Metody eksperymentalne w fizyce wysokich energii

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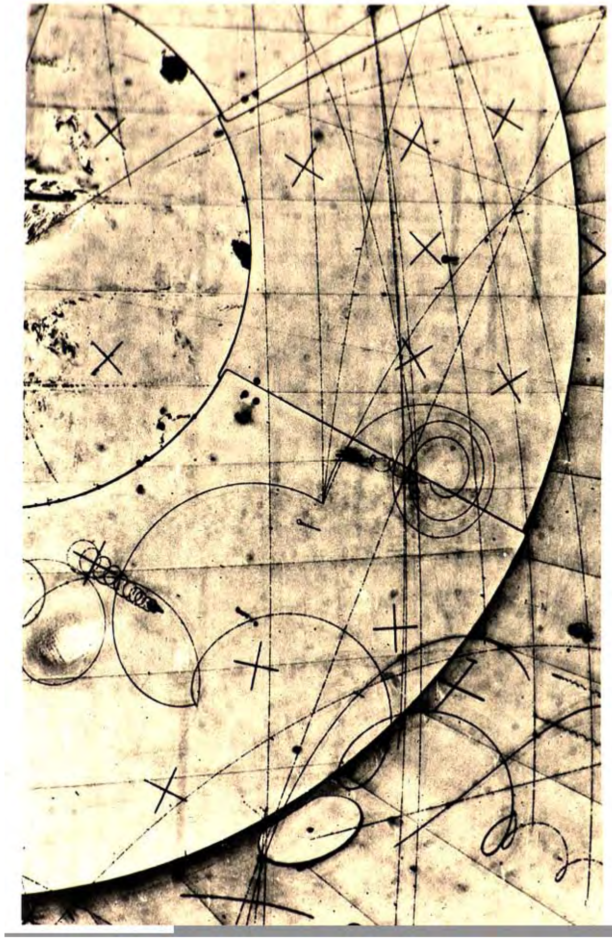
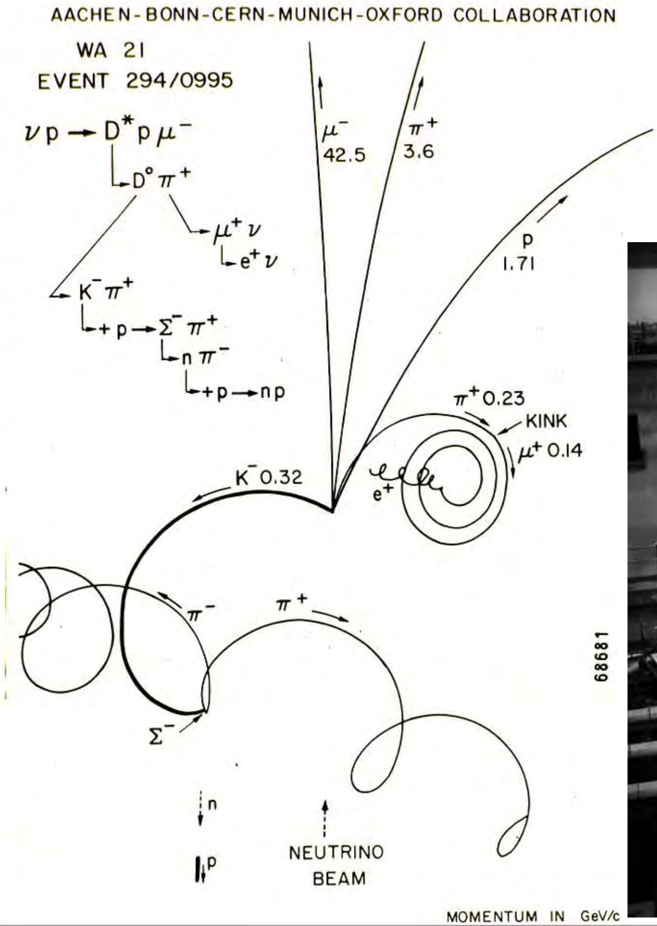
Zakład Cząstek i Oddziaływań Fundamentalnych IFD

Wykład IX

- Eksperymenty akceleratorowe

Ideałem jest pełna rekonstrukcja przypadku





BEBC, equipped with the largest superconducting magnet in service at the time.

D* (excited D-meson, carrying the "charm" quantum number): production and decay during a wide band exposure in experiment WA21, in the BEBC liquid hydrogen bubble chamber.

O. Ullaland/2006

Pojedyncze detektory pozwalają bardzo precyzyjnie zmierzyć:

- pozycję cząstki (detektory krzemowe, detektory śladowe)

- tor cząstki (detektory śladowe)
  => w polu magnetycznym: pęd cząstki

- prędkość cząstki (TOF, detektory Czerenkowa)

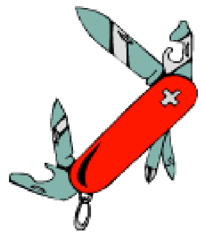
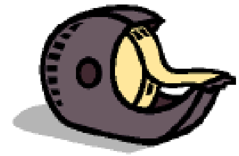
- energię cząstki (kalorymetry)

- typ cząstki (TRD, na podstawie oddziaływania w materii)

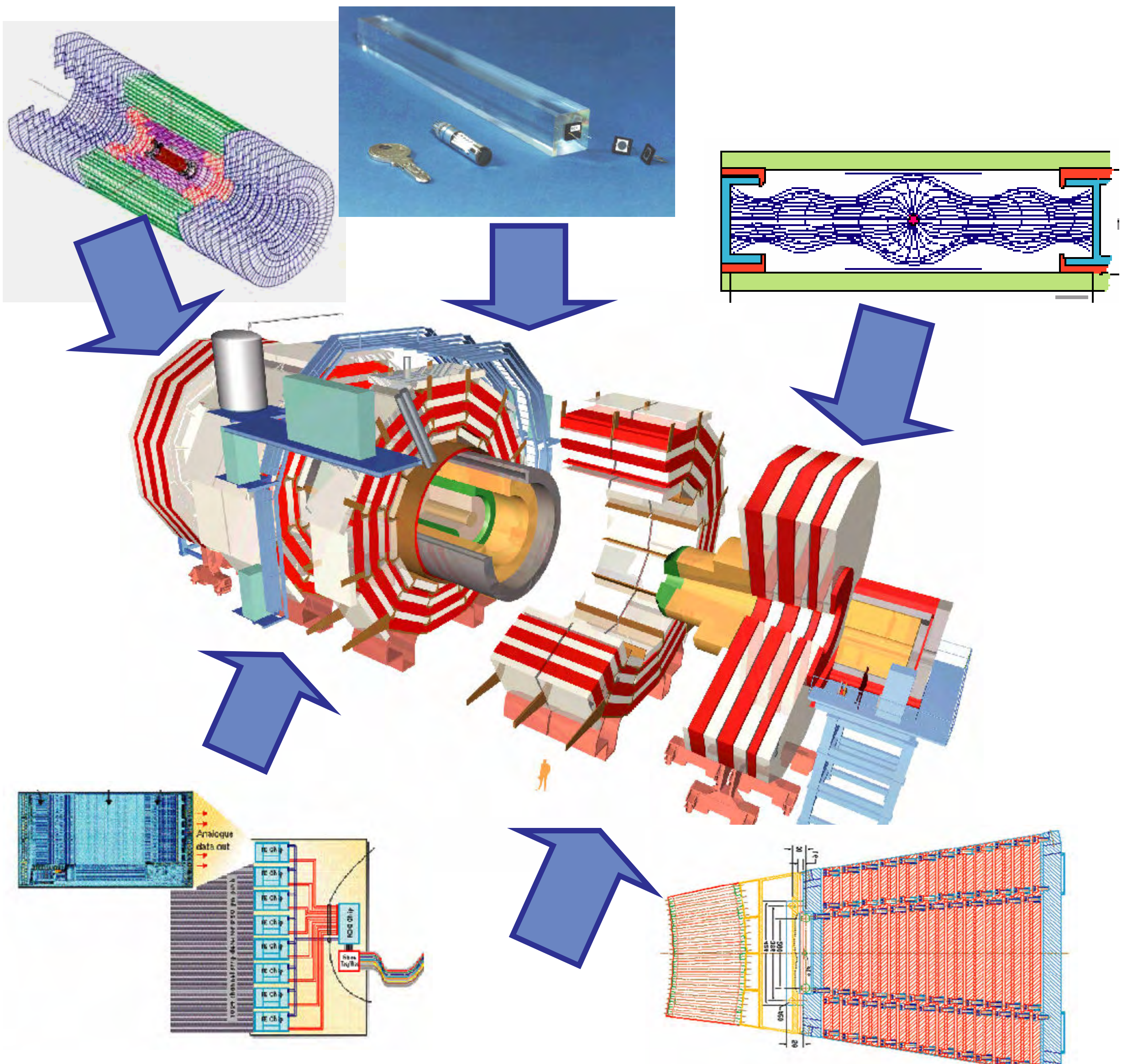
Na tej podstawie jesteśmy często w stanie zidentyfikować cząstkę
ale naogół tylko w ograniczonym zakresie kinematycznym

Jak uzyskać optymalny pomiar układu wielu cząstek ?

Let’s find some tools …


and put everything together !



Jak zaprojektować detektor ?

Co decyduje o wyborze konstrukcji?
Jakie są ograniczenia?

It starts with the Physics

- What is the physics measurement that is driving the experiment?
- What are the final states – how will you measure them? Examples include
  - Pizero ID (separation of two photons?)
  - J/Psi – good tracking
  - Light quarks – good calorimeter
  - b and c quarks (tagging)
- What level of precision are you after?
  - Precision has a cost; dollars, complexity, and readout speed

It continues with the Physics

- Can you trigger on the physics process of interest?
  - Separate the unique signature of the physics of interest from the literally billions of collisions that go on each day
- What is the rate?
  - Drives both the trigger and data acquisition system
  - Do you need to worry about “dead-time”?
  - How will you calibrate your detector?
  - How will you measure the various detector efficiencies

Global Detector Systems

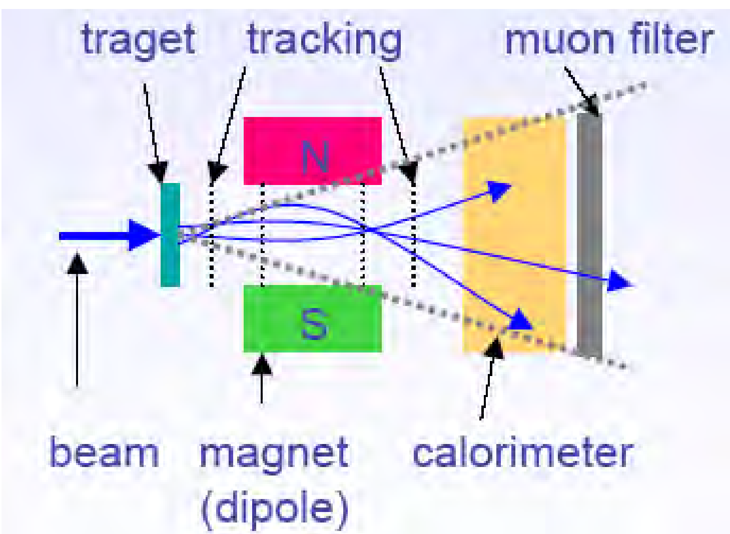
Overall Design Depends on:

- Number of particles
- Event topology
- Momentum/energy
- Particle identity

No single detector does it all…

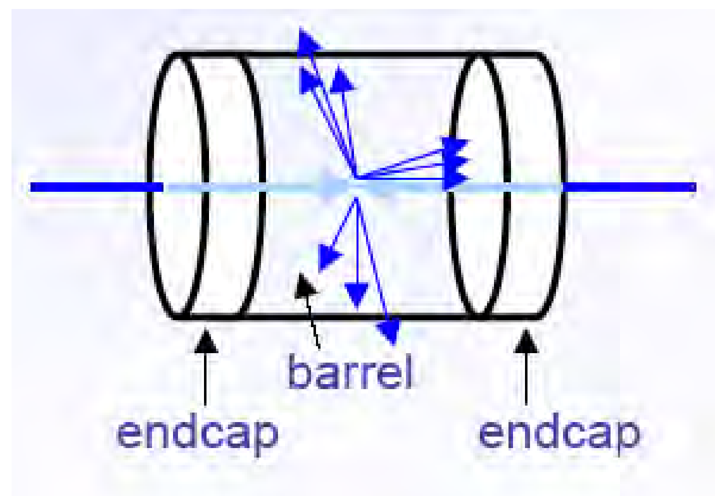
→ Create detector systems

Fixed Target Geometry



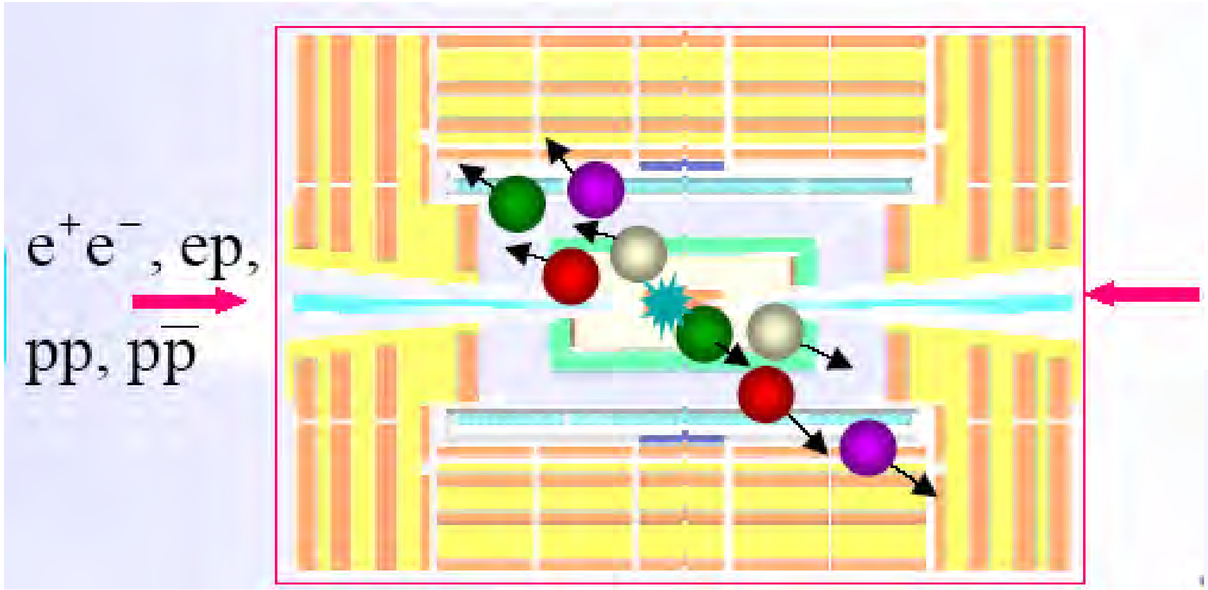
- Limited solid angle ($d\Omega$) coverage (forward)
- Easy access (cables, maintenance)

Collider Geometry



- "full" solid angle $d\Omega$ coverage
- Very restricted access

Ideal Detectors



End products

- charged particles
- neutral particles
- photons

An "ideal" particle detector would provide...

- Coverage of full solid angle, no cracks, fine segmentation
- Measurement of momentum and energy
- Detection, tracking, and identification of all particles (mass, charge)
- Fast response: no dead time

However, practical limitations: Technology, Space, Budget, and engineering prevent perfection...

We can’t build a perfect detector

- A perfect detector has no “holes”
  - Reality is that in order to read the detector, we need to get the signals out. This is done with cables. Cable paths force us to have “seams” in the detector where we don’t know what is happening
- A perfect detector is identical in every direction with respect to the collision point
  - We need to support these detectors which means that the material is not isotropic.
- A perfect detector is 100% efficient

Detector Design Constraints

- What is the current technology and where do we expect technology to be when the experiment is ready to take data
  - Most experiments these days take a long time. The time between “the expression of interest” to “ready for collisions” is measured in years
  - All of the technology required for the experiment to work does not have to be “ready” (commercial) at the proposal stage
  - Typically time for R&D
  - Moore’s law for computing is often relied upon

Detector Design Constraints

- Total construction cost
  - How much $$$ do you have to work with
  - How many physicists are available to participate in construction (how big is your collaboration?)
  - When do you want to be ready for collisions?
  - How "hard" will you be pushing current technology –
    - how much financial and schedule contingency is required? (more below)
  - An honest assessment of how well the collaborations skills and interests align to the work that lies ahead
- Amount of time it takes to read the detector out after a collision – or reversed, how quickly do you need to read out the detector
  - Sets the drift time tracking chambers,
  - Integration time in calorimeters
  - Digitization time
  - Logging Time

Detector Design Constraints

- Size of the collision hall and specific characteristics of the building
  - Floor space
  - Weight?
  - How far underground?
  - Crane coverage?
  - Accessability of detector components
  - Gasses, cryogens, flammability, explodability, and ODH issues
  - Available AC power
  - Cooling

RISK!

- Is the level tolerable
  - Can’t push the envelope of technology for every detector
    - Will guarantee a blown schedule and cost over runs
    - Need to use new technologies judiciously
    - New Technology should not be used as a “carrot” to draw in collaborators that might otherwise pass.

The Bottom Line!

- There is no single "correct" answer to the above constraints
  - Every experiment finds its own "way"
- Detector designers perform a difficult and almost impossible optimization task

Detectors are an amazing blend of science, engineering, management and human sociology

Jakie są ogólne zasady?

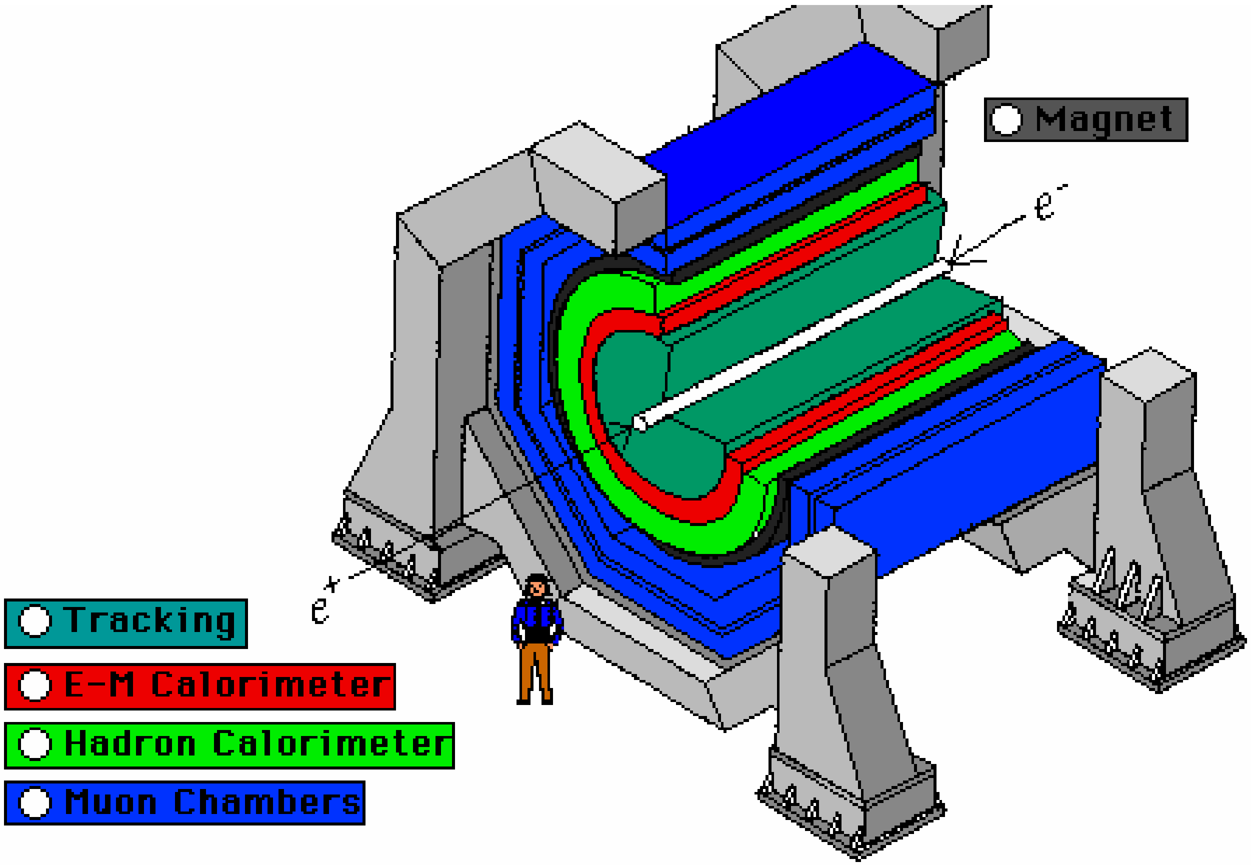
Z jakich elementów powinien składać się detektor?
Jak powinny być rozmieszczone?

Individual Detector Types

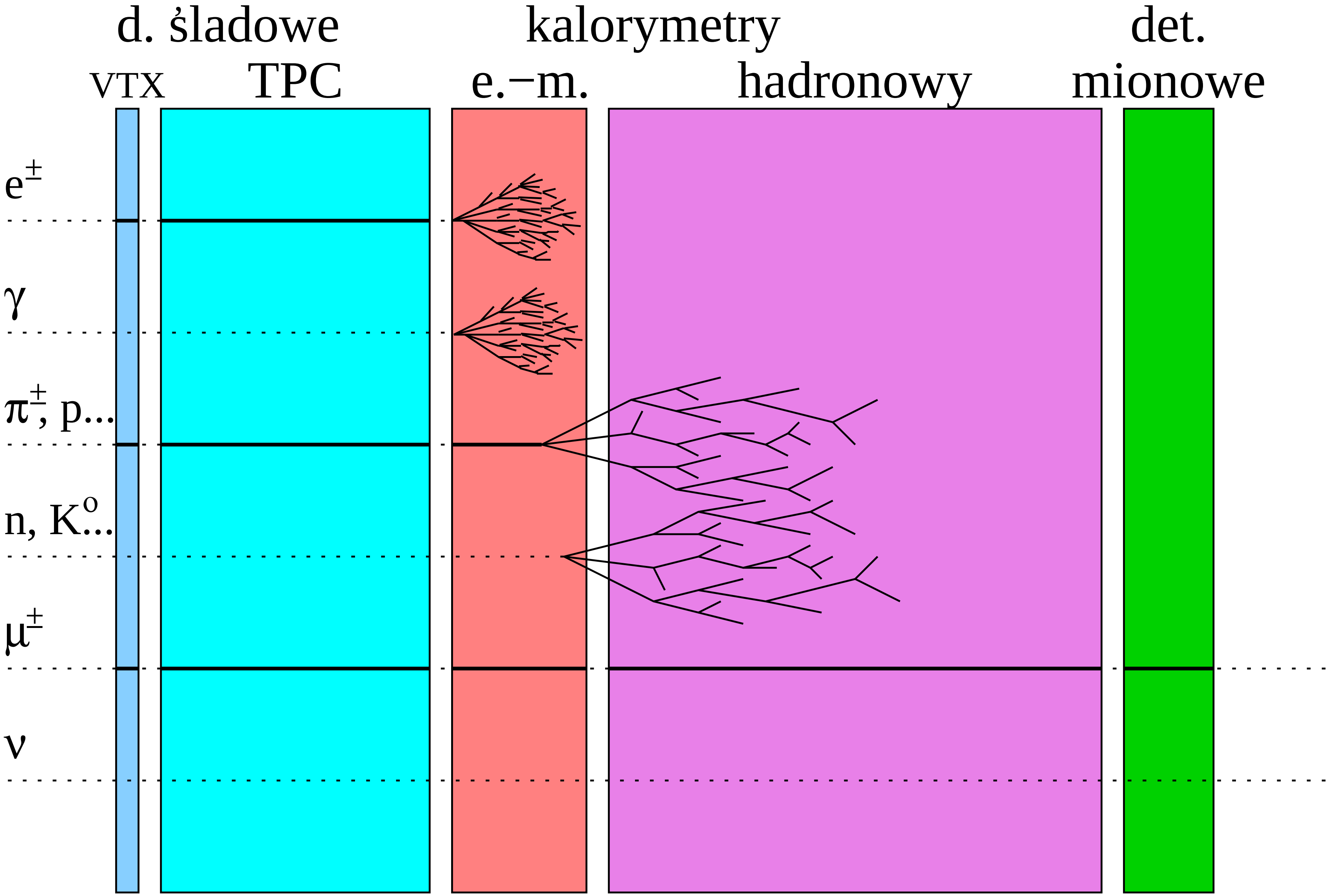
Modern detectors consist of many different pieces of equipment to measure different aspects of an event.

