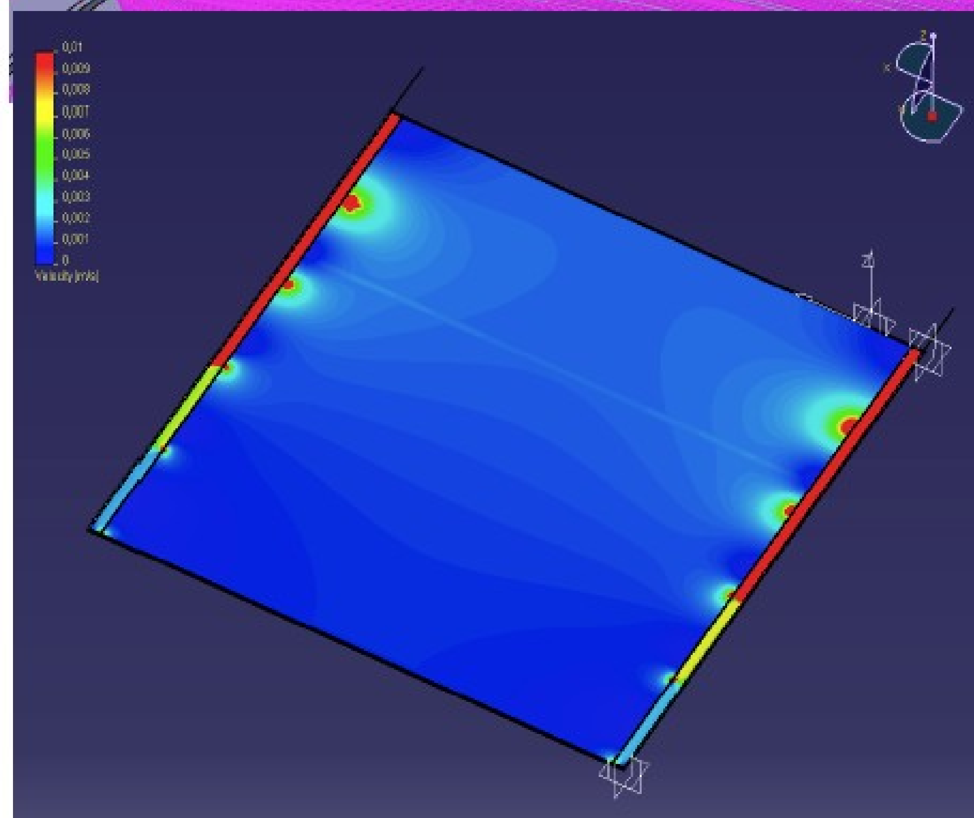
Readout electronics

- HARDROCv2 from LAL-Omega
  - 64 ch readout chips
    - indep Gains
  - 3 indep thresholds
  - Auto-triggering
    - Zero suppr.
  - independent gains
  - power pulsing
    - 7µW/ch @ 0.5% duty cycle
  - 128 events memory
- Cost (for ILD , 72 Mch)
  - ASIC: ~0.12€ / channel
  - PCB ~ 600€/m²




1m2 GRPC
Silk-screen printing (industrial) method w
Max Res./Min Res. < 2



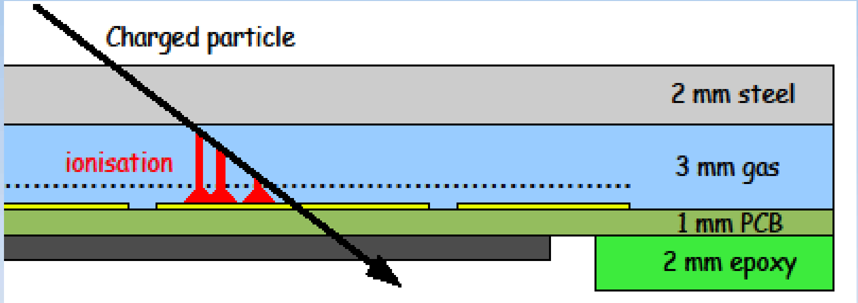

0,01
0,009
0,008
0,007
0,006
0,005
0,004
0,003
0,002
0,001
0
Velocity [m/s]

Micro-Megas

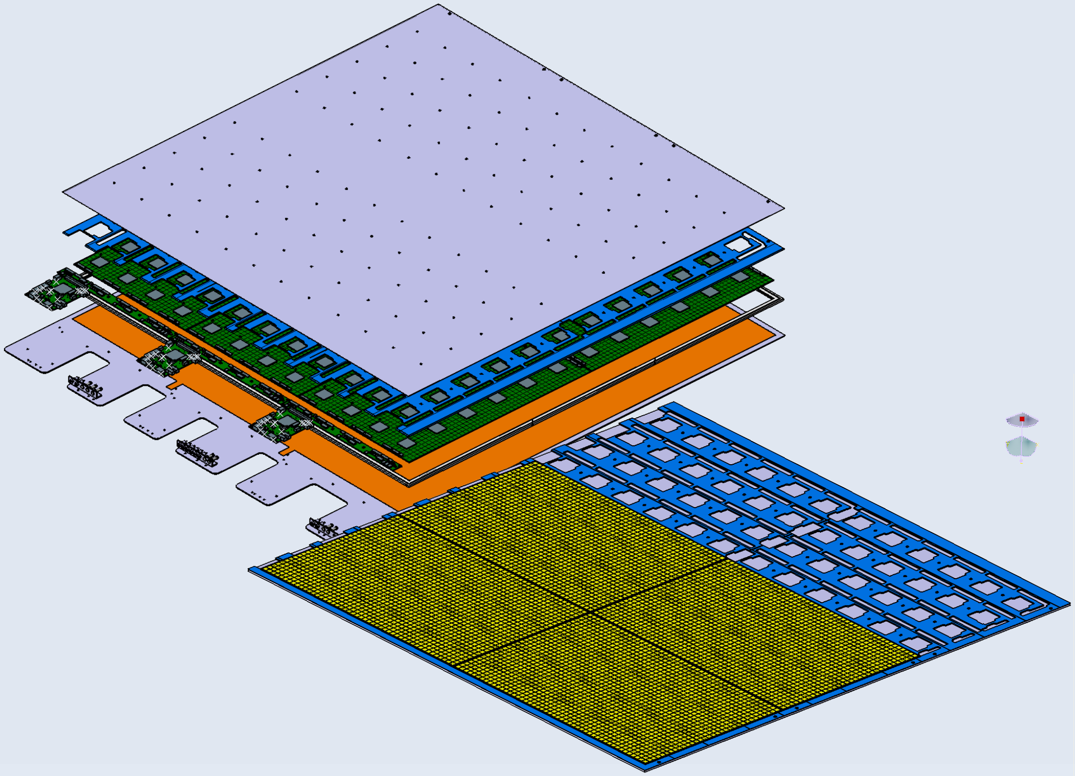
In earlier R&D phase than RPC
(more challenging: protection against sparking, smaller signals) but progressing well...

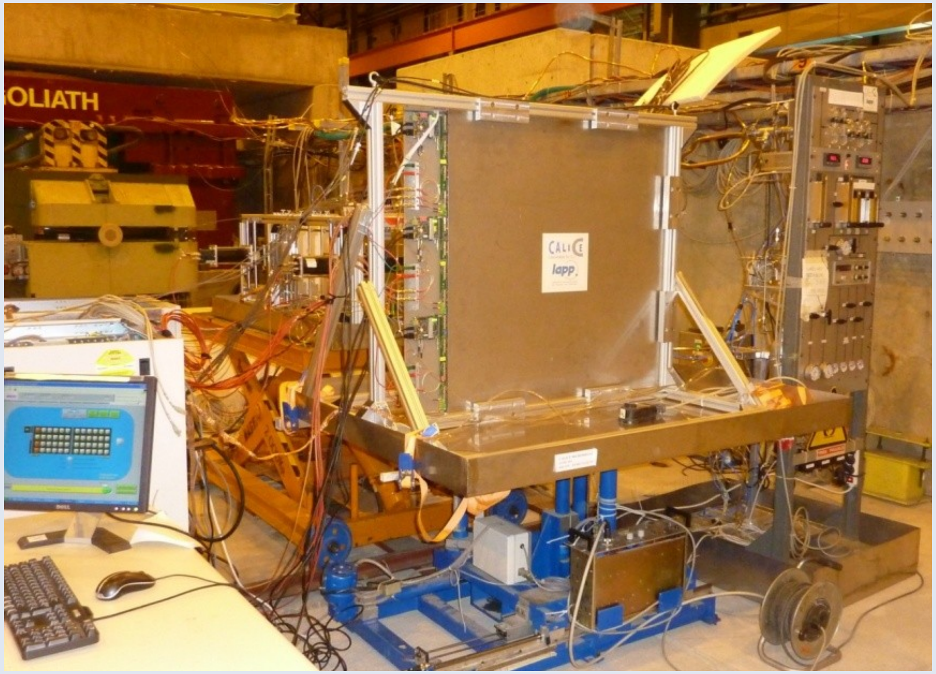
No pratical rate limitation (~10^9 mm^{-2} s^{-1} !!)