Measuring a particle's properties:

1. **Position**
2. **Momentum**
3. **Energy**
4. **Charge**
5. **Type**



Detektory uniwersalne



Detektory uniwersalne

Schemat budowy

Ten schemat opisuje większość współczesnych eksperymentów przy kolajderach (LEP, HERA, Tevatron, LHC, ILC):

Kolejno od środka detektora:

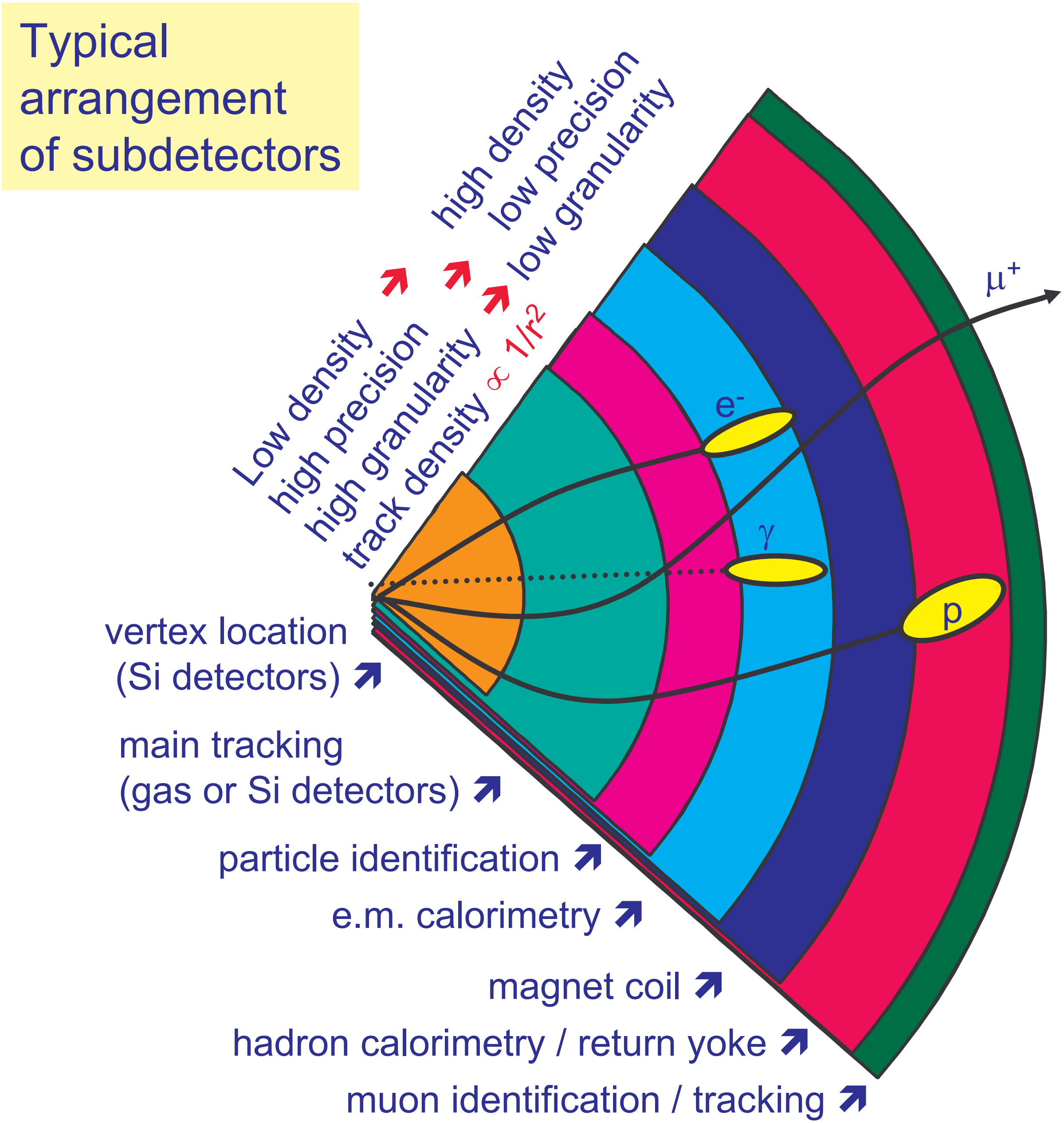
- detektor wierzchołka
  jak najbliżej osi wiązki, określa gdzie zaszło zderzenie, identyfikuje rozpady cząstek krótkożyciowych
  (tzw. wierzchołki wtórne)
  najczęściej detektor półprzewodnikowy
- detektory śladowe
  pomiar torów cząstek naładowanych, wyznaczenie pędów cząstek z zakrzywienia w polu magnetycznym
  najczęściej detektory gazowe
  (minimalizuje oddziaływania cząstek w detektorze)

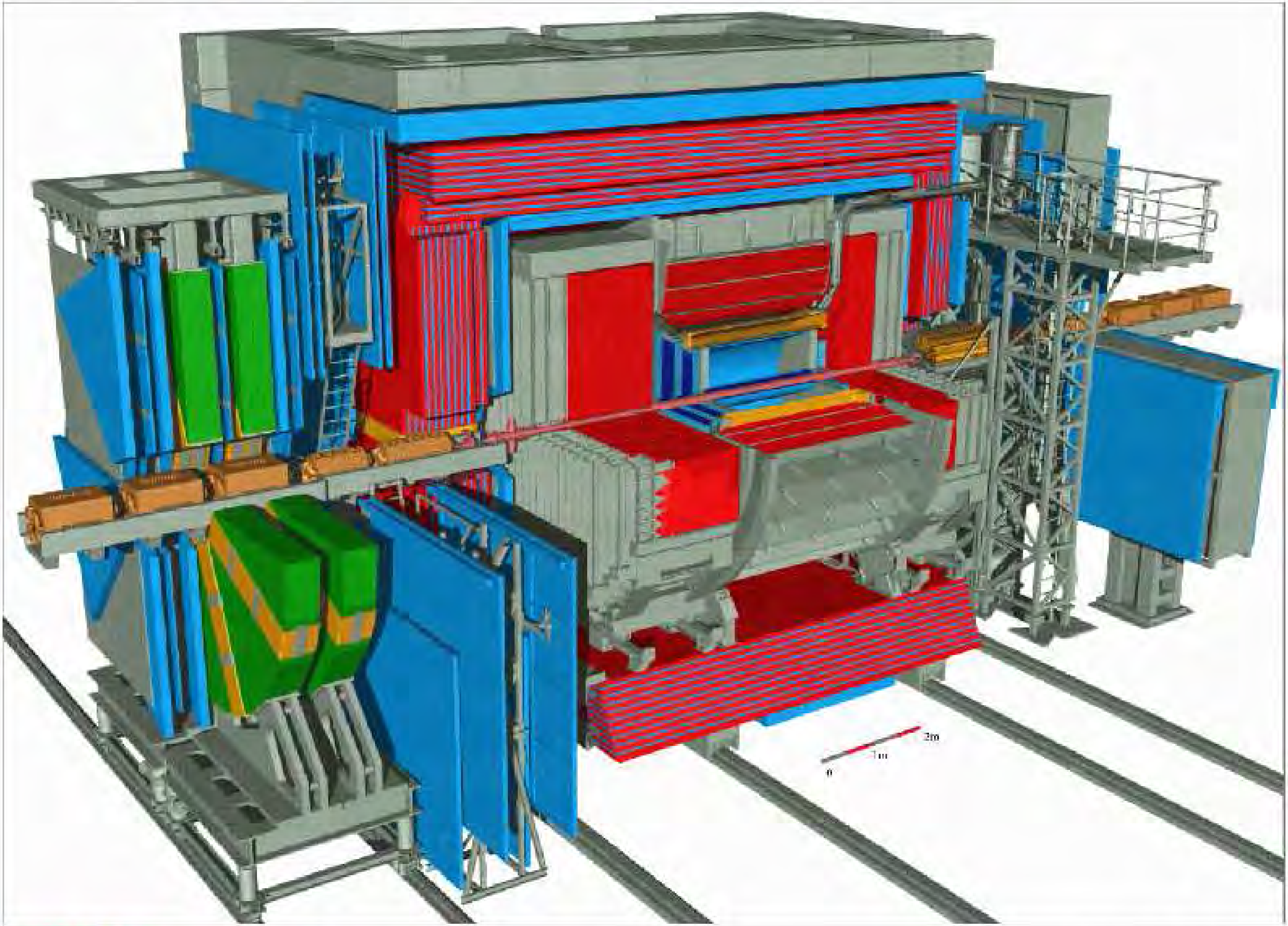
Detektory uniwersalne

WYDZIAŁ FIZYKI
UNIWERSYTET WARSZAWSKI

Schemat budowy

- kalorymetr elektromagnetyczny
  pomiar energii elektronów i fotonów
  gęsty materiał absorbujący lawinę cząstek
  (międź, ołów, wolfram)
- kalorymetr hadronowy
  pomiar energii hadronów (protony, neutrony, piony, kaony)
  gęsty materiał absorbujący lawinę cząstek; lawina hadronowa jest wielokrotnie dłuższa od elektromagnetycznej.
- detektory mionowe
  identyfikacja mionów - jedyne cząstki naładowane, które mogą przejść przez kalorymetry bez dużych strat energii

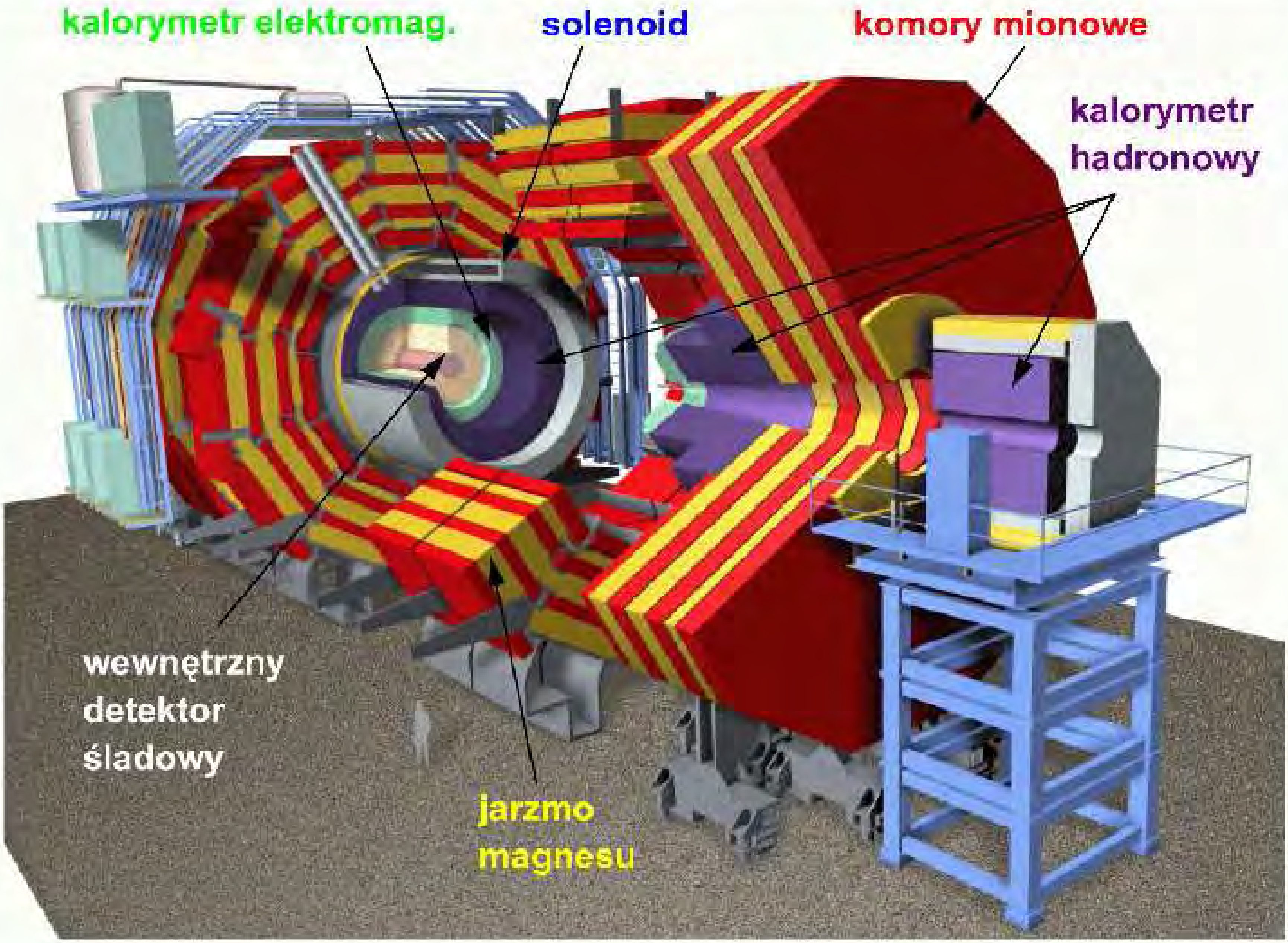

Typical arrangement of subdetectors
Low density
high precision
high granularity
track density ∝ 1/r²
high density
low precision
low granularity
e⁻
γ
p
μ⁺
vertex location (Si detectors)
main tracking (gas or Si detectors)
particle identification
e.m. calorimetry
magnet coil
hadron calorimetry / return yoke
muon identification / tracking



ZEUS (HERA)

Software : SDRC-IDEAS level VI i
Performed by : Carsten Hartmann
Status : October 1993

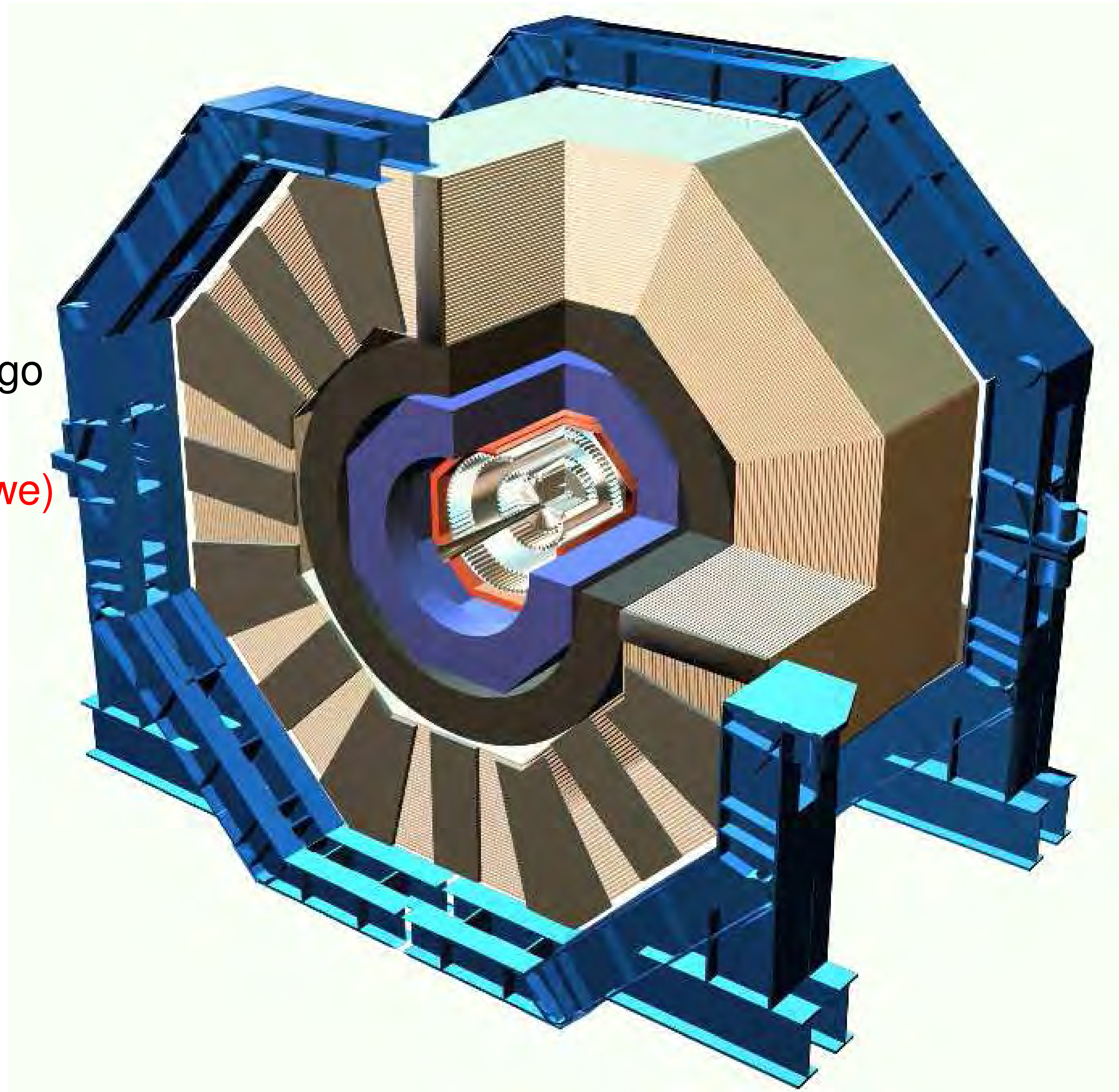
Compact Muon Solenoid

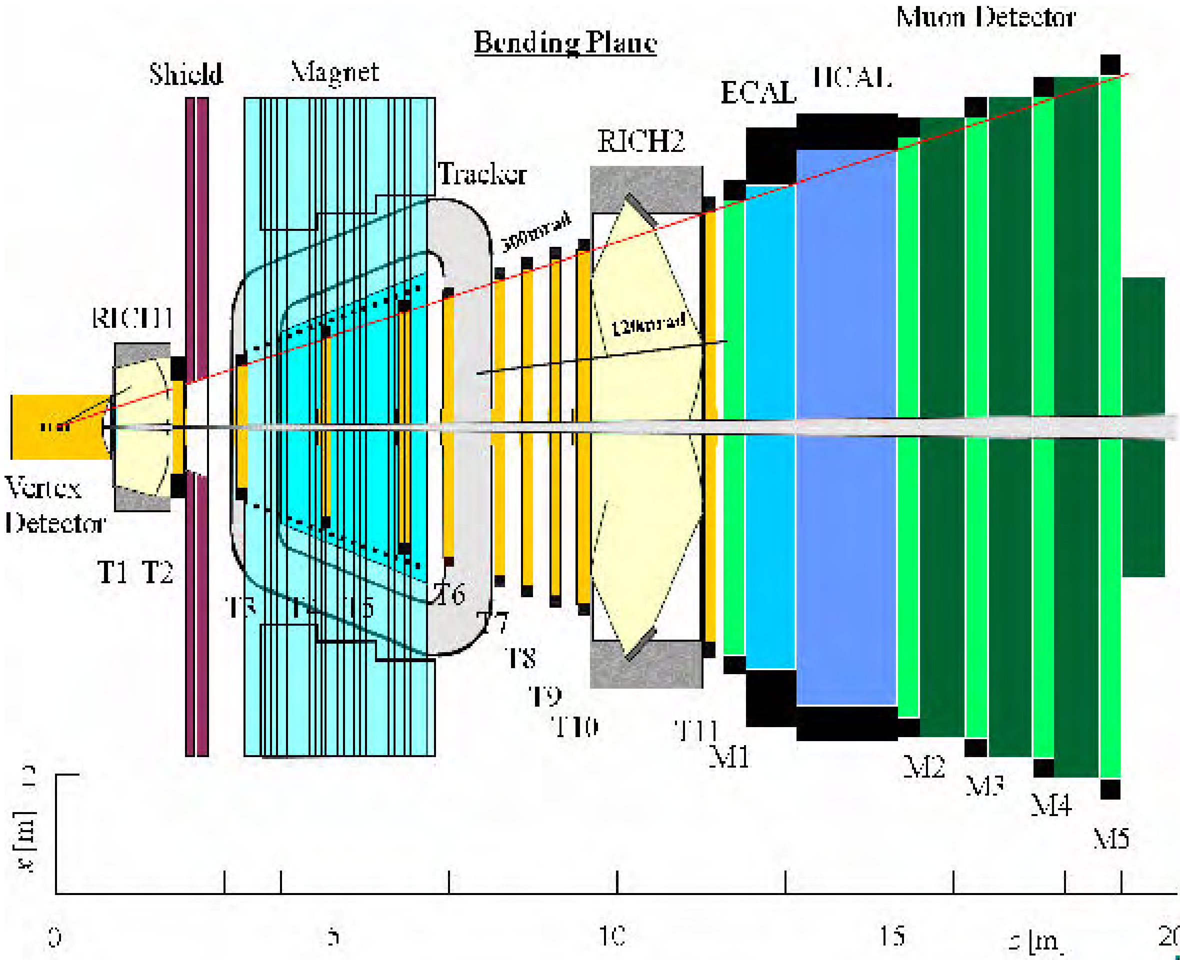


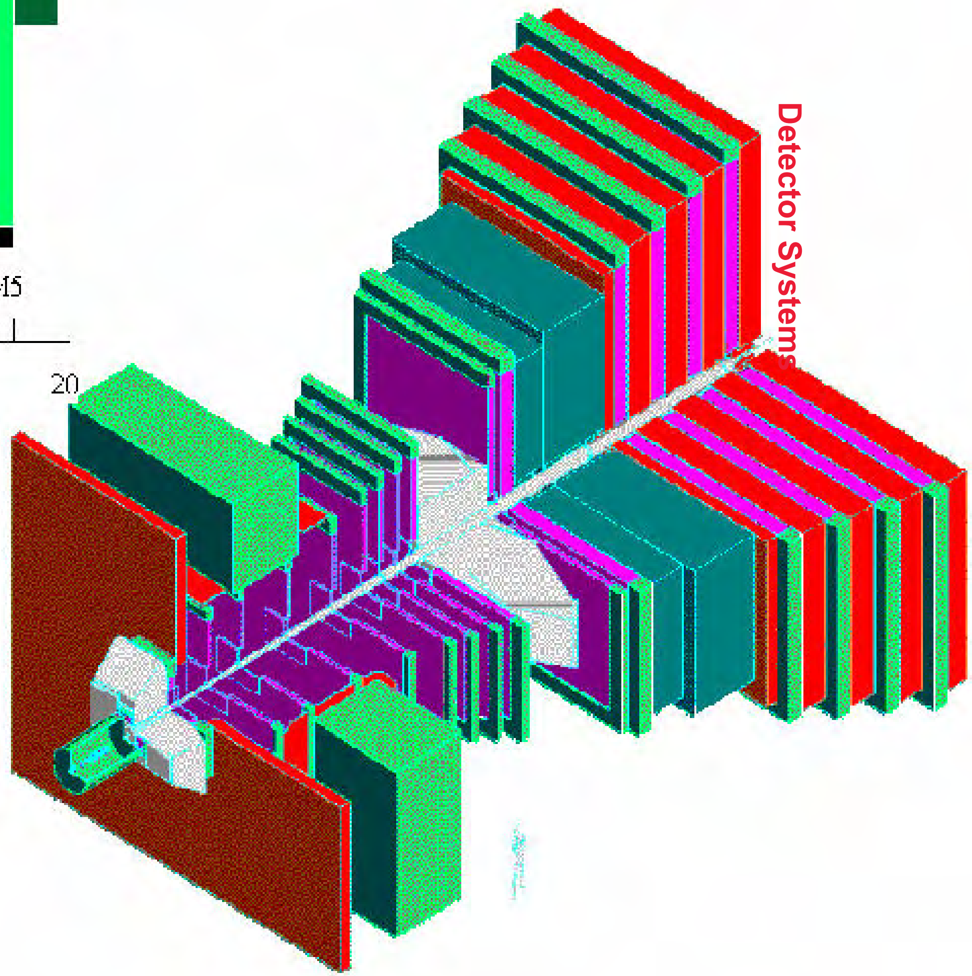
SiD

Projekt detektora dla eksperymentu przy ILC

Koncepcja detektora opartego w całości o detektory półprzewodnikowe (krzemowe)







Detector Characteristics

Length: 20 m

Width: 12 m

Height: 12 m

Weight: 2’000 tons

Generic features required of ATLAS and CMS

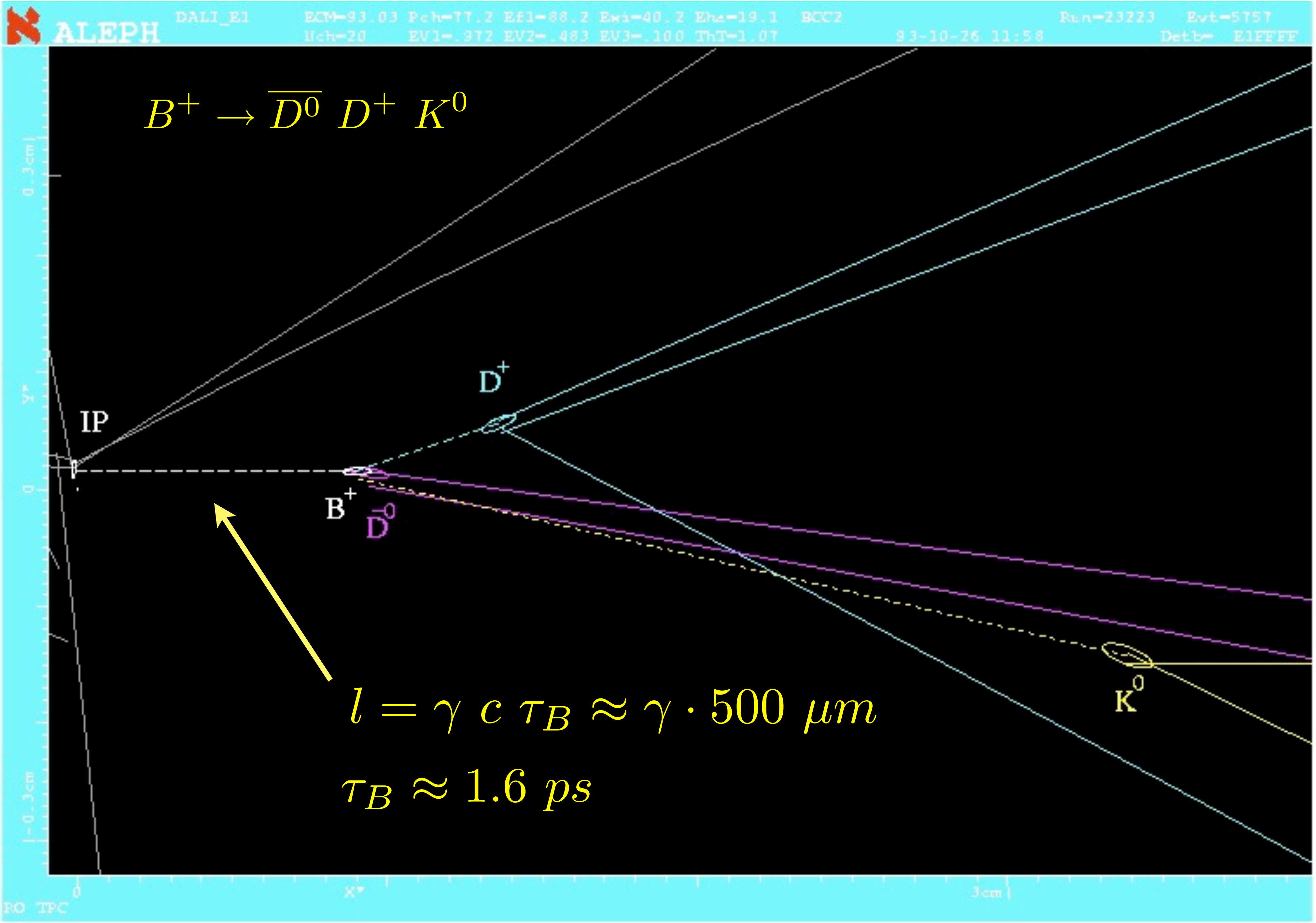
- **Detectors must survive for 10 years or so of operation**
  - **Radiation damage to materials and electronics components**
  - **Problem pervades whole experimental area (neutrons): NEW!**

- **Detectors must provide precise timing and be as fast as feasible**
  - **25 ns is the time interval to consider: NEW!**

- **Detectors must have excellent spatial granularity**
  - **Need to minimise pile-up effects: NEW!**

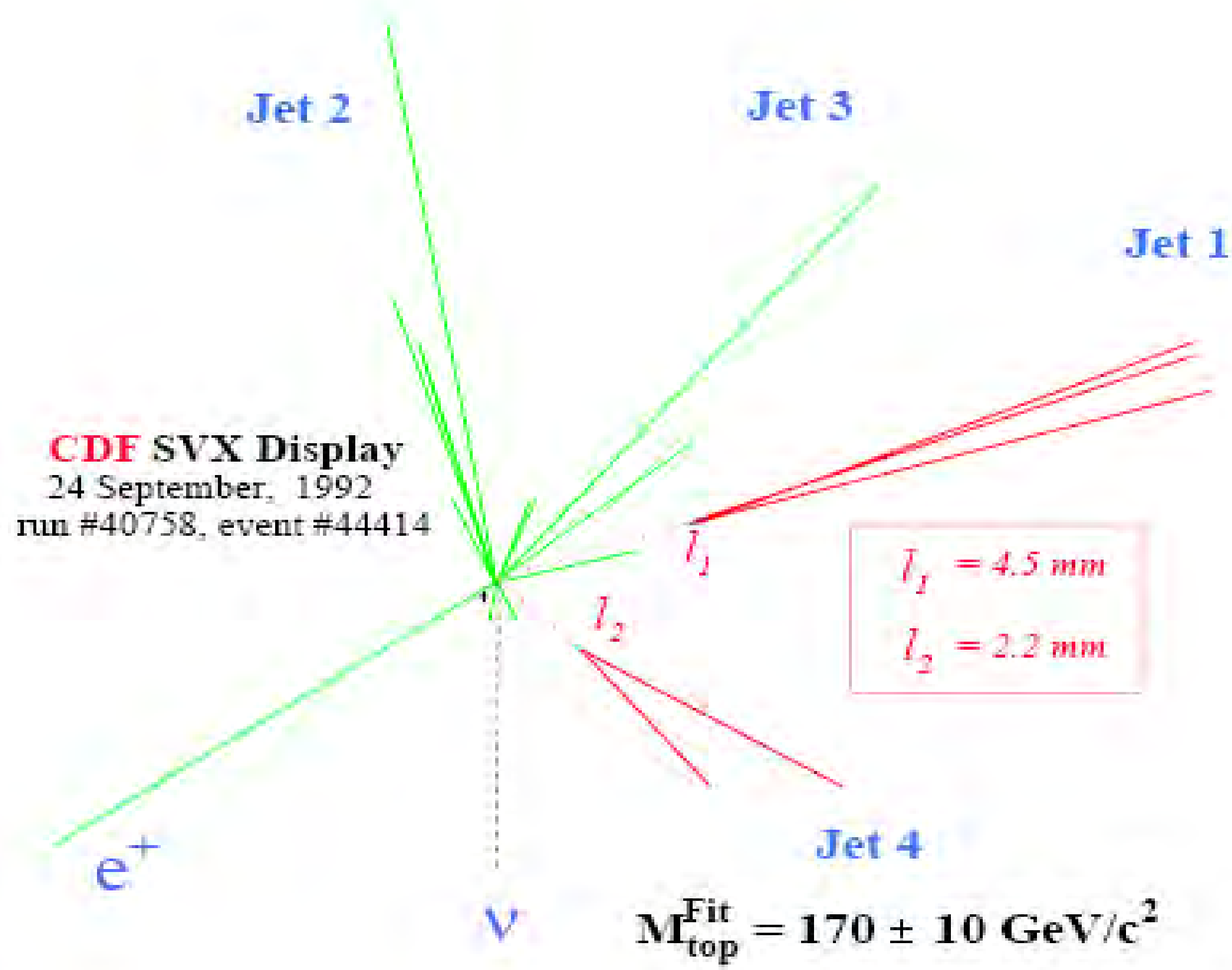
- **Detectors must identify extremely rare events, mostly in real time**
  - **Lepton identification above huge QCD backgrounds (e.g. /jet ratio at the LHC is ~ 10^{-5}, i.e. ~ 100 worse than at Tevatron)**
  - **Signal X-sections as low as 10^{-14} of total X-section: NEW!**

Detektor wierzchołka



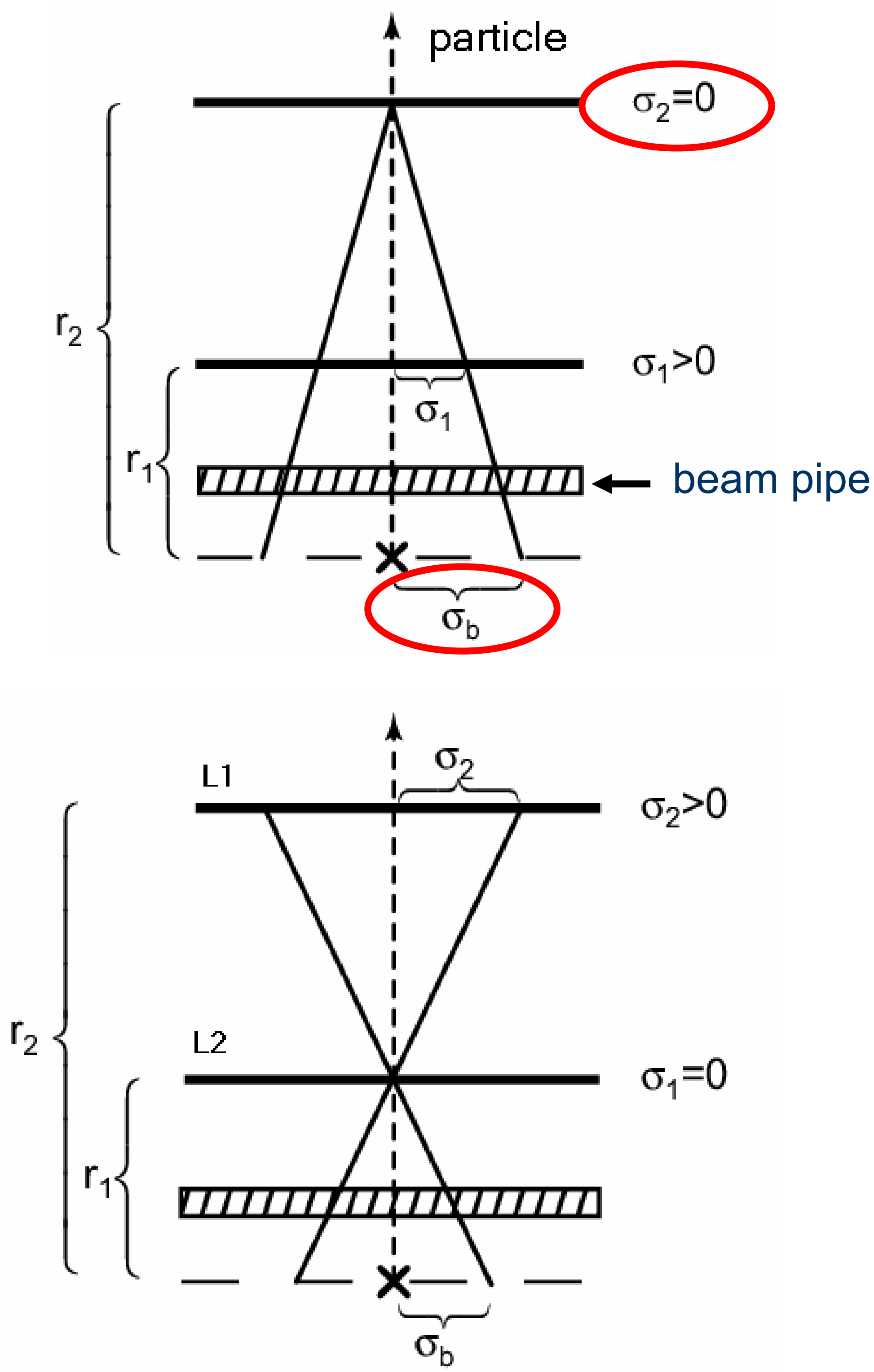
The life time of B-mesons can be measured from the decay length l, if the momentum of the B-meson (γ-factor) is measured as well.

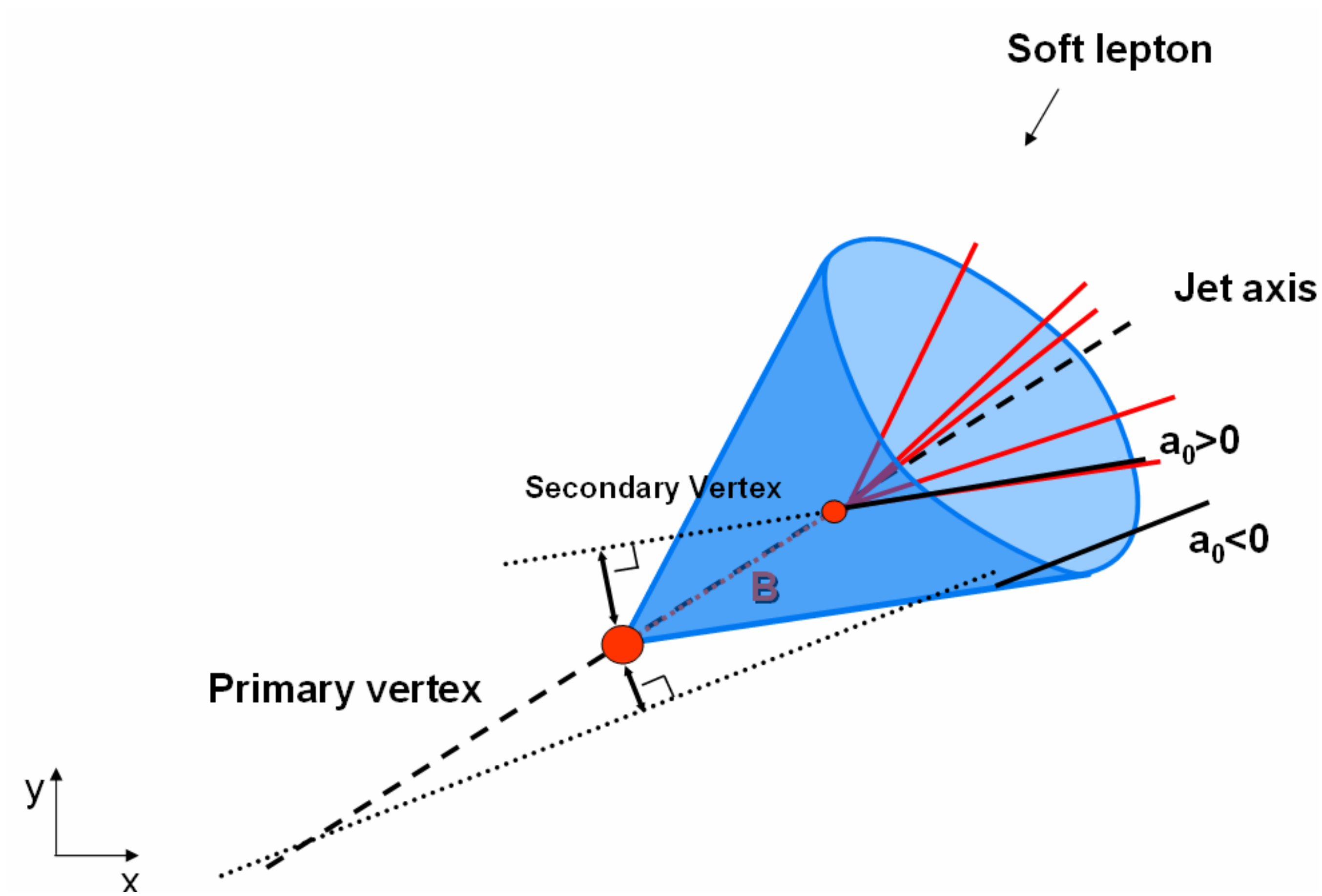
CDF's 1st Top Event… (run 1)



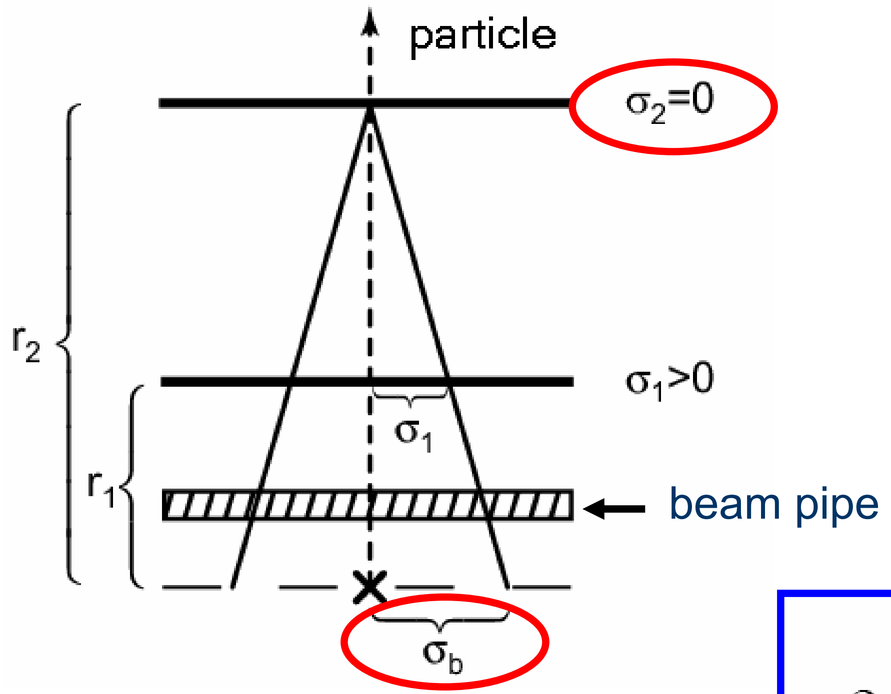
How to get best possible vertex resolution?