Cost ~ 2000€/m²



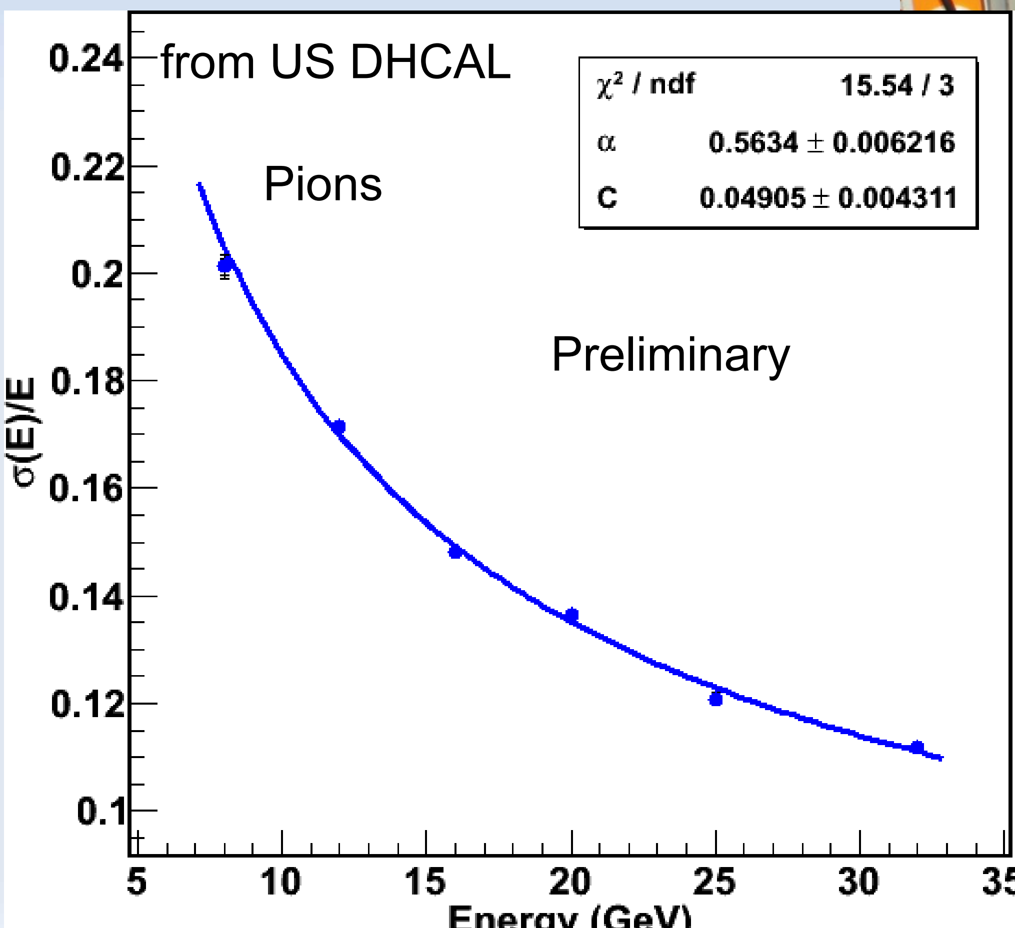
LAPP CALICE group





RPC Prototypes

- 2× 1 m³
  - Phys DHCAL (US) & techn. SDHCAL (FR)
  - 10000 ch / m²
  - 40 layers
  - 400000 channels

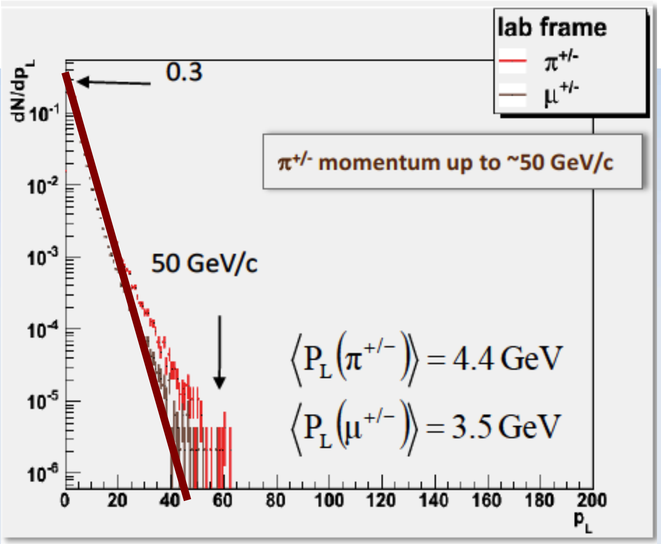


Rates in HCAL

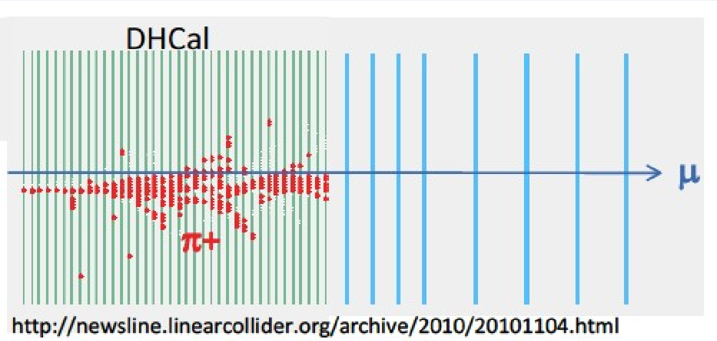
Calorimeter for ILC

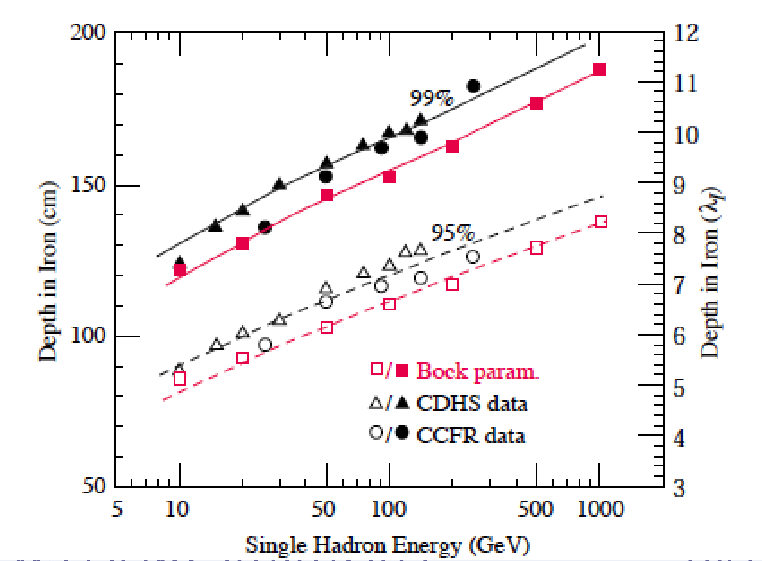
Number of min bias events (for Pb+Pb)

- $\sigma_I = 68.8 \times (A^{1/3}_{proj} + B^{1/3}_{targ} - 1.32)^2$ ➔ $\sigma^{PbPb}_{minbias} = 68.8 \times (208^{1/3} + 207.19^{1/3} - 1.32)^2 =$ **7.62 barn**
- **Nevents/sec** ~ $0.3\ 10^6 \times 7.62$ ~ **2.3 MHz**