Impact parameter resolution (simplified)





Impact parameter resolution (simplified)

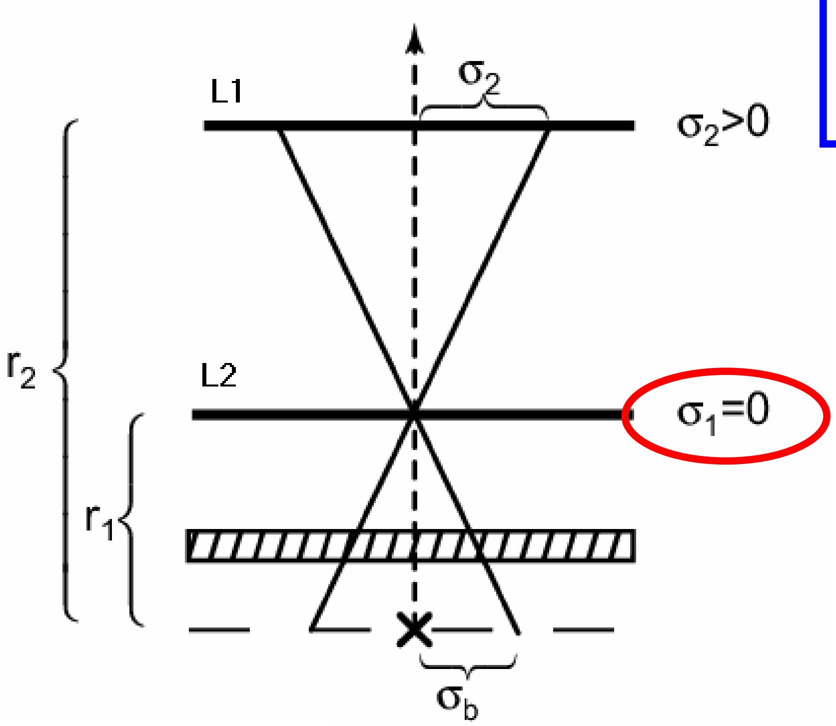


$$\frac{\sigma_b}{\sigma_1} = \frac{r_2}{r_2 - r_1}$$

small !

small !

$$\sigma^2 = \left(\frac{r_1}{r_2 - r_1}\,\sigma_2\right)^2 + \left(\frac{r_2}{r_2 - r_1}\,\sigma_1\right)^2 + \sigma_{MS}^2$$



$$\frac{\sigma_b}{\sigma_2} = \frac{r_1}{r_2 - r_1}$$

small x/X_0

$$\sigma_{MS} \sim \frac{1}{p}\sqrt{\frac{x}{X_0}}$$

Vertex Resolution

$x1, x2 =$ measurement planes

$y1\ , y2 =$ measured points, with errors δy

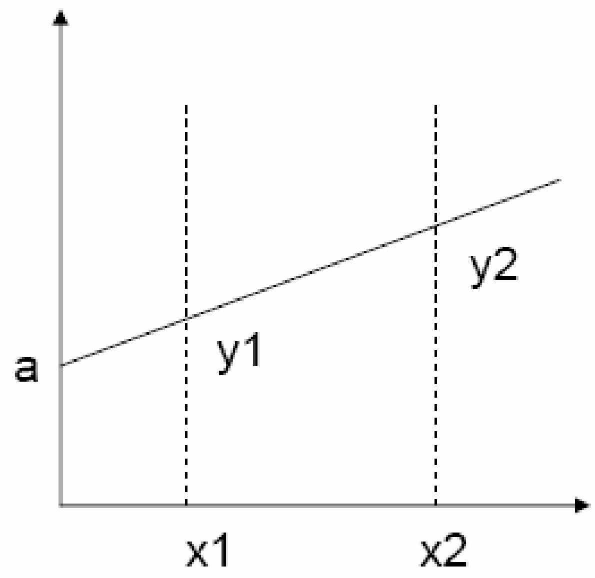
$$y = a + bx$$

$$b = \text{slope} = \frac{y1 - y2}{x1 - x2} = \frac{y1 - y2}{\Delta x}$$

$$a = \text{intercept} = \frac{1}{2}(y1 + y2) - \frac{1}{2}(y1 - y2)\left(\frac{x1 + x2}{\Delta x}\right) = \bar{y} - b\bar{x}$$

$$(\delta b)^2 = \left(\frac{\partial b}{\partial y1}\right)^2 (\delta y)^2 + \left(\frac{\partial b}{\partial y2}\right)^2 (\delta y)^2 \Rightarrow \delta b = \frac{\sqrt{2}\delta y}{\Delta x}$$

$$\delta a = \frac{\delta y}{2}\sqrt{1 + \frac{8\bar{x}}{\Delta x}}$$



for good resolution on angles (φ and θ) and intercepts (d, z_0)

- Precision track point measurements
- Maximize separation between planes for good resolution on intercepts
- Minimize extrapolation - first point close to interaction

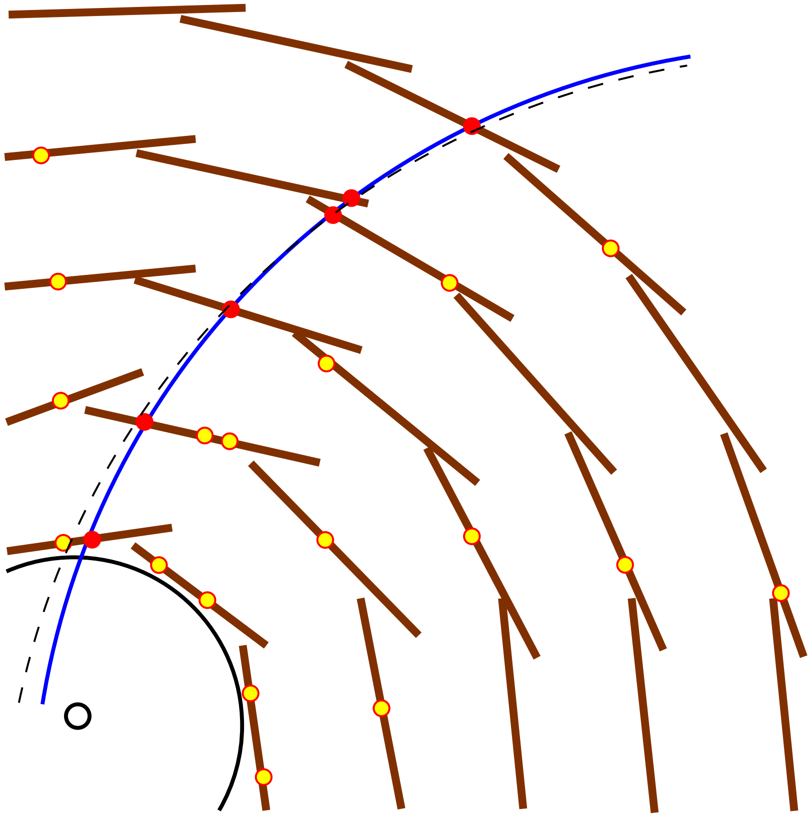
Detektor wierzchołka

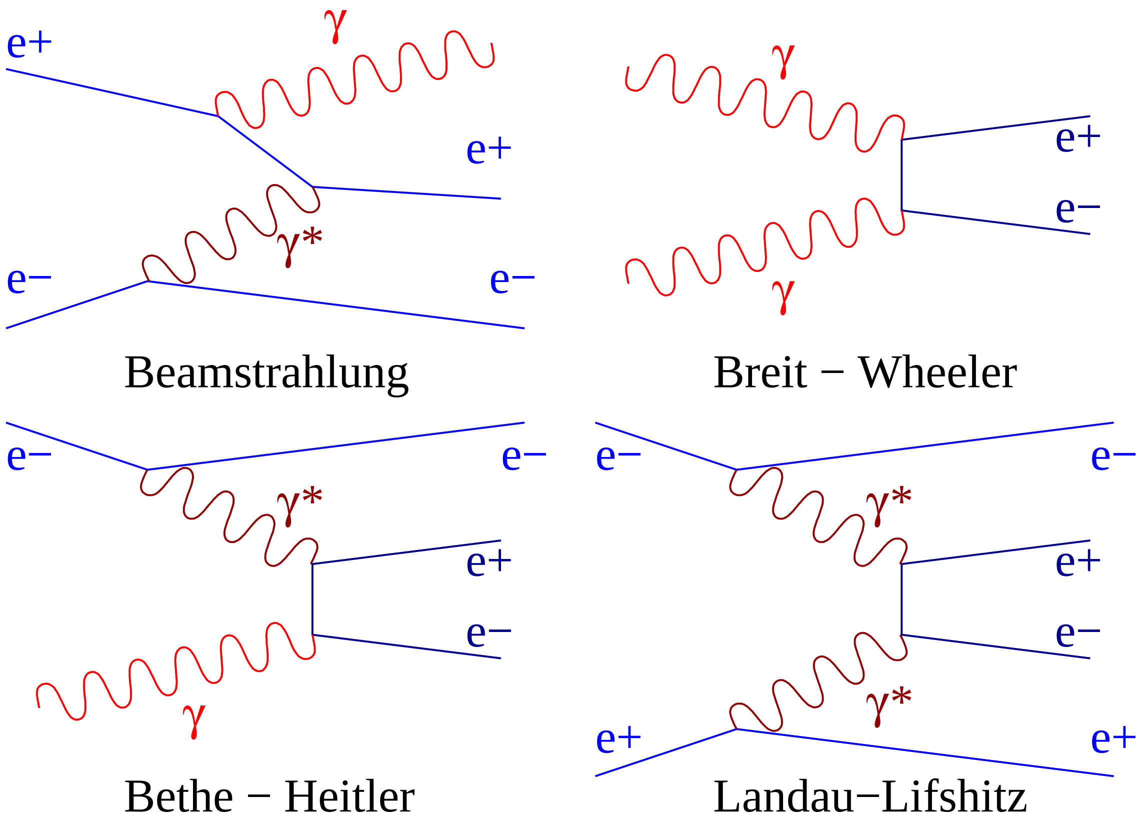
Odległość od osi wiązki: kluczowa dla wyniku pomiaru

precyzja pomiaru vs profil/tło wiązki

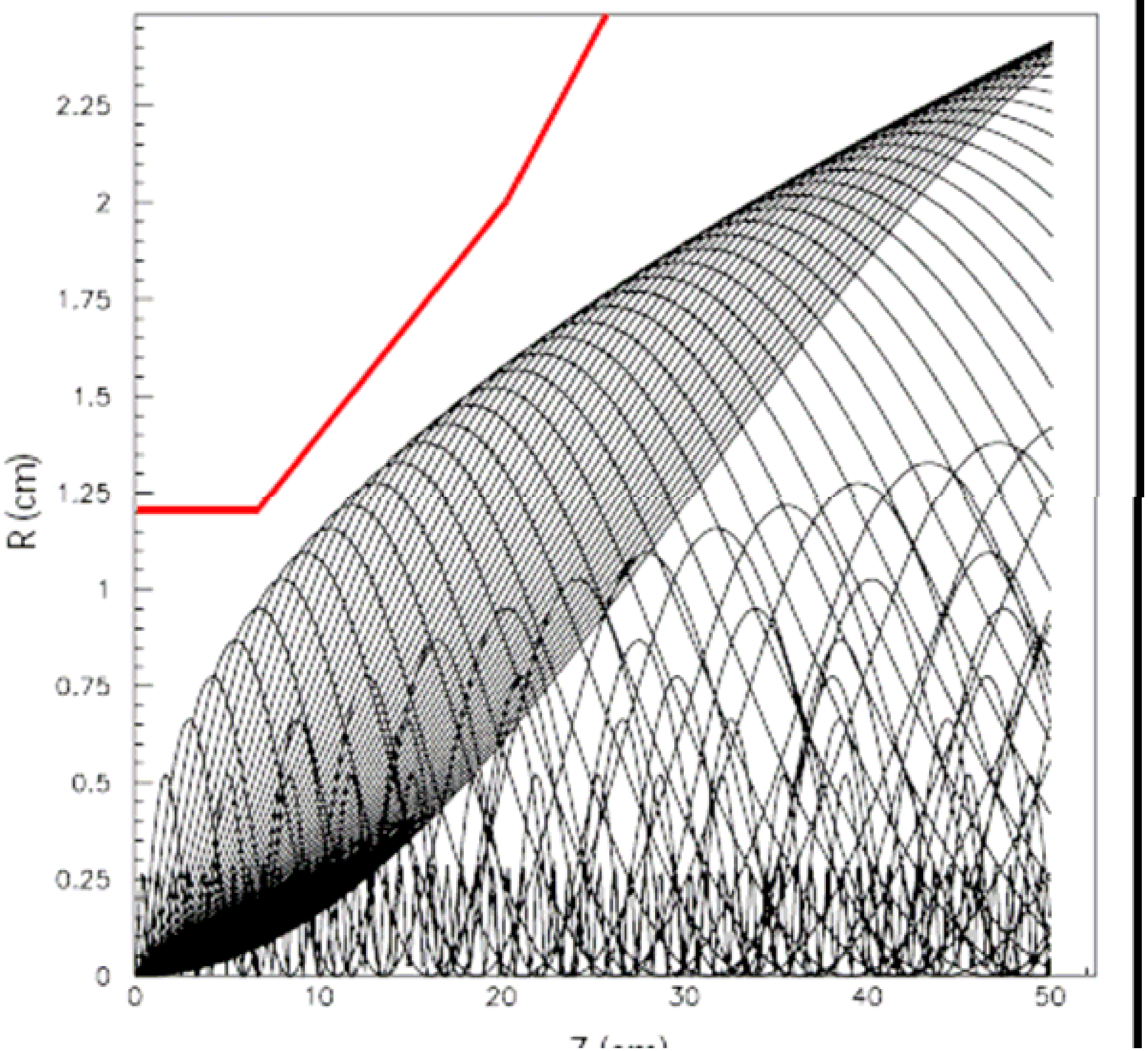
Co jeszcze wpływa na precyzję pomiaru?

W oddziaływaniu pomiędzy wiązkami powstają pary e^+e^- o małych pędach poprzecznych, z których część zostawia ślady (ang. "hit") w detektorze wierzchołka utrudniając rekonstrukcję innych torów. W pięciowarstwowym detektorze oczekuje się około 60 000 dodatkowych "hitów".



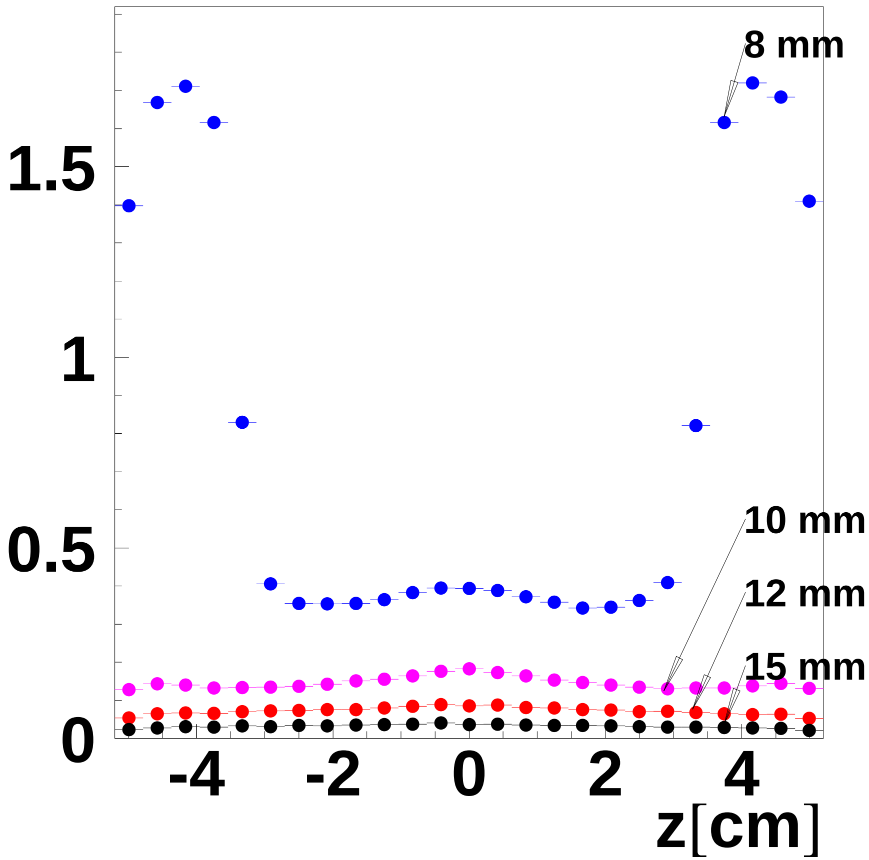


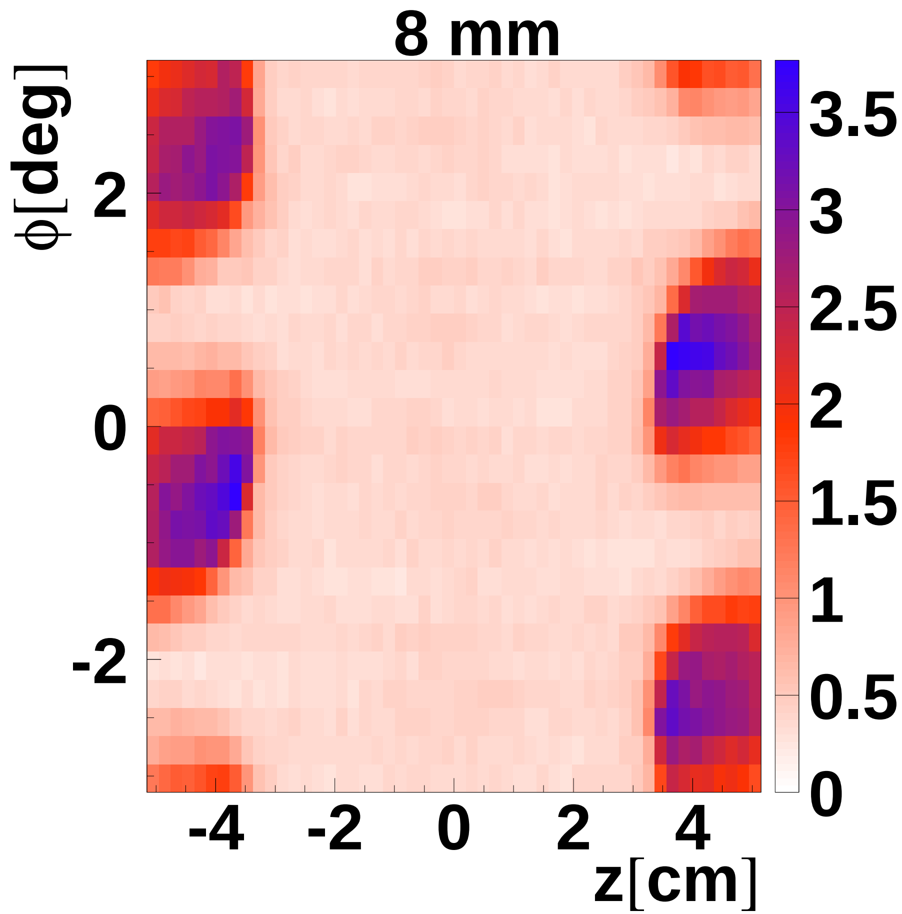
Background level at ILC depends strongly on B



Gęstość śladów w pierwszej warstwie [1/mm^2/BX]

Pary e^+e^- symulowane za pomocą Guinea Pig. Gęstości liczone dla różnych wartości promienia pierwszej warstwy.

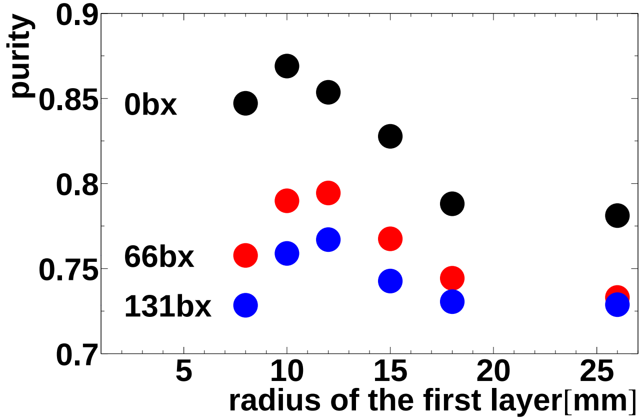


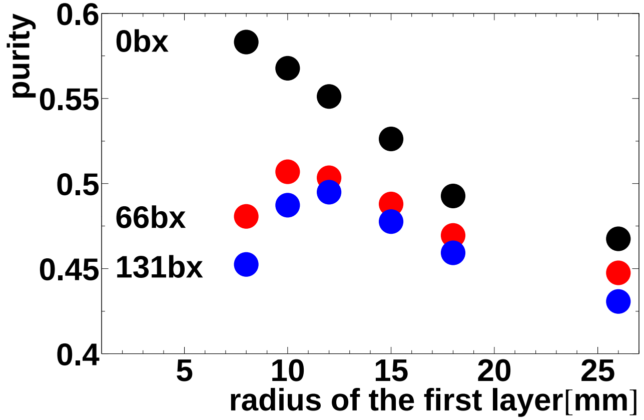


Jet flavour tagging performance

b selection | c selection

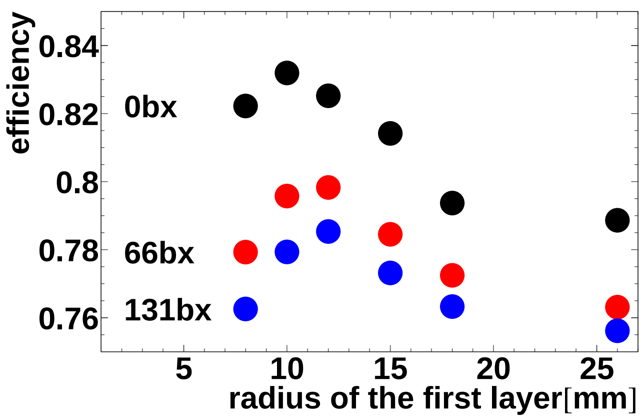
Efficiency 0.8

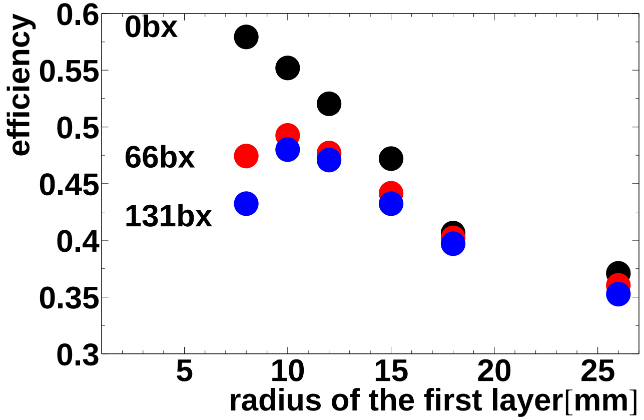




Efficiency 0.6

Purity 0.8





Purity 0.6

Spatial resolution 4 μm, layer thickness 0.1% X_0. R$_1 = 26$ mm - only 4 layers.

Detektor wierzchołka

Odległość od osi wiązki:

precyzja pomiaru (ekstrapolacja) vs tło wiązki

Segmentacja (rozmiar piksela):

precyzja pomiaru vs objętość danych, straty mocy

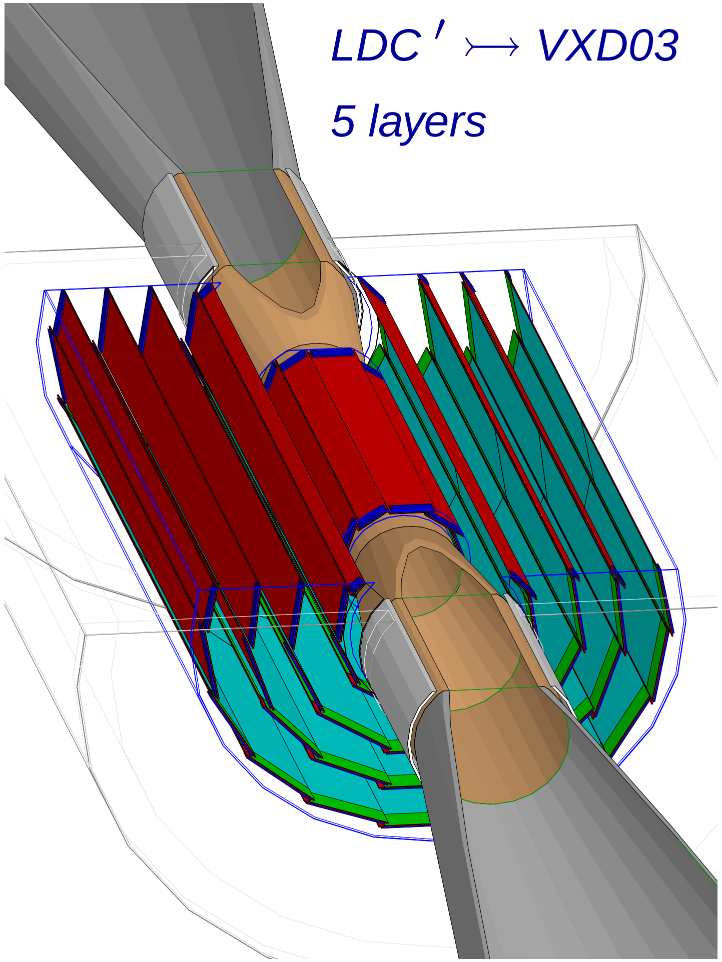
Technologia:

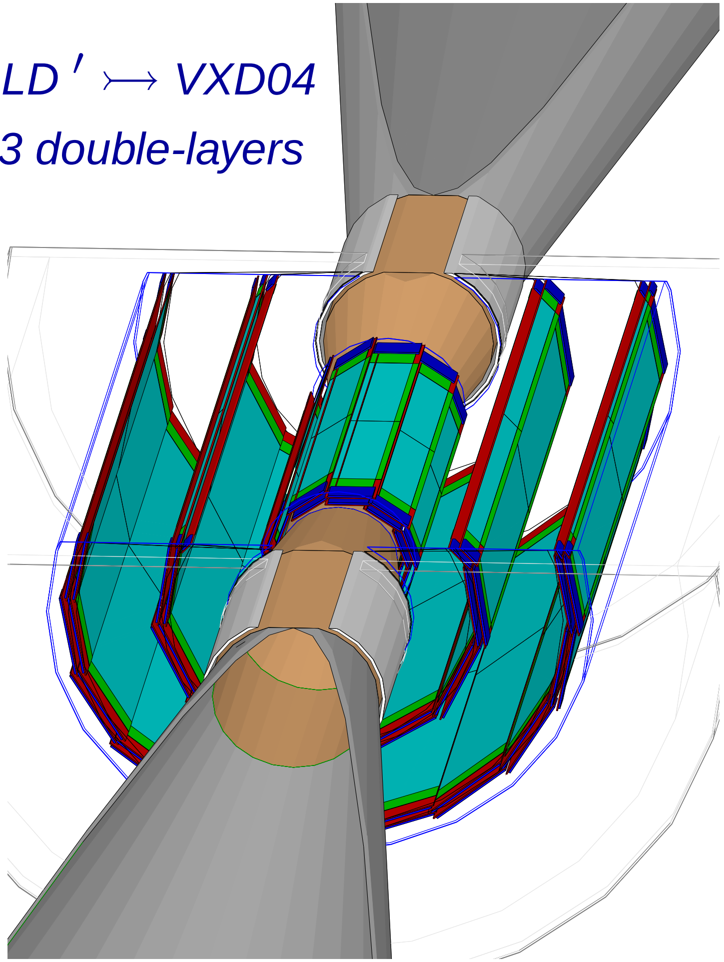
odporność radiacyjna vs koszt, szybkość odczytu

Grubość detektora:

rozpraszanie vs stabilność mechaniczna

- Maintain 2 alternative long-barrel approaches :

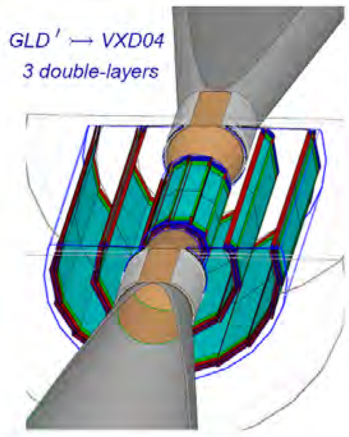


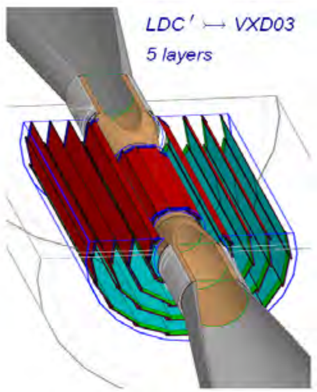


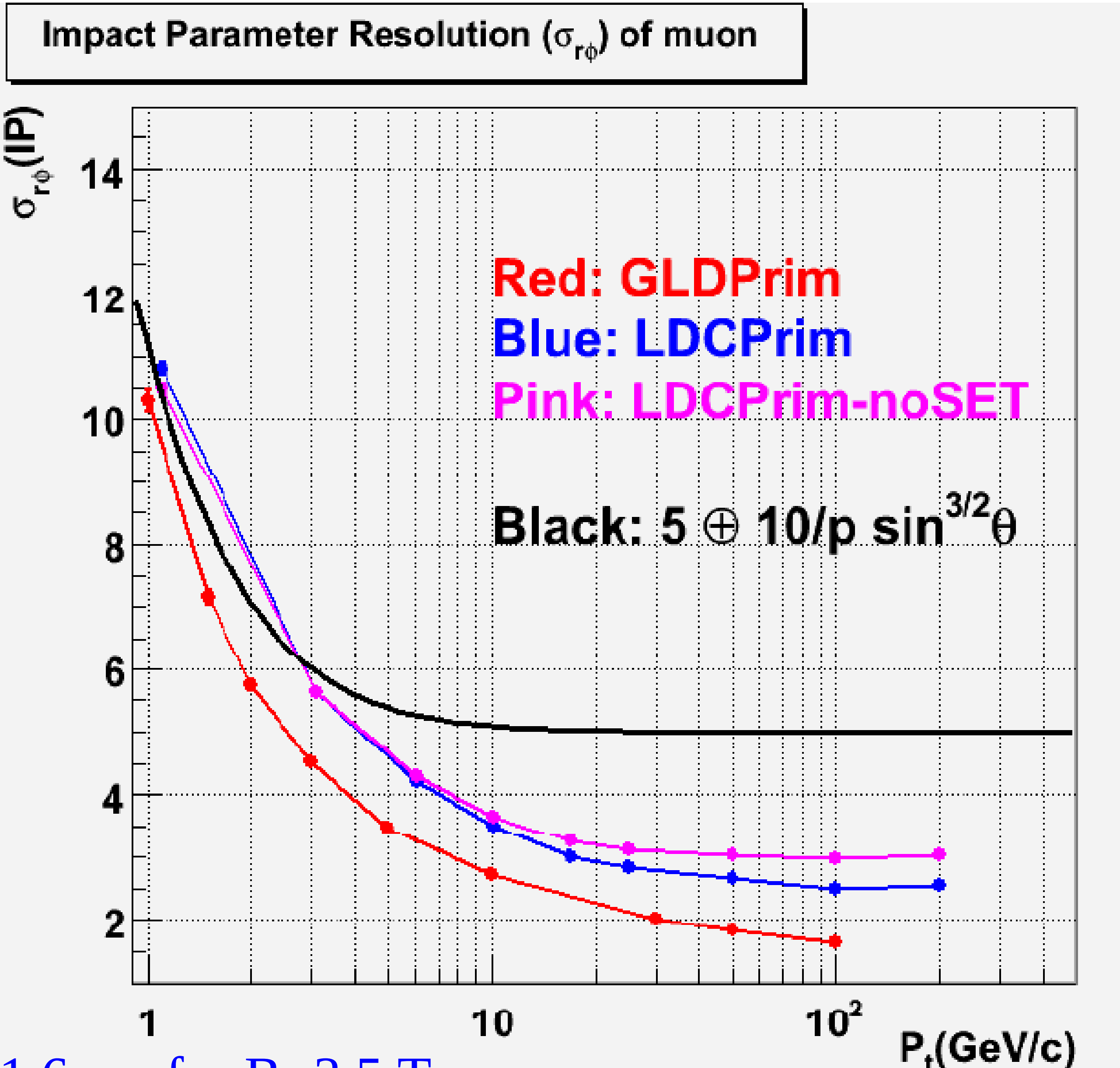
- Two read-out modes considered :
  - **continuous** *read-out*
  - *read-out* **delayed** *after bunch-train ⟼ 3 double layers expected to help*

    ⇛ mini-vectors

Vertex Detector



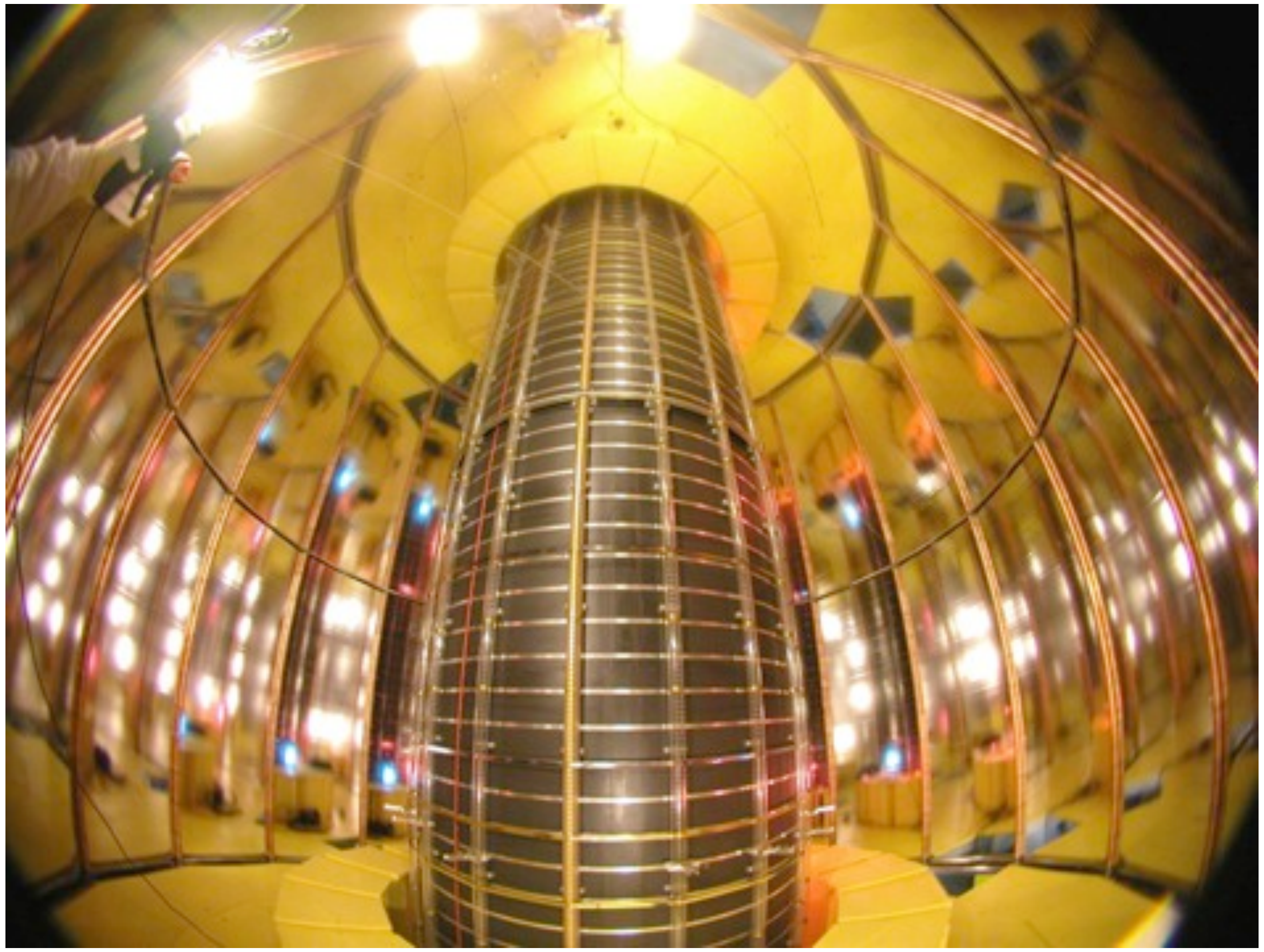




Inner layer at r=1.6 cm for B=3.5 T

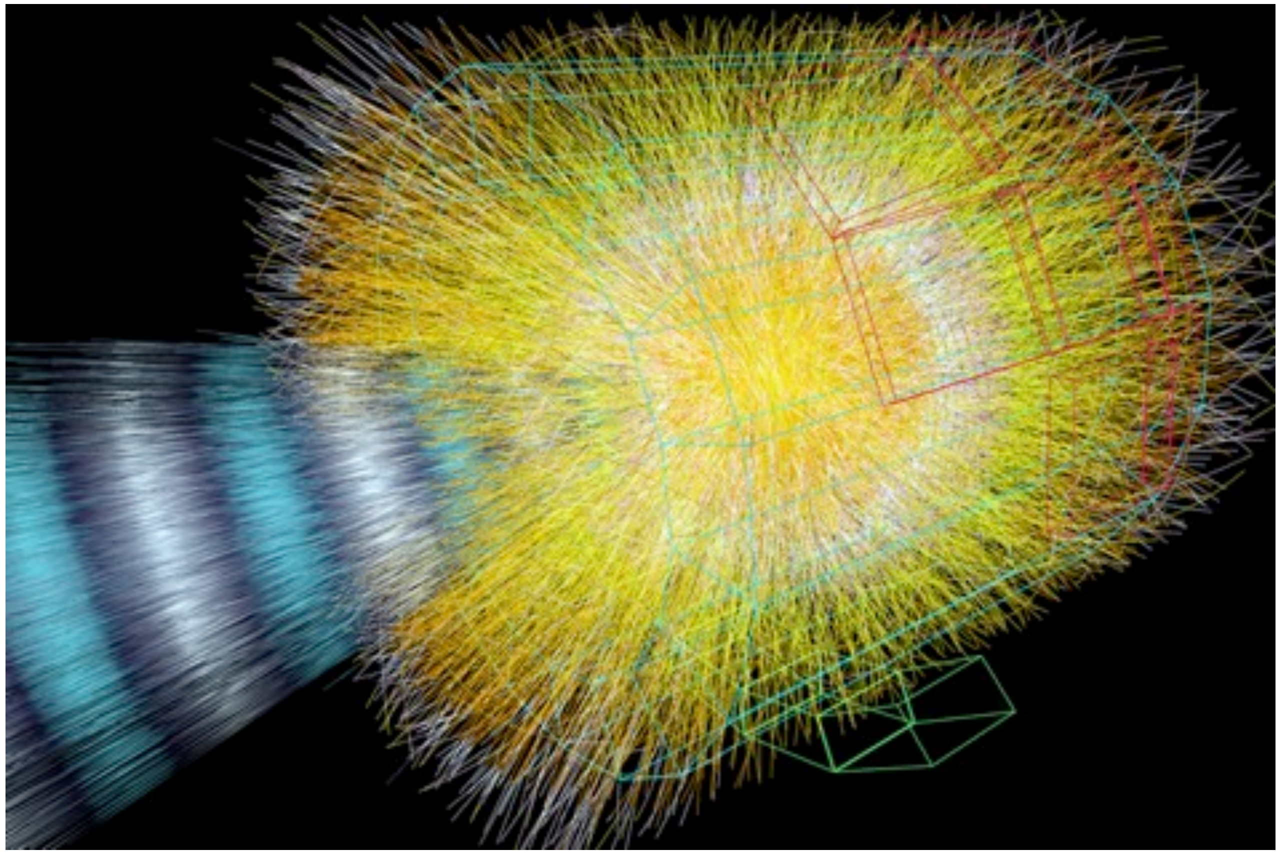
Centralny detektor śladowy

6. ALICE TPC

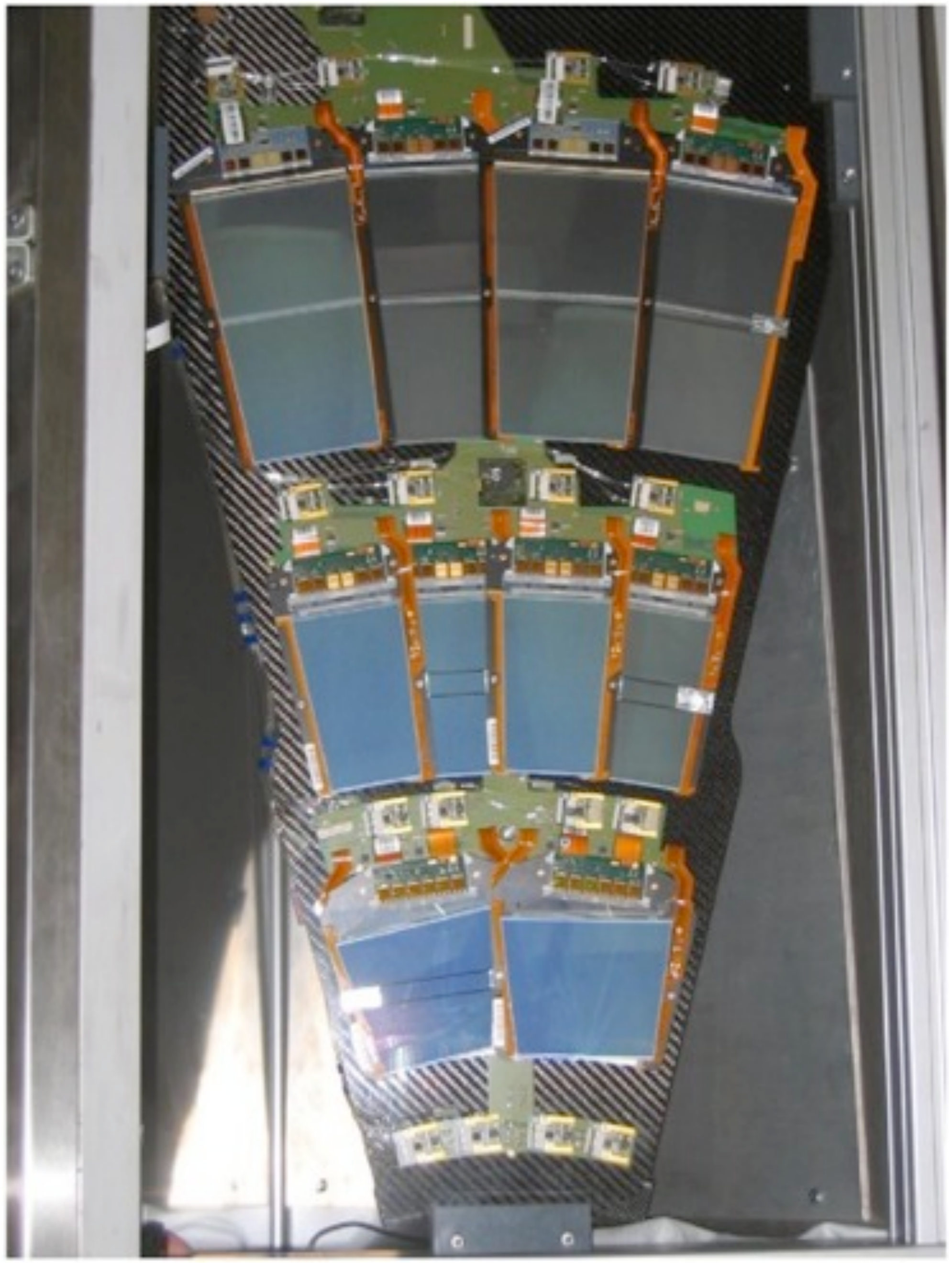


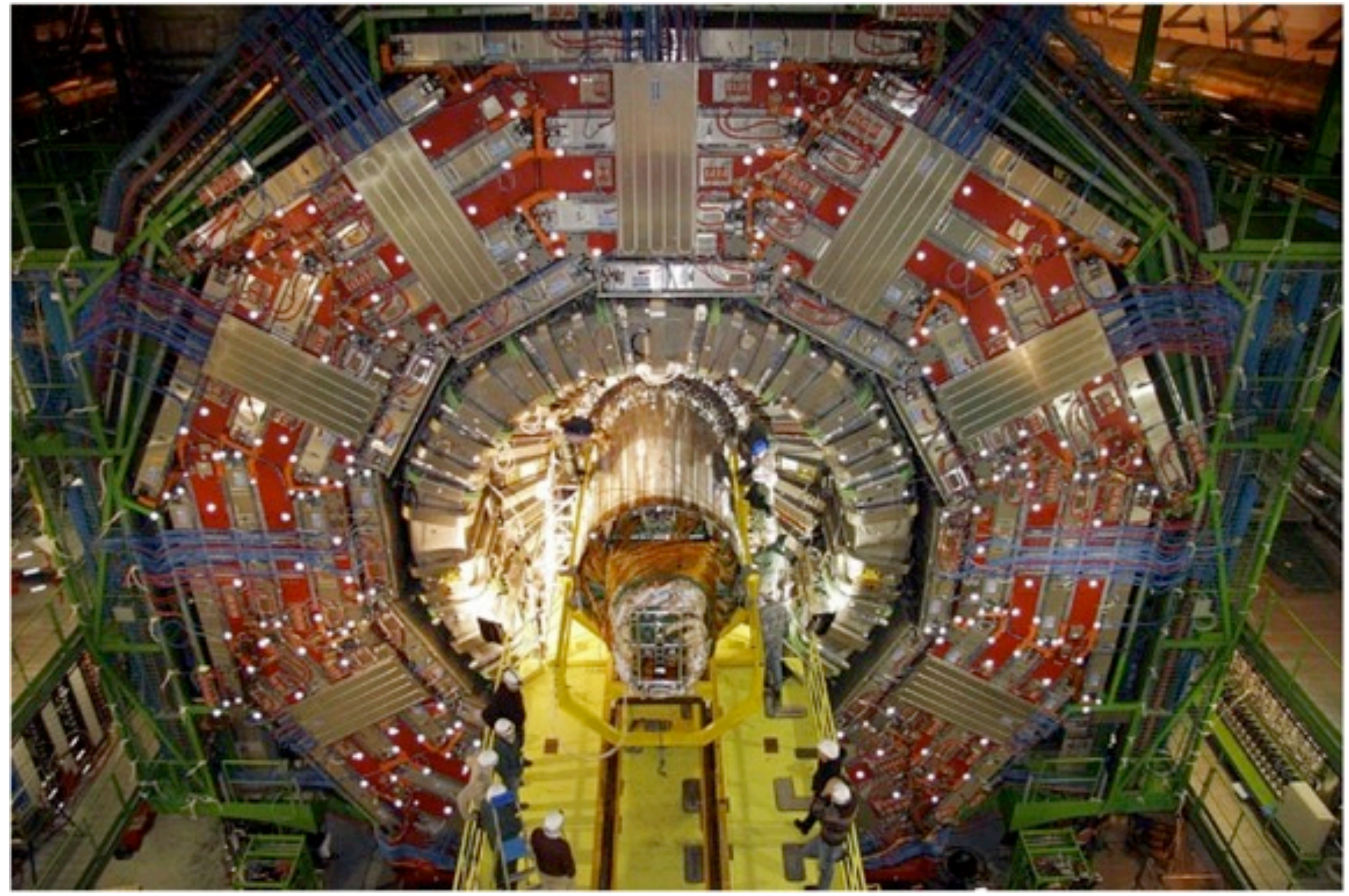
View inside the ALICE TPC

Simulated heavy ion collision in the ALICE TPC.