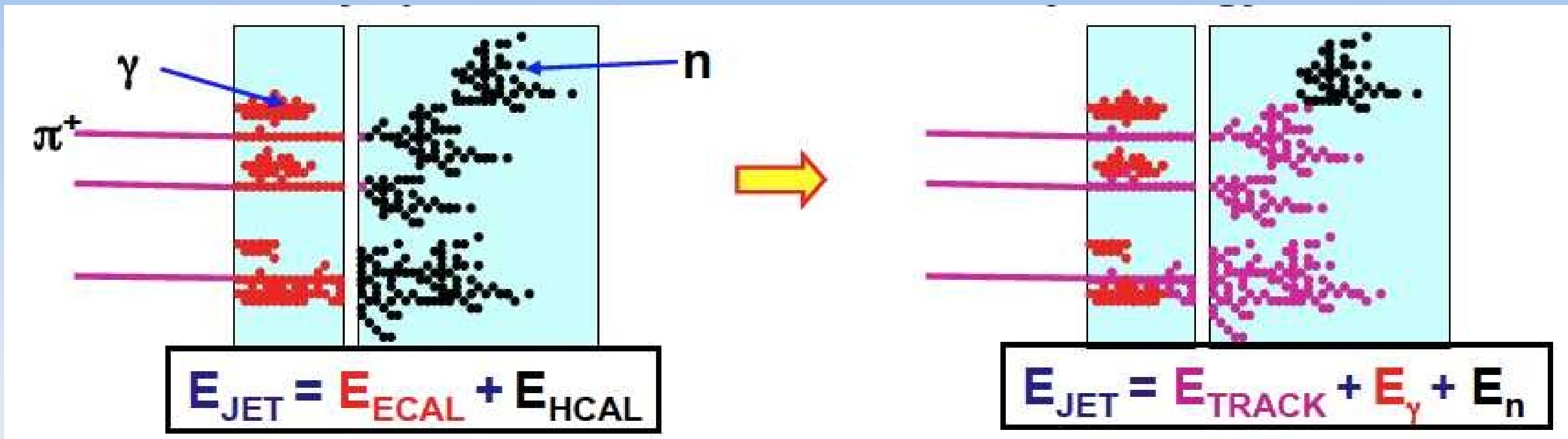


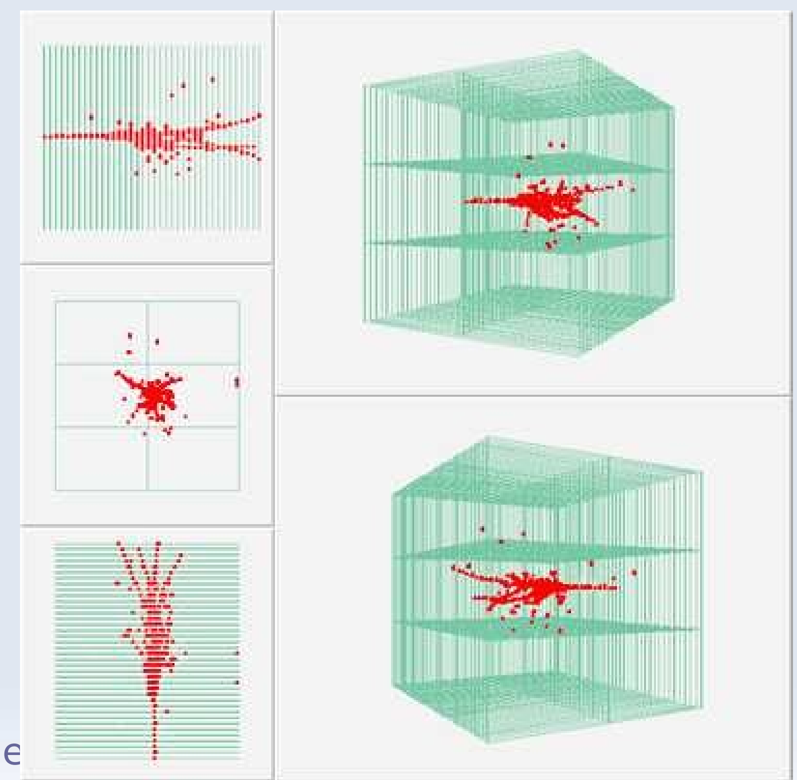
- Average # of π = 0.3×4.4 = 1,32 π / evt ???
- ~2.3MHz × 1.32 = 3MHz of π
  - contained in 70×70 cm²; occupancy ≤10%
- Acceptable rates ~100kHz (for semi conductive RPC):
  - 1/30 reduction rate ~1 m of Iron
  - → first layers in μMegas
- More realistics numbers on π's needed...
- **Key feature: early layer to follow μ tracks...**