14. CMS Silicon Tracker

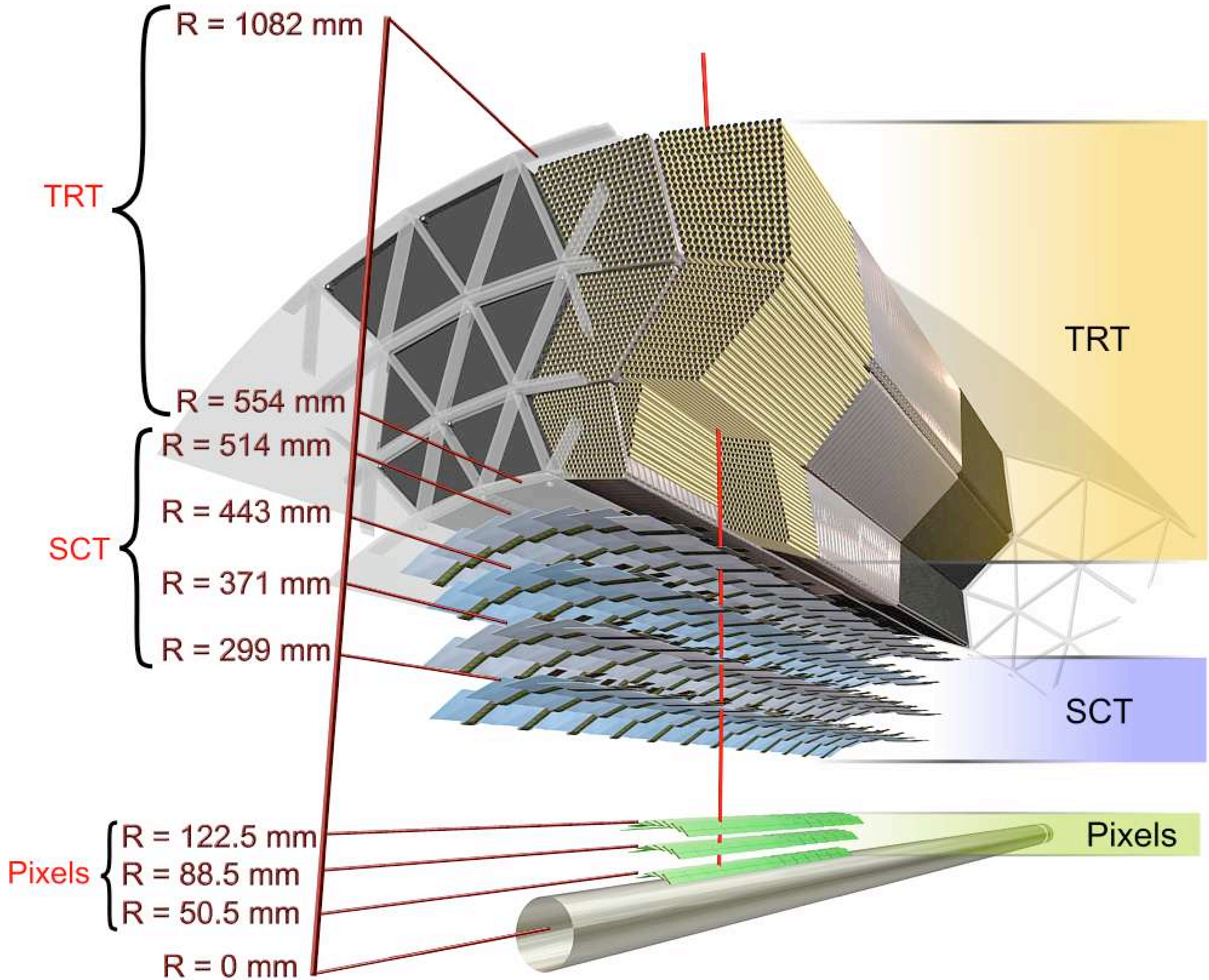




Micro Strip:
- 214 m^2 of silicon strip sensors
- 11.4 million strips
- Diameter: 2.4 m

Pixel:
- Inner 3 layers: silicon pixels (~ 1 m^2)
- 66 million pixels (100x150 μm^2)
- Precisio: $\sigma(r\varphi) \sim \sigma(z) \sim 15\ \mu m$

14. ATLAS - Sensors traversed by charged track



Charged track of p_T =10 GeV at η=0.3. traverses:

- beryllium beam pipe
- 3 pixel layers
- 4 double SCT layers
- about 36 TRT straws

Centralny detektor śladowy

Różne możliwe technologie:
- komora projekcji czasowej
- detektory półprzewodnikowe
- detektory gazowe

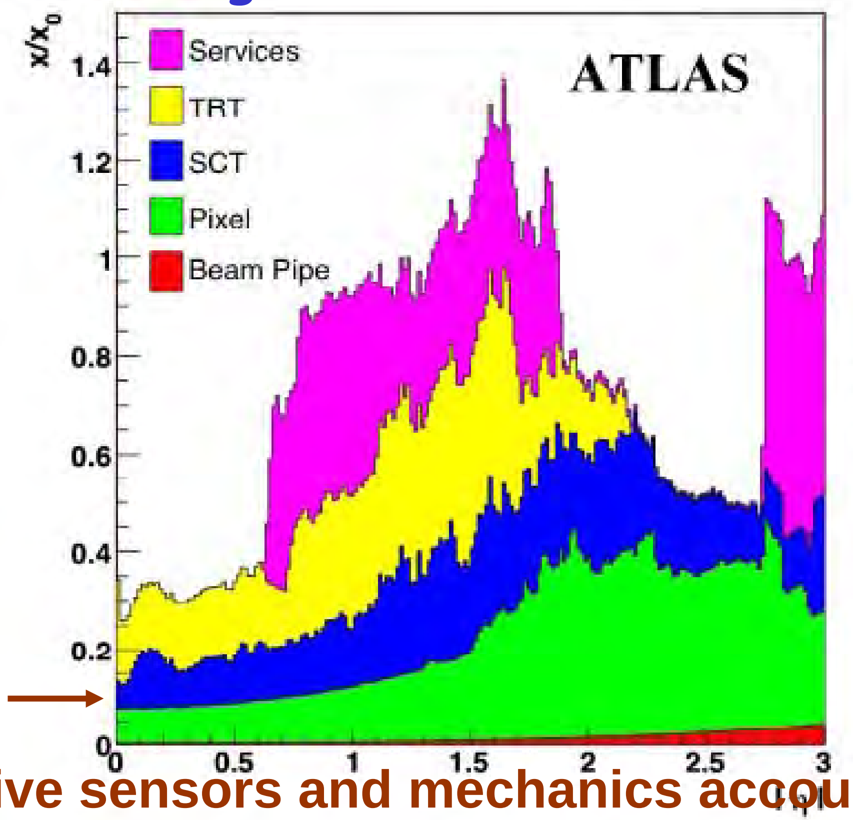
Każda ma swoje zalety i wady. Wszystko należy uwzględnić:

+ precyzja pomiaru położenia (Si, gas)
  => precyzja pomiaru pędu (geometria, rozmiar, pole magnetyczne)
+ precyzja pomiaru dE/dx (TPC, Si)
+ liczba punktów pomiarowych (TPC, Si)
+ czas odczytu (Si, TPC)
+ wpływ tła, nakładających się przypadków
+ tło kombinatoryczne
+ ew. inne funcje (np. TRD)
+ gwielokrotne rozpraszanie/**bilans materiału przed kalorymetrem**

ATLAS/CMS: from design to reality

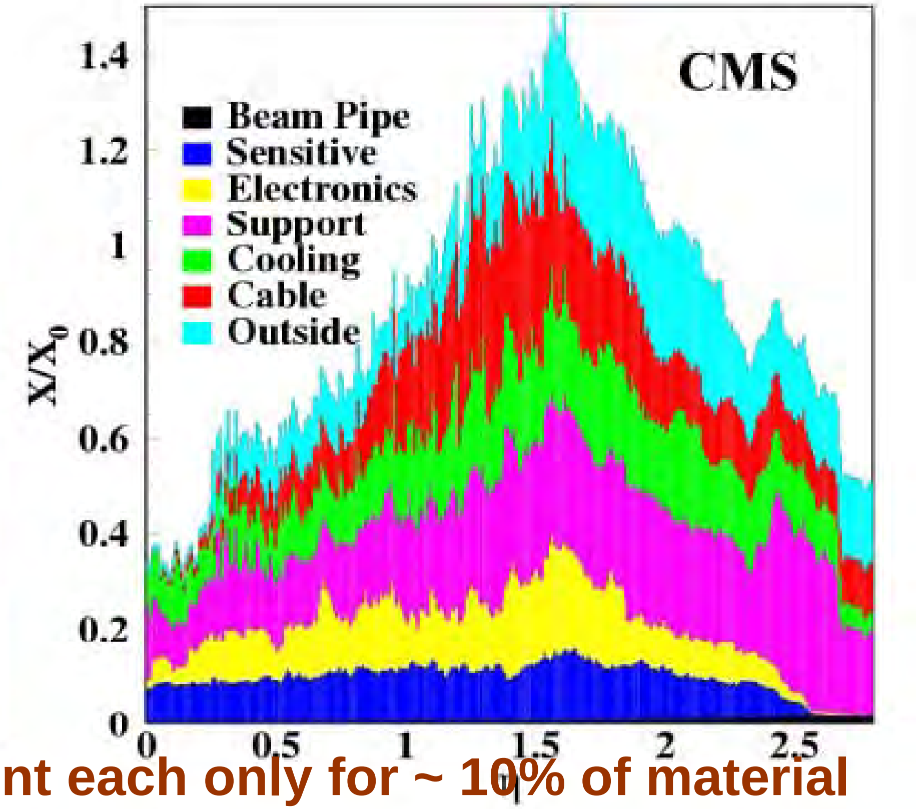
Amount of material in ATLAS and CMS inner tracker

Weight: 4.5 tons



LEP detectors

Weight: 3.7 tons

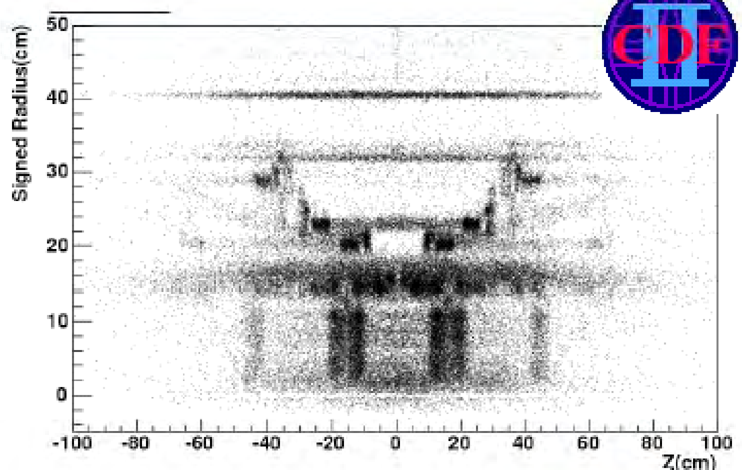


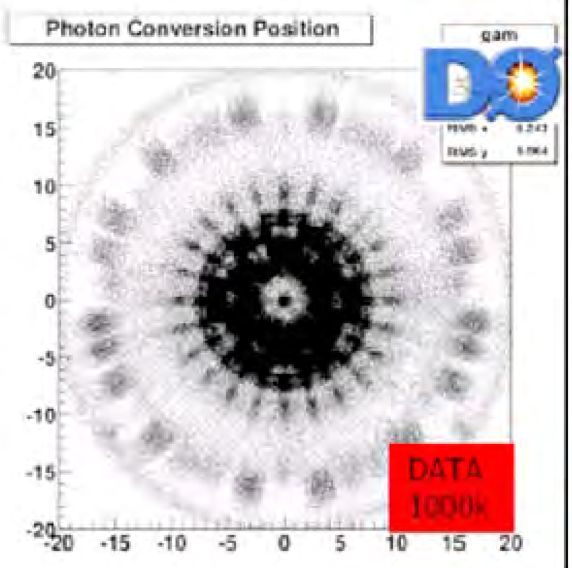
- Active sensors and mechanics account each only for ~ 10% of material budget
- Need to bring 70 kW power into tracker and to remove similar amount of heat
- Very distributed set of heat sources and power-hungry electronics inside volume: this has led to complex layout of services, most of which were not at all understood at the time of the TDRs

Can lessons be learned from Tevatron?

Material: X-raying the detector

- Conversions can indicate location of material in detector
  - → Normalized to inner cylinder of tracking chamber
  - → Overall normalization difficult
    - ➢ Acceptance and efficiency depend on r
- Useful to find missing (or misplaced!) pieces

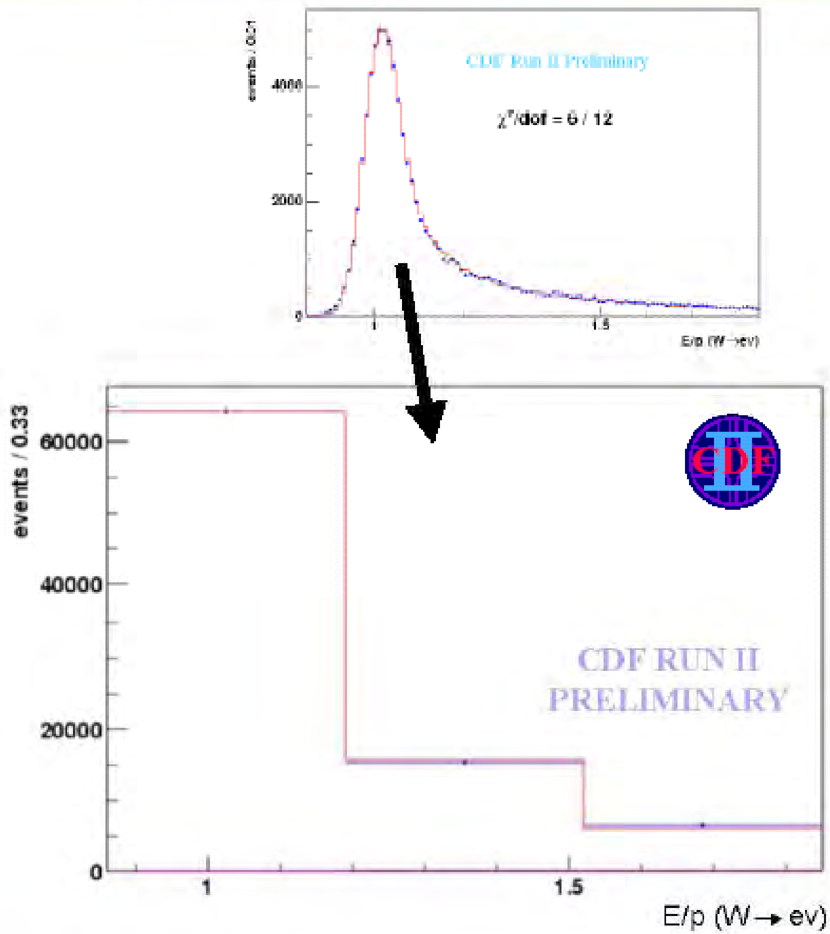




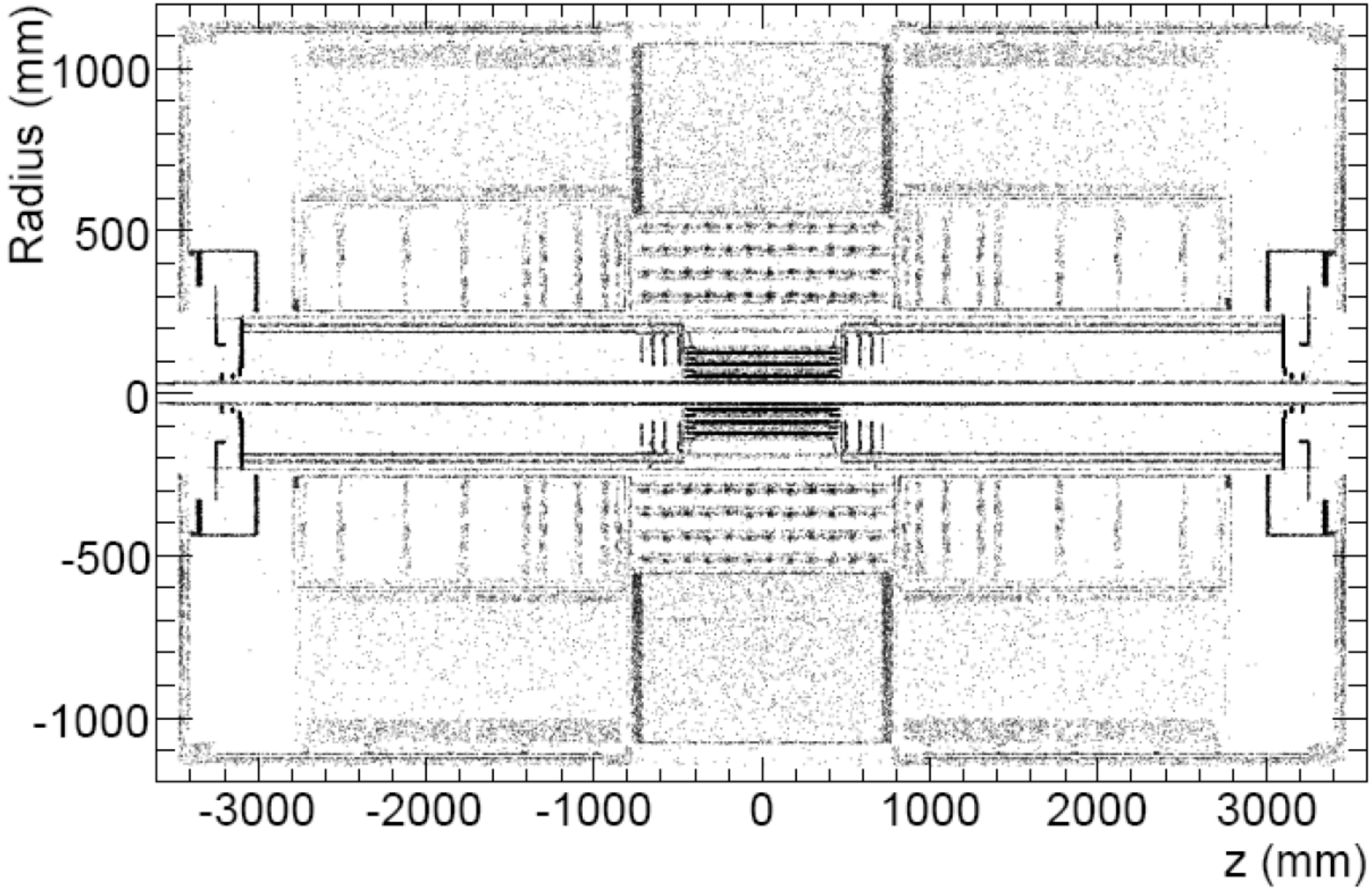
Can lessons be learned from Tevatron?

Material from E/P

- Use radiative tail of E/P to measure material
- Gives average material
- Can be combined with energy-loss measurements of muons (J/ψ) to give roughly type of material
  - → CDF discovered it was missing Copper cables this way



Photon Conversion Image of Material

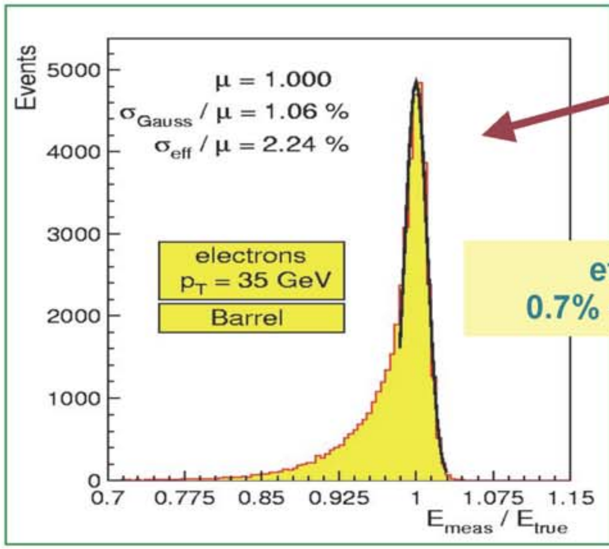


ATLAS simulation

Electrons are affected too

Effects of material in front

CMS

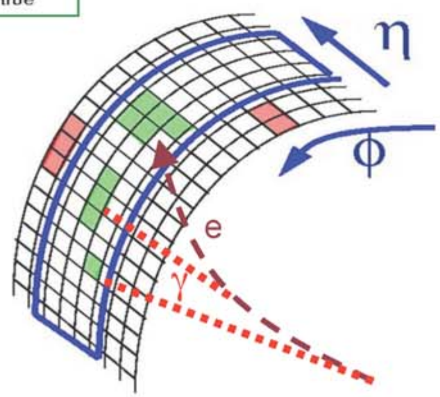


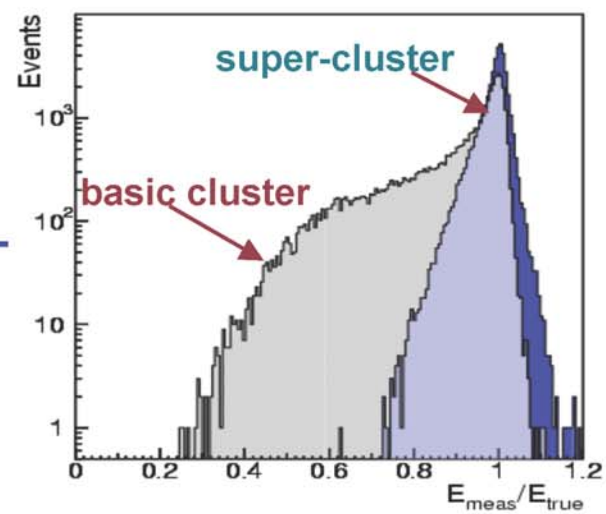
50% electrons undergo

non-negligible bremsstrahlung

effect on resolution at p_T 35 GeV:
0.7% → 1.06% (gauss) → 2.2 % (effective)

dynamic clustering algorithms (superclusters) can resum photon energies





Kalorymetry

Projektując kalorymetr chcielibyśmy zoptymalizować:

- dokładność pomiaru energii (w rozważanym zakresie)
- dokładność rekonstrukcji pozycji (pęd poprzeczny, matching toru)
- możliwość pomiaru kierunku i/lub czasu
- możliwość rekonstrukcji profilu kaskady (identyfikacja)