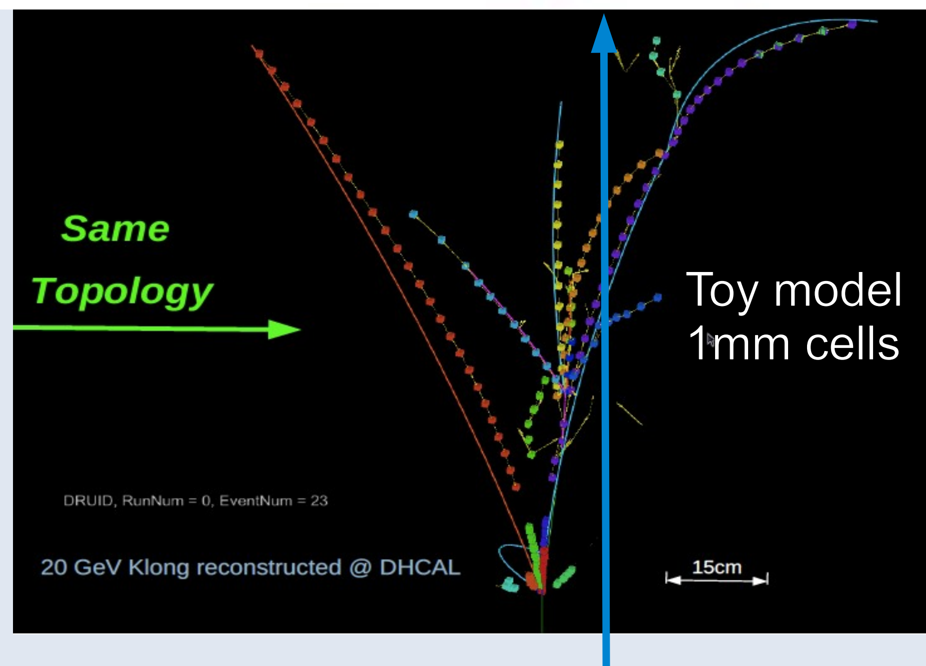




Calorimetry for PFA







Optimal granularity depends density of particle

Muons Multiple scattering

ψ^{RMS}_{plane} **in rad**

$$\theta_0 = \frac{13.6\ \text{MeV}}{\beta c p}\, z\, \sqrt{x/X_0}\Big[1 + 0.038 \ln(x/X_0)\Big]$$

m of Fe	0.2	0.5	1.0	2.0	3.0	5.0
x/X0 pμ {GeV}	11	28	57	114	171	285
3.0	0.010	0.016	0.023	0.033		
σ/cm	0.193	0.787	2.278	6.592		
7.0	0.004	0.007	0.010	0.014	0.018	0.023
σ/cm	0.083	0.337	0.976	2.824	5.257	11.495
15.0	0.002	0.003	0.005	0.007	0.008	0.011
σ/cm	0.039	0.157	0.456	1.318	2.453	5.364

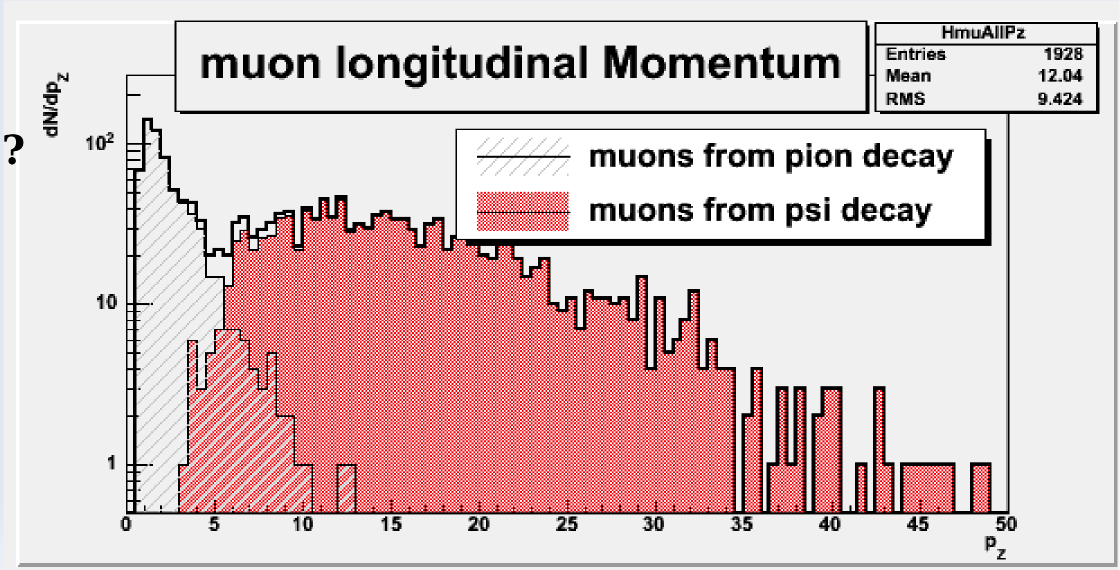
θ_0 = fit of a Gaussian distribution on
$RMS_{plane} = 1/\sqrt{2}\ RMS_{space}$
precision ≤ 11% for
$0.001 < x/X_0 < 100$

ψ = planar angle of opening at the exit $\sim 1/\sqrt{3}\ \theta_0$

7 GeV (~lowest J/ψ μ's) μ will scatter over

- 0.3 cm for 0.5m of Fe ← **proper interlayer ?**
- 1 cm for 1m
- 3 cm for 2m
- 5 cm for 3m
- 11 cm for 5m

Addtional layers needed at beginning



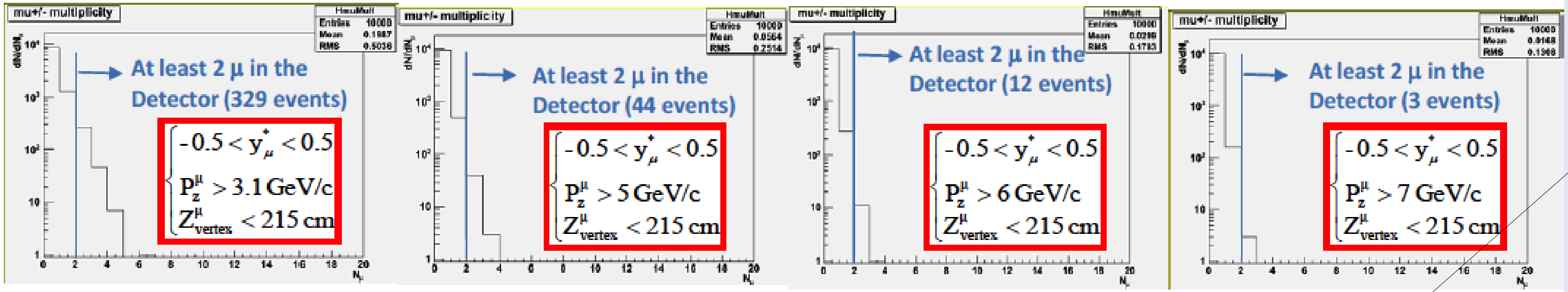
Triggering

Detector – trigger rate in Pb+Pb

- **Pb Beam intensity**
  - NA50 → 5.10^7 ions/bunch → 10^7 ions/sec (with a bunch time length ~ 5 sec)
  - **Luminosity :** $\mathcal{L} = N_b \times N_T = N_b \times (\rho \times e \times \mathcal{N}_A)/A = 10^7 \times (11.35 \times 1 \times 6.02\ 10^{23})/207.19$ = **0.3 $\mu b^{-1}s^{-1}$**
- **Number of min bias events (for Pb+Pb)**
  - $\sigma_I = 68.8 \times (A^{1/3}_{proj} + B^{1/3}_{targ} - 1.32)^2$ → $\sigma^{PbPb}_{minbias} = 68.8 \times (208^{1/3} + 207.19^{1/3} - 1.32)^2$ = **7.62 barn**
  - **Nevents/sec** ~ $0.3\ 10^6 \times 7.62$ ~ **2.3 MHz**
- **Event rejection :**

10 000 Pb+Pb minbias events generated with EPOS 1.6

Absorber starts @ 205 cm
$\pi^{+/-}$ stop decaying after 1 λ_I in tungsten (λ_I~10cm)
→ **$\pi^{+/-}$ stop decaying @ 2.15 m**



Fine with RPC (≪100 Hz / cm²)

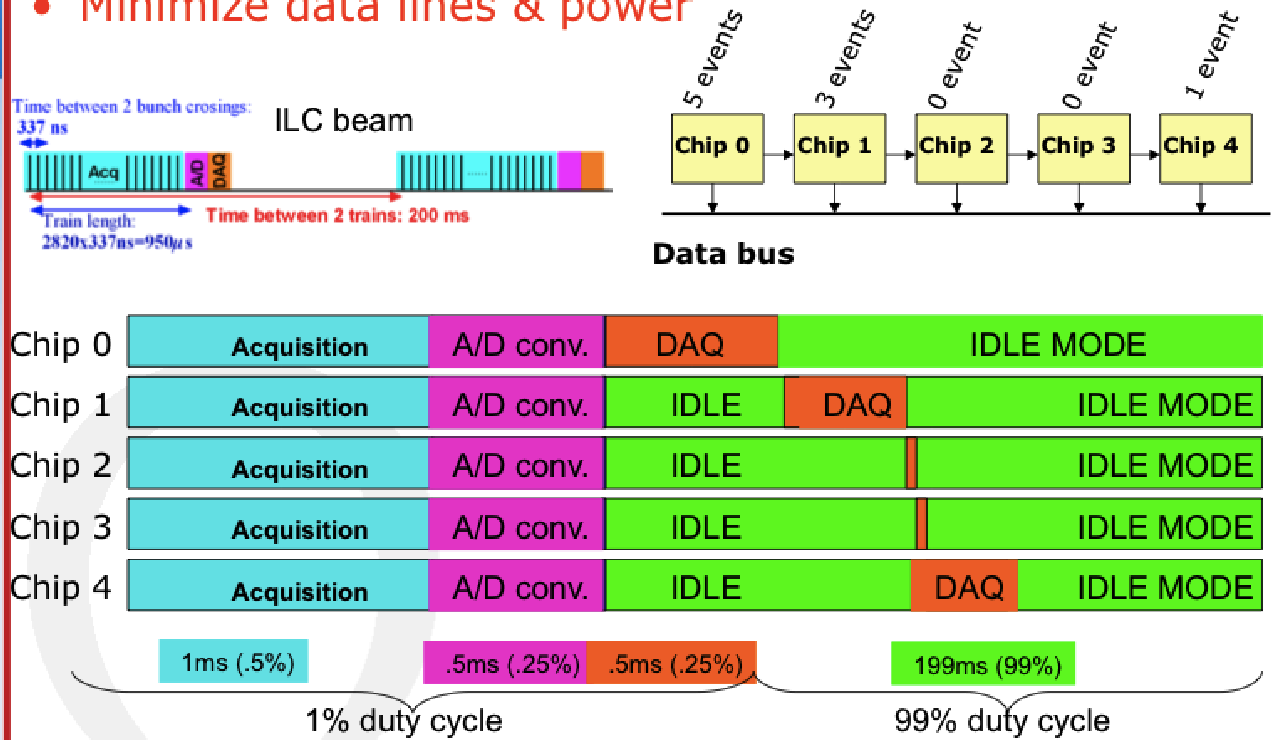
3.2m Fe abs.: P_z>5 GeV/c: Trigger accepts 44/10000 events → N_{events}/sec ~ 2.3 MHz x 4.4 10^{-3} ~ **10 kHz**
3.8m Fe abs.: P_z>6 GeV/c: Trigger accepts 12/10000 events → N_{events}/sec ~ 2.3 MHz x 1.2 10^{-3} ~ **2.8 kHz**
4.5m Fe abs.: P_z>7 GeV/c: Trigger accepts 3/10000 events → N_{events}/sec ~ 2.3 MHz x 3 10^{-4} ~ **700 Hz**

Frédéric Fleuret - LLR   31

CALICE electronics

Read out: token ring

- Readout architecture common to all calorimeters
- Minimize data lines & power



ILC

- Embedded electronics
  - cooling
  - power pulsing DC = 0.5%
- Triggerless
- Built-in memory