Niestety nie można wszystkich tych parametrów polepszyć jednocześnie

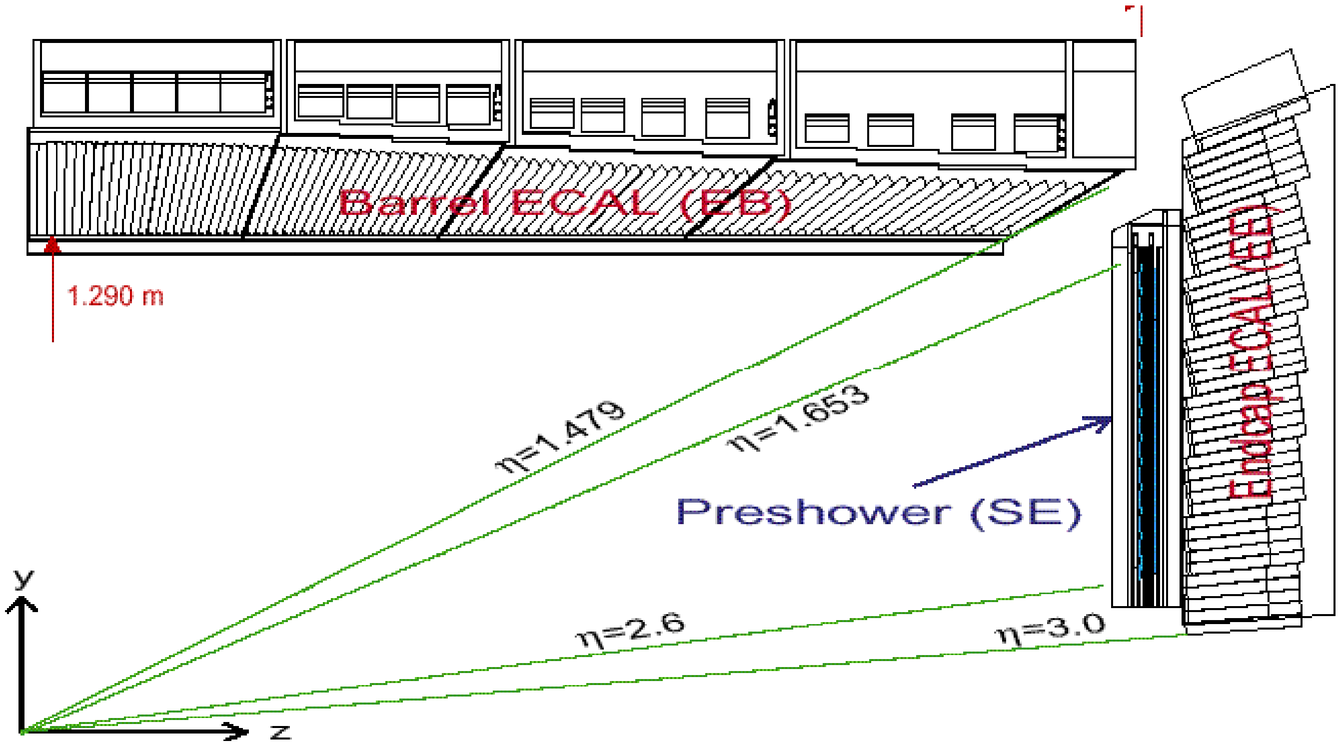
Pomiar energii: kalorymetr jednorodny, minimalna segmentacji
Pomiar pozycji: duża segmentacja poprzeczna
Pomiar kierunku i profilu kaskady: duża segmentacja podłużna

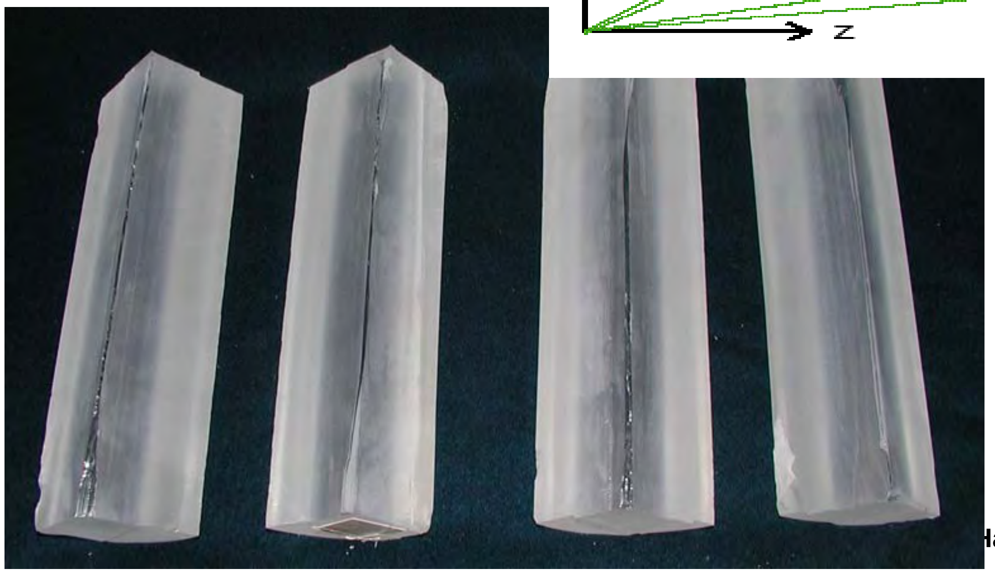
Trzeba optymalizować pod kątem fizyki: procesy "wzorcowe"

Koszt ogranicza wybór materiałów, rozmiary i liczbę kanałów...

Electrons and photons in ATLAS/CMS

CMS $PbWO_4$ crystal calorimeter

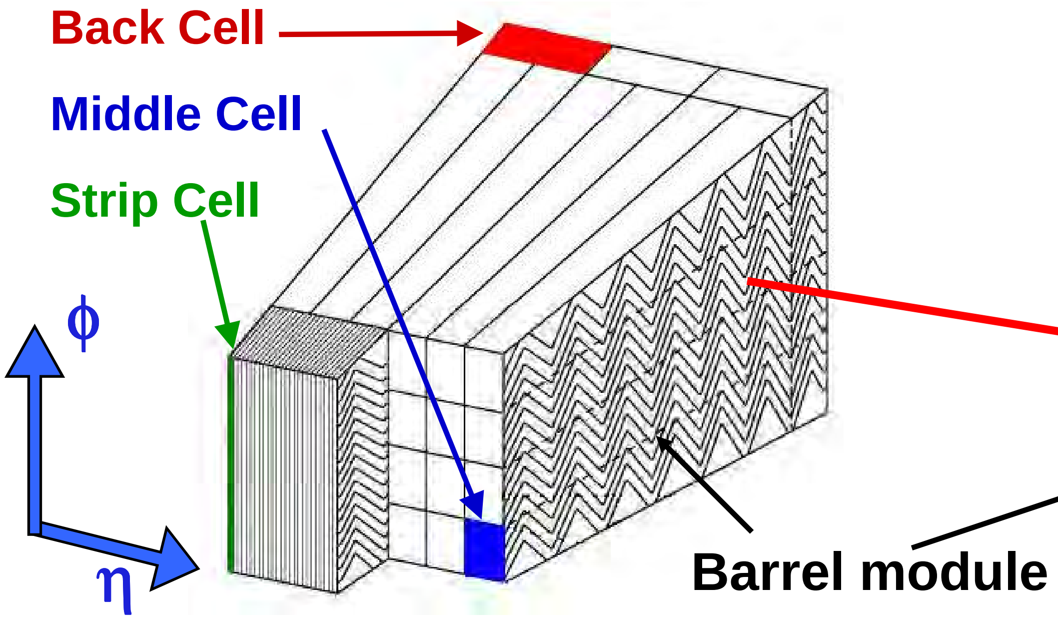


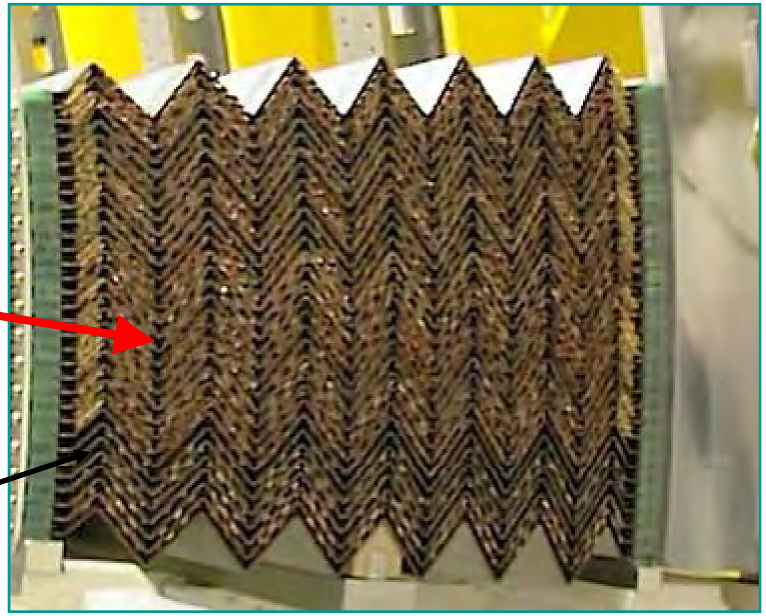


- Barrel: 62k crystals 2.2 x 2.2 x23 cm
- End-caps: 15k crystals 3 x 3 x 22 cm

Electrons and photons in ATLAS/CMS

ATLAS LAr EM Calorimeter description





EM Calo (Presampler + 3 layers):

- **Presampler** 0.025x0.1 (ηxϕ)
  ⇒ *Energy lost in upstream material*
- **Strips** 0.003x0.1 (ηxϕ)
  ⇒ *optimal separation of showers in non-bending plane, pointing*
- **Middle** 0.025x0.025 (ηxϕ)
  ⇒ *Cluster seeds*
- **Back** 0.05x0.025 (ηxϕ)
  ⇒ *Longitudinal leakage*

- **LAr-Pb sampling calorimeter (barrel)**
- **Accordion shaped electrodes**
- **Fine longitudinal and transverse segmentation**
- **EM showers (for $e^{\pm}$ and photons) are reconstructed using calorimeter cell-clustering**

LHC benchmark: SM H→ γγ

1) Irreducible background from qq → γγ and gg → γγ (box)

2) Reducible background from π^0,η (→ γγ) in jet fragmentation:
   - final states with many photons → look for single photons
   - non-isolated photons inside jets → look for isolated photons
   - Very difficult problem: at $p_T \approx$ 50 GeV, jet-jet / γγ ≈ 10^7 → need to reject each jet by a factor 10,000 to bring the reducible background well below the irreducible one
   - However, at $p_T \approx$ 50 GeV, π^0/jet ≈ 10^{-3}
     → separate isolated photons from π^0 decays at 50 GeV
     → photons from π^0 decays will be distant by ≈ 1 cm
     → need granular position detector after ~ 4-5 X_0 in

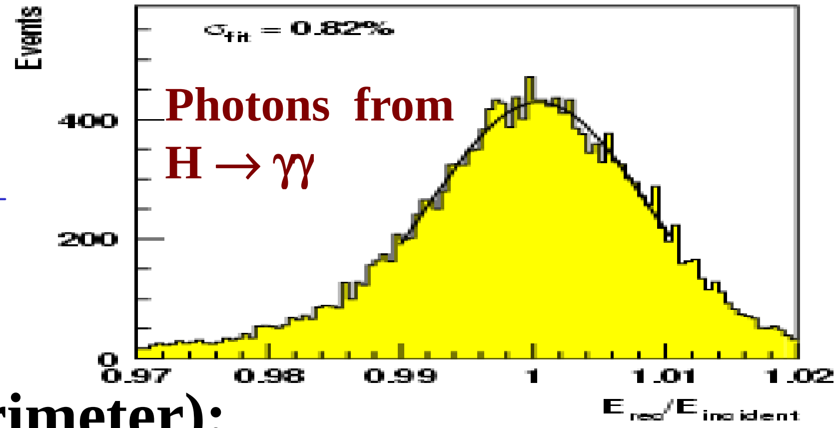
SM H→ γγ

Energy resolution

CMS EM calorimeter (crystals):

$$\frac{\sigma(E)}{E} \approx \frac{3\text{-}5\%}{\sqrt{E}}$$

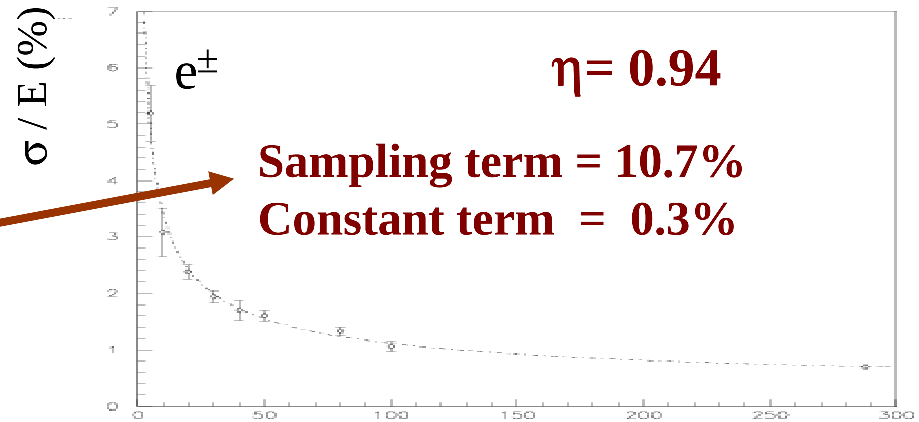
CMS, full simulation high L



ATLAS EM calorimeter (liquid-argon/lead sampling calorimeter):

$$\frac{\sigma(E)}{E} \approx \frac{10\%}{\sqrt{E}}$$

Module zero test beam data



⬇

Mass resolution

(m_H=100 GeV, low L):

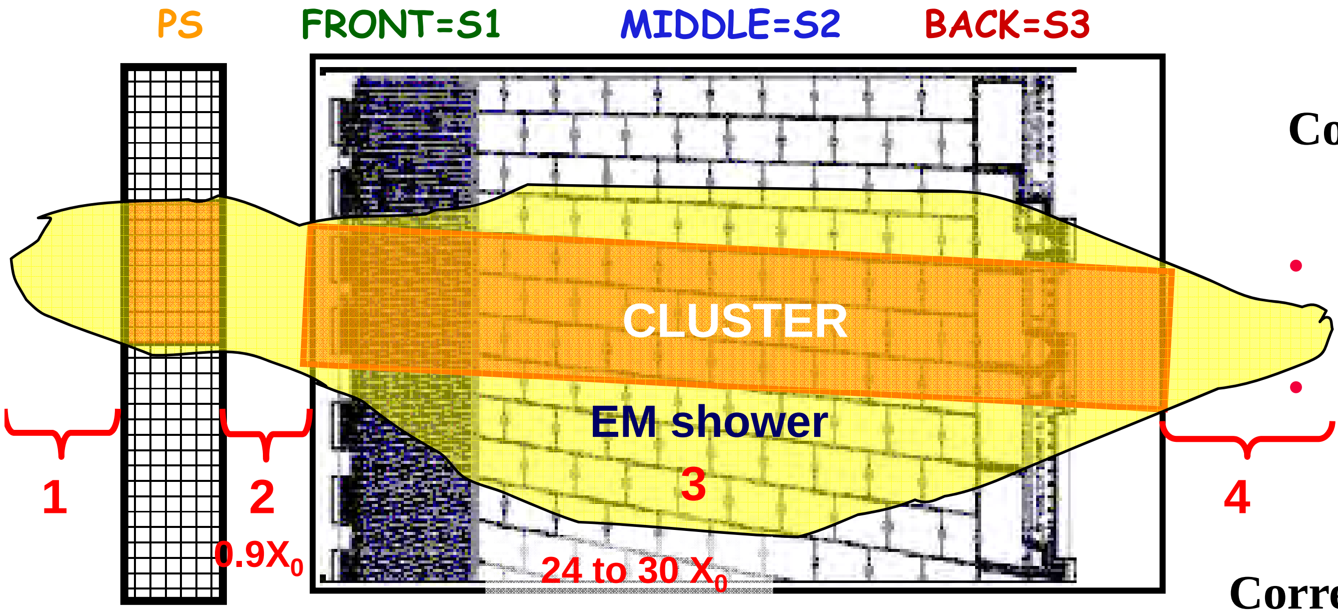
ATLAS : 1.1 GeV

CMS : 0.6 GeV

$$\frac{S}{\sqrt{B}} \sim \frac{1}{\sqrt{\sigma_m}}$$

Electrons and photons in ATLAS/CMS

ATLAS EM Calorimeter energy reconstruction



Corrections due to cluster position:

- $\Delta\eta$ (S-shape modulation) ± 0.005
- $\Delta\phi$ (offset in accordion) ± 0.001

Corrections for energy losses:

1. Before PS
2. Between PS & Calo
3. Outside cluster: depends on clustering method
4. After calorimeter: ~ Energy in BACK

2-7% overall energy correction

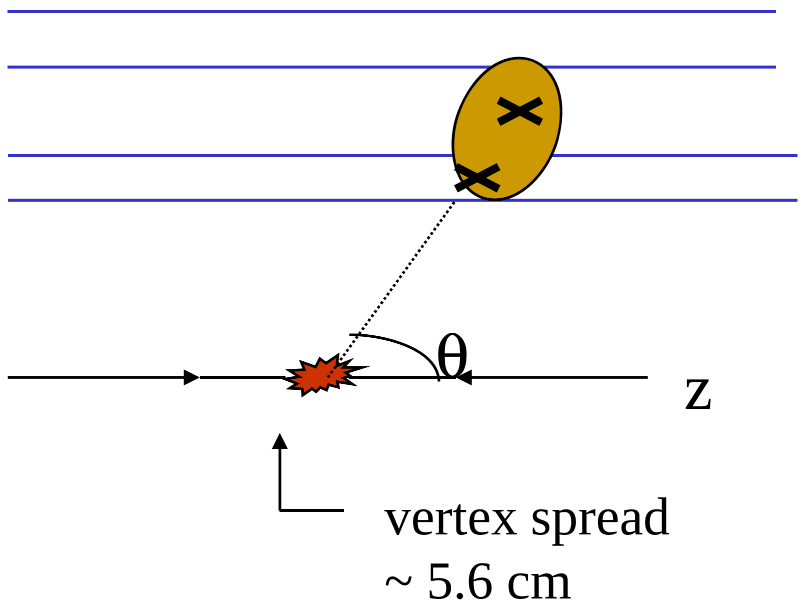
>7% at low energy, high η

Two main clusterization methods:

- Fixed size sliding window:
  - 3×3, 3×7… cells, 2nd sampling $\eta \times \phi$;
  - Some energy left out, especially for small sizes.
- Topological clusters:
  - Variable size cluster, minimize noise impact;
  - Additional splitting algorithm is also provided.

SM H→ γγ

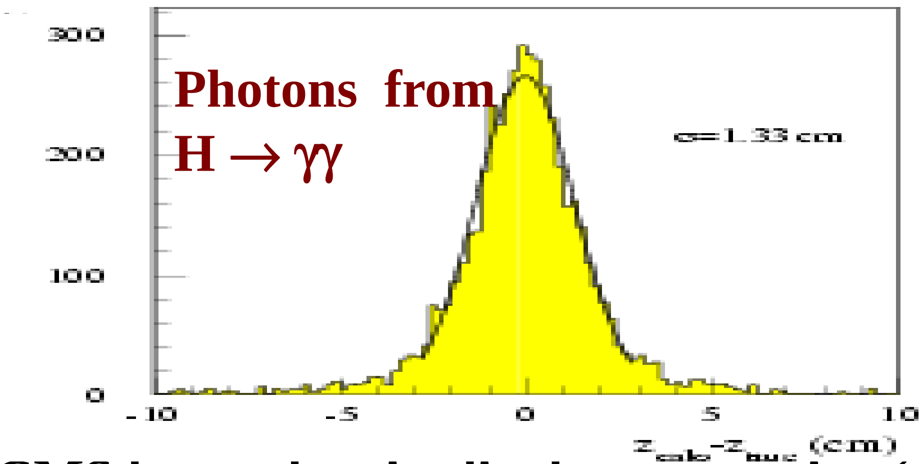
Angular resolution and acceptance



- ATLAS calorimeter has longitudinal segmentation

→ **can measure γ direction**

ATLAS, full simulation
Vertex resolution using EM calo longitudinal segmentation

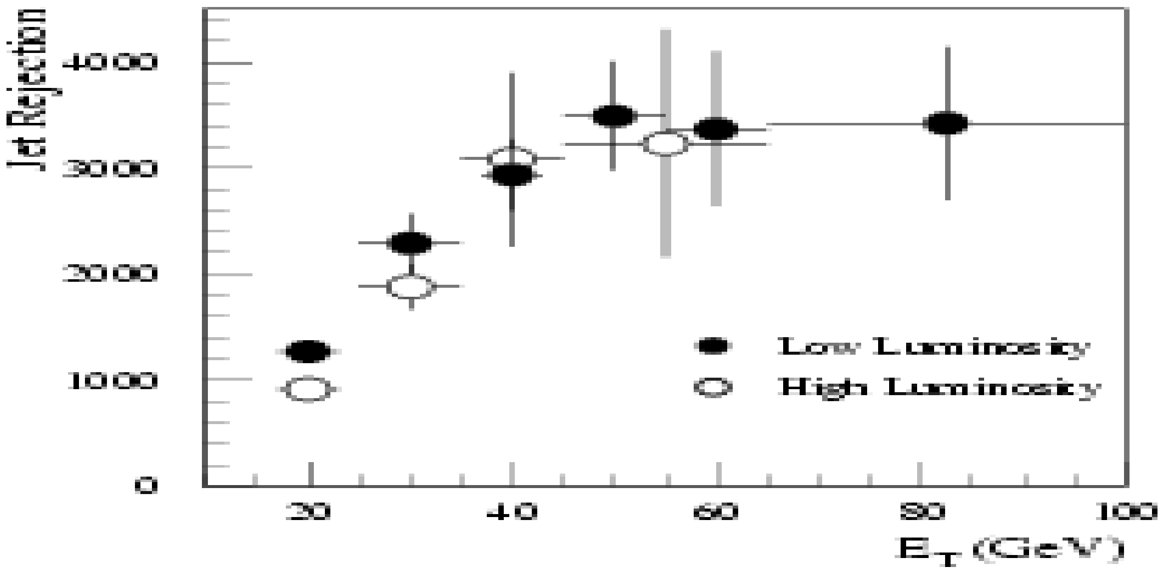


$$\sigma(\theta) \approx \frac{50 \text{ mrad}}{\sqrt{E}}$$

CMS has no longitudinal segmentation (and no preshower in barrel)
→ vertex measured using secondary tracks from underlying event
→ often pick up the wrong vertex
→ smaller acceptance in the Higgs mass window