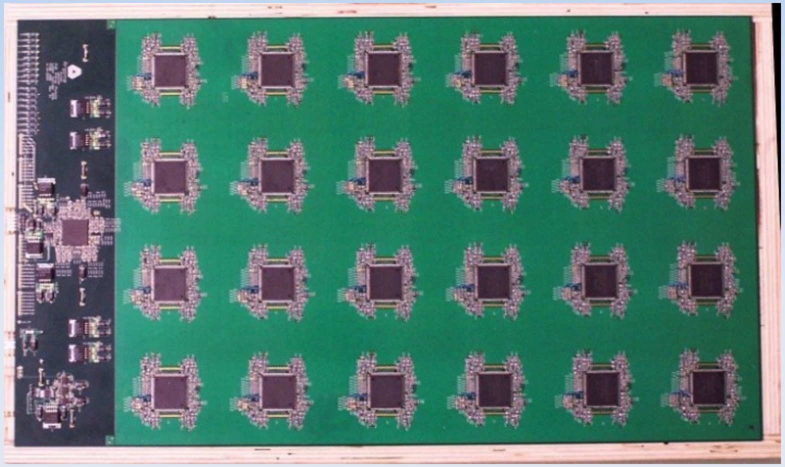
Fixed Target

- Embedded electronics ECAL & HCAL & inner muons
  - cooling
  - power pulsing : DC ~ 10%
- Triggered → implement a circular buffer for built-in memory
- Slight modifications needed

- Embedded electronics outer Muons
  - ~~cooling~~
  - power pulsing : DC ~ 10%
- Continuous readout for trigger on auto-trigger
- a priori : No modification needed

Costs scaling laws

- From ILD Letter of Intend
  - Electronics
    - ASIC: ~0.12€ / channel
    - PCB ~ 600€/m²
  - Sensors:
    - RPC : ~200 € / m²
    - µMegas ~ 2000€/m² → early layers ?
  - Iron:
    - ~120k€/m³



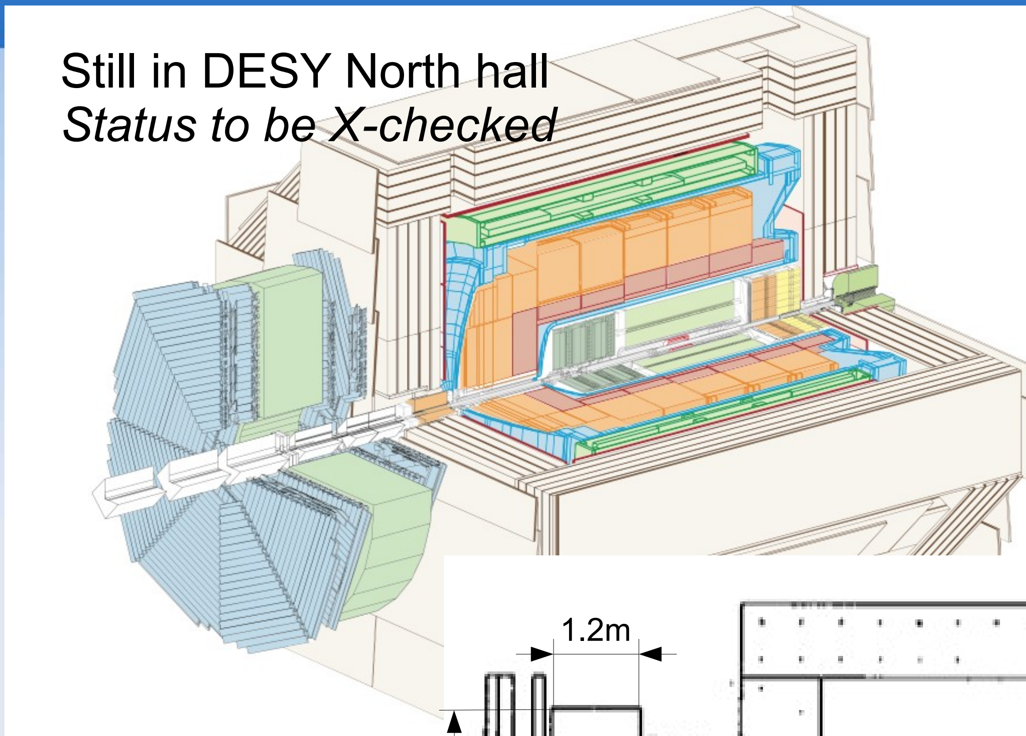
- 1 DHCAL (without Fe)
  - ∅ 60 cm × 30 layers → 33 m²
  - 1 cm² cells → 33000 × 0.12 + 33×600 + 200×33 = 30k€ (89000 for µMegas)
  - 5×5 mm² cells → 132000 × 0.12 + 33×600 + 200×33 = ~42k€ [cost = technology!]
- instrumented Fe
  - ∅ 100 cm × 10 layers → 31 m²
  - identical prices

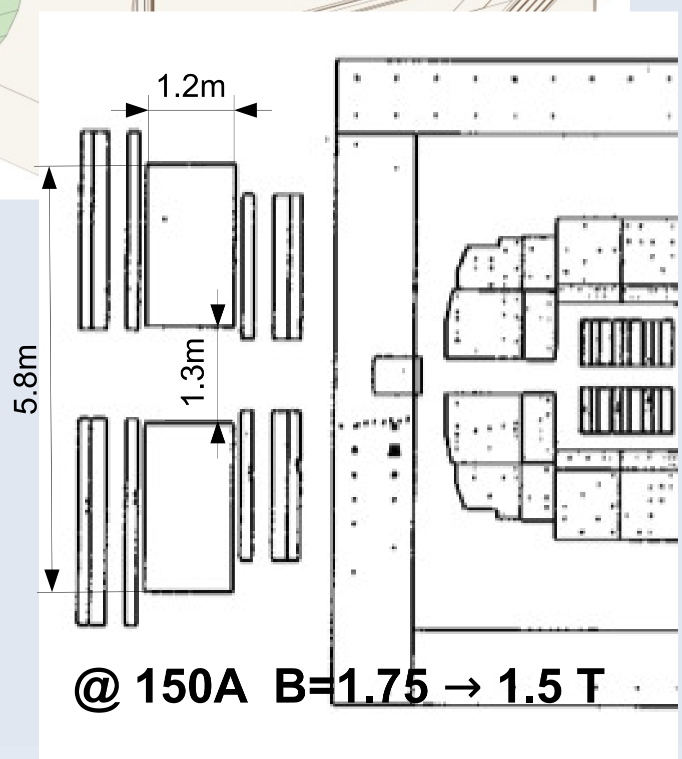
+ 40k for DAQ
+ 40k for gas system

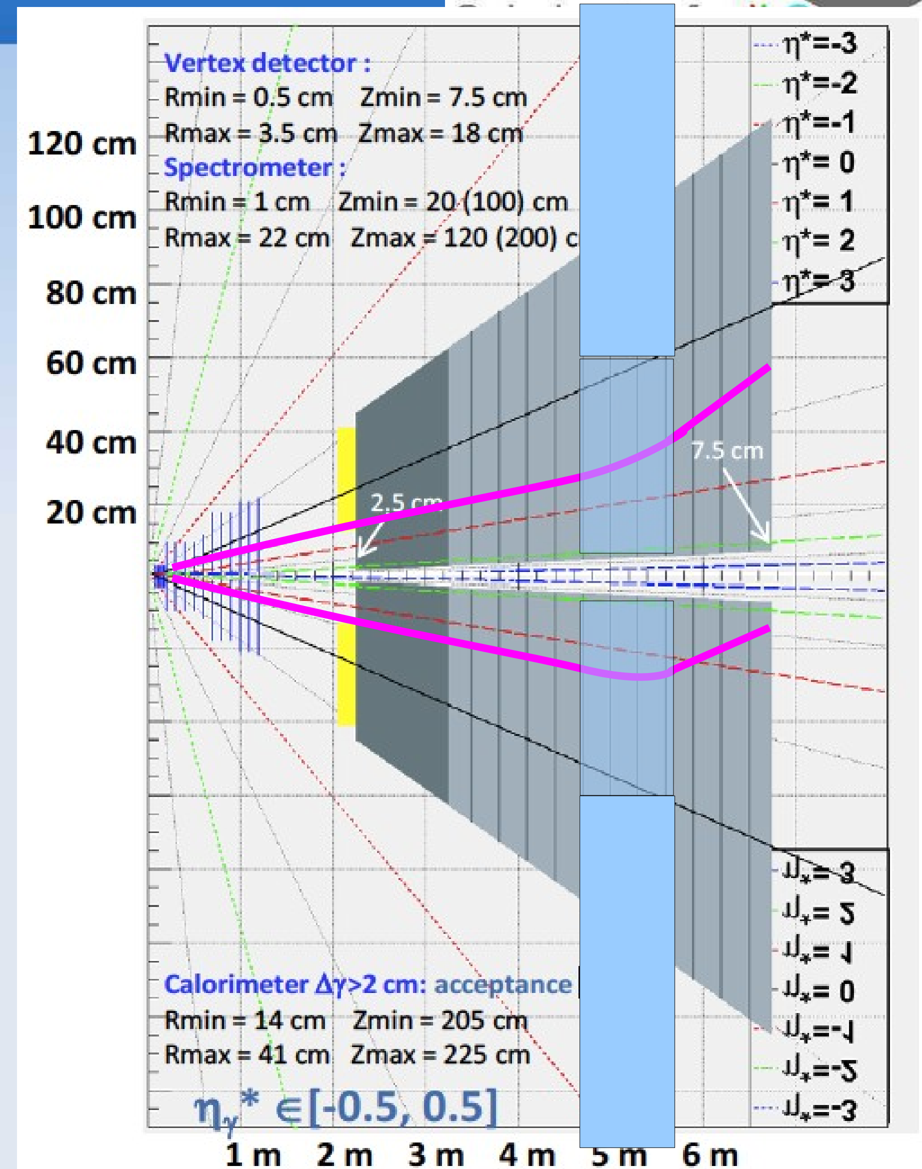
Additional consideration

- Strips vs Pads
  - at low occupancy → 5mm ×10–30 cm strips ?
    - Electronics cost ∝ (cell size)²
- Magnetic field → H1 Toroid ?
- Triggering to be reviewed wrt to ILC electronics
  - → Circular buffering in chips
  - 1 threshold
- Streamer mode vs avalanche mode
  - streamer → higher signal → simplified electronics → costs ↘
    - for ex : kPix chips (1024 channels) from FNAL/Argonne

H1 toroid magnet







→ Would need completion or complete re-design

Summary

- Gas digital calorimetry is optimal for hadronic pattern shower reconstruction
  - insensitivity to neutrons, very high granularity possible.
- Gas sensors for DHCAL and DMuons
  - GRPC are cheap and reliables but limited in rate
  - µMegas are more expensive and require care but unlimited in rate
    - Combine both for reasonnable cost
- Density of sensor layer & granularity require some optimisation wrt **density of particle**
  - identification & tracking of muons
  - 1×1cm² done and almost immediately usable
    - ×4 in granularity achievable: perf to be evaluated.
- CALICE electronics needs only small adaptations