SM $H \rightarrow \gamma\gamma$

Rejection of QCD jet background



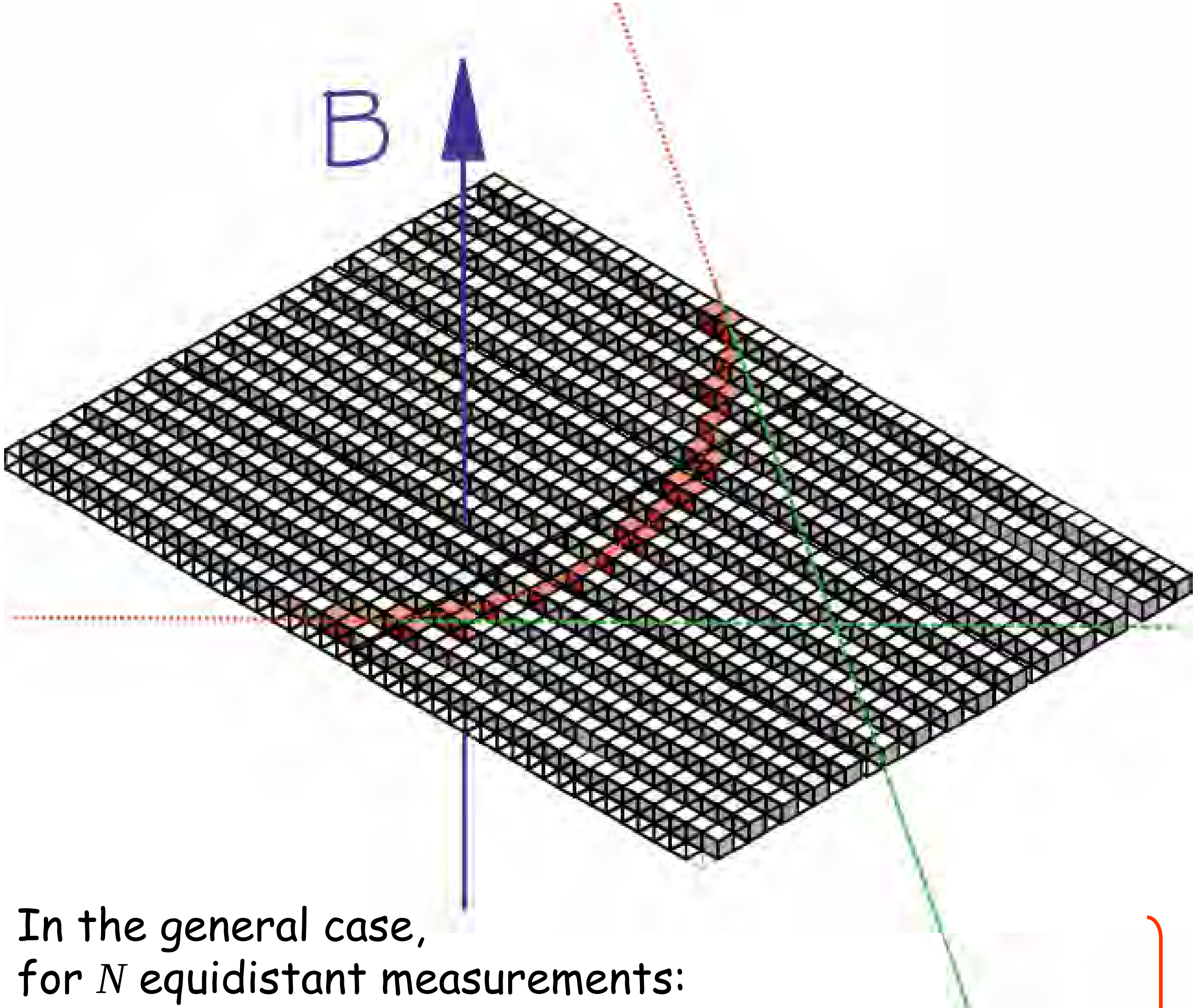
ATLAS EM calo : full simulation

ε_{γ} **=80%**

Most rejection from longitudinal calo segmentation and 4 mm η-strips in first compartment (γ / π^0 separation)

Spektrometr mionowy

Error in momentum measurement



In the general case,
for N equidistant measurements:

$$\left.\frac{\sigma(p_\perp)}{p_\perp}\right|_{measured} = \frac{1}{0.3}\frac{\sigma(x)\cdot p_\perp}{BL^2}\sqrt{\frac{720}{N+4}}$$

for $N \geq \sim 10$

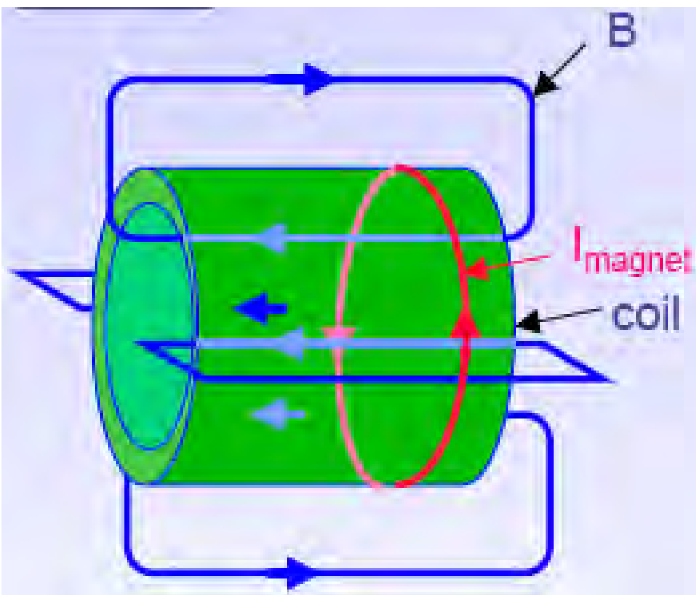
In short → $\frac{\sigma(p_\perp)}{p_\perp^2} = const.$

O. Ullaland/2006

Magnets for 4π Detectors

Solenoid

+ Large homogeneous field inside
- Weak opposite field in return yoke
- Size limited by cost
- Relatively large material budget



Examples:

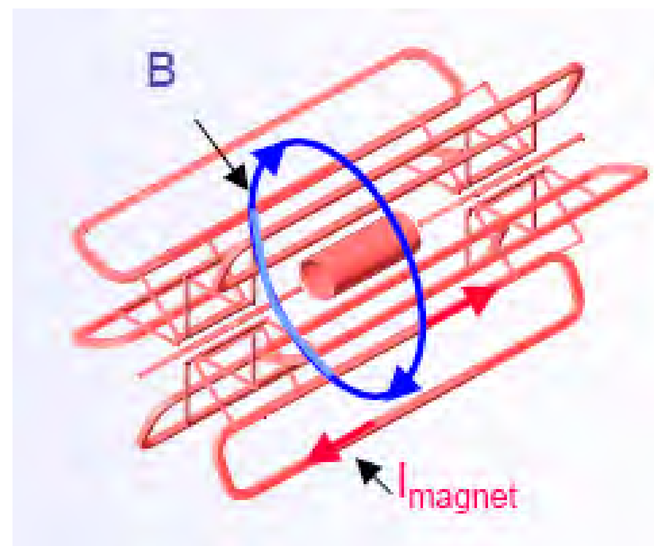
•Delphi: SC, 1.2 T, 5.2 m, L 7.4 m

•CDF: SC, 1.4T, 2 m, L 6m

•CMS: SC, 4 T, 5.9 m, L 12.5 m

Toroid

+ Field always perpendicular to p
+ Rel. large fields over large volume
+ Rel. low material budget
- Non-uniform field
- Complex structural design

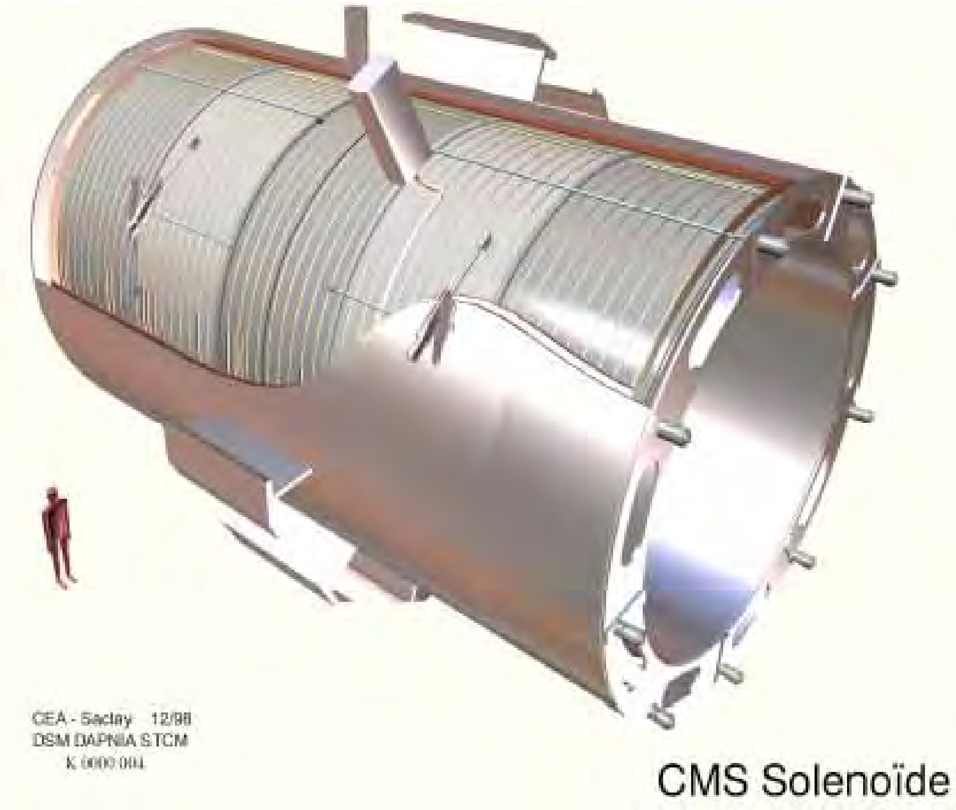


Example:

•ATLAS: Barrel air toroid, SC, ~1 T, 9.4 m, L 24.3 m

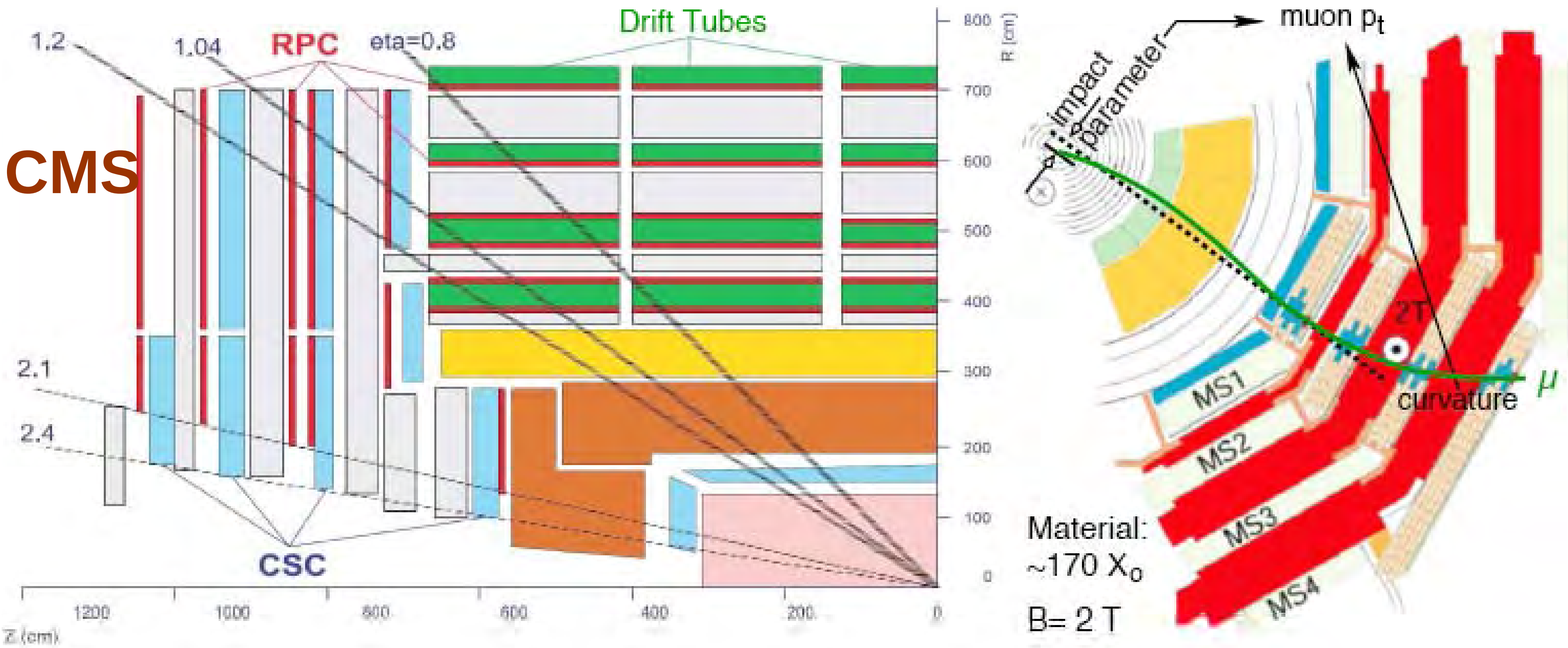
Charge and Momentum

Two ATLAS toroid coils



Superconducting CMS Solenoid Design

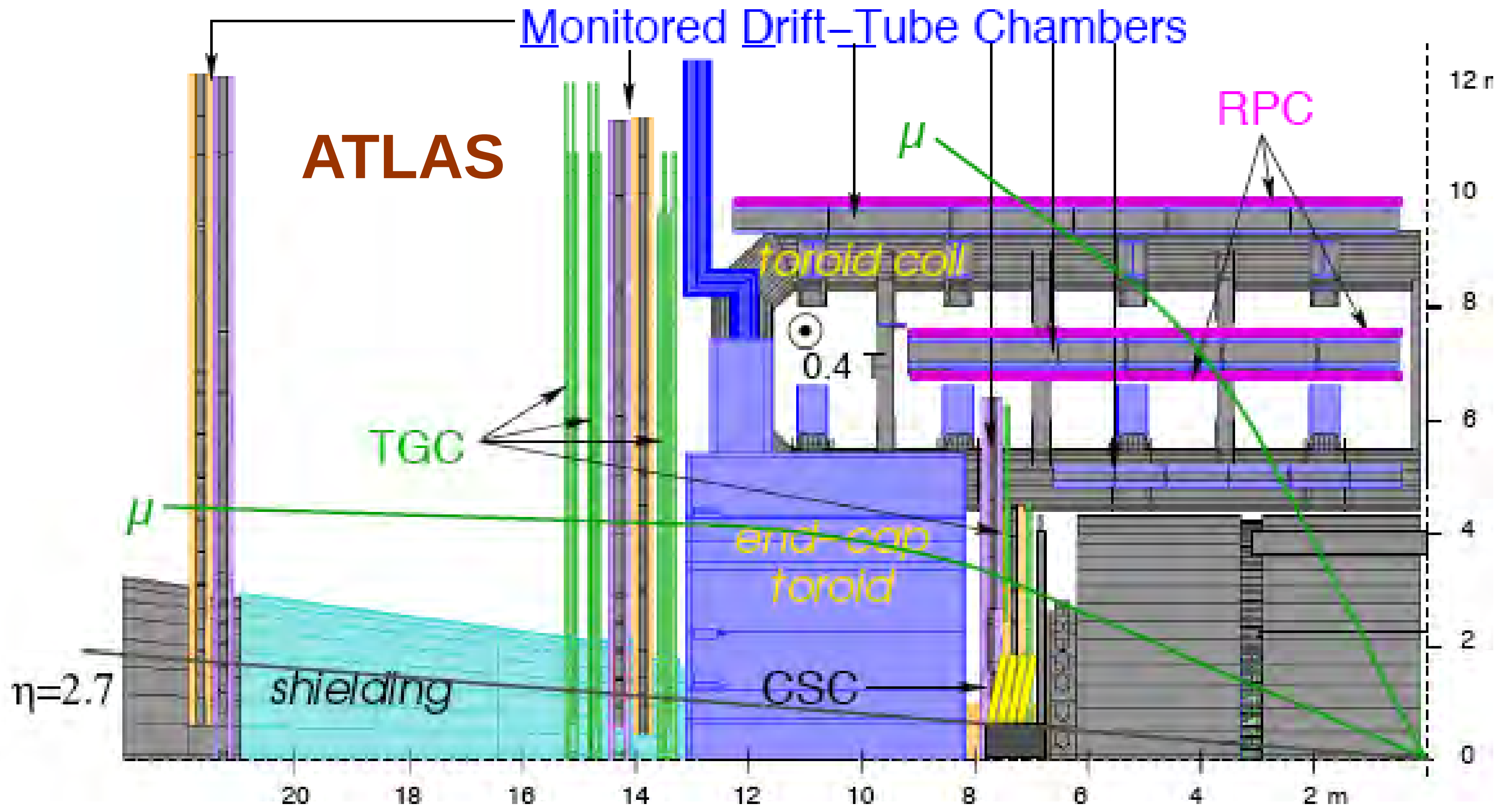
ATLAS/CMS: muon measurements



CMS muon spectrometer

- **Superior combined momentum resolution in central region**
- **Limited stand-alone resolution and trigger (at very high luminosities) due to multiple scattering in iron**
- **Degraded overall resolution in the forward regions ($|\eta| > 2.0$) where solenoid bending power becomes insufficient**

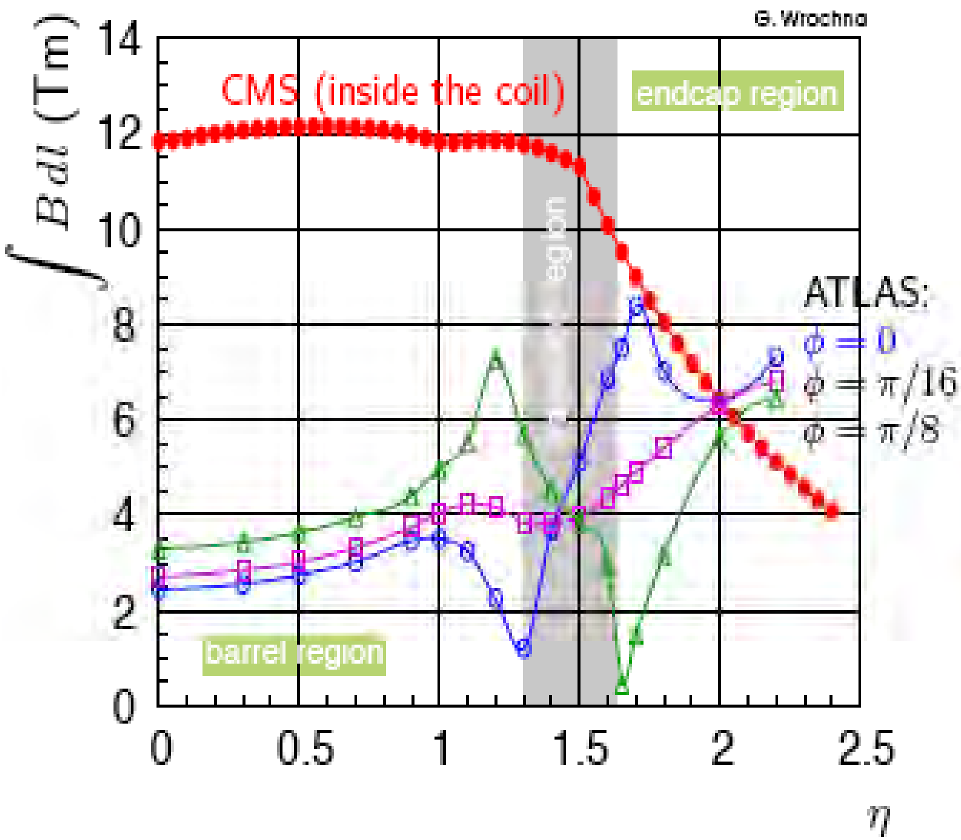
ATLAS/CMS: muon measurements



ATLAS muon spectrometer

- **Excellent stand-alone capabilities and coverage in open geometry**
- **Complicated geometry and field configuration (large fluctuations in acceptance and performance over full potential η x ϕ coverage (|η| < 2.7)**

ATLAS/CMS: muon measurements



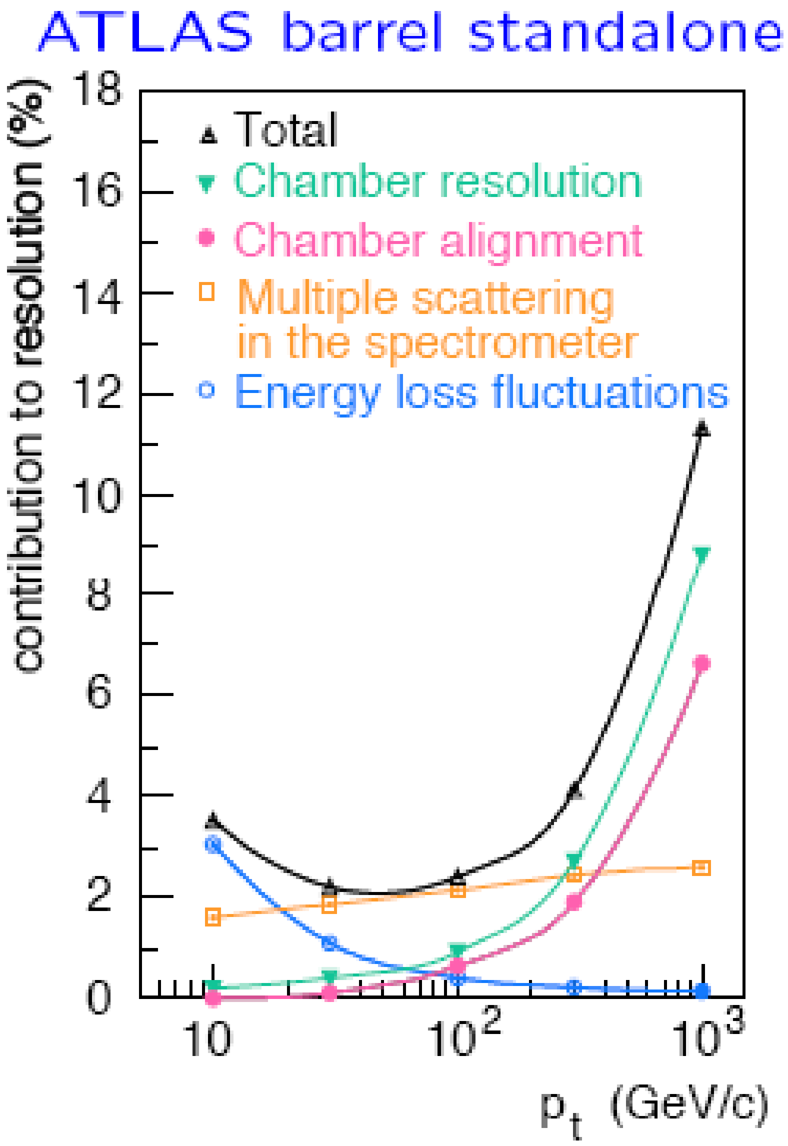
Barrel: $\approx 5\times$ higher bending power in CMS, **but** $\approx 14\times$ larger multiple scattering.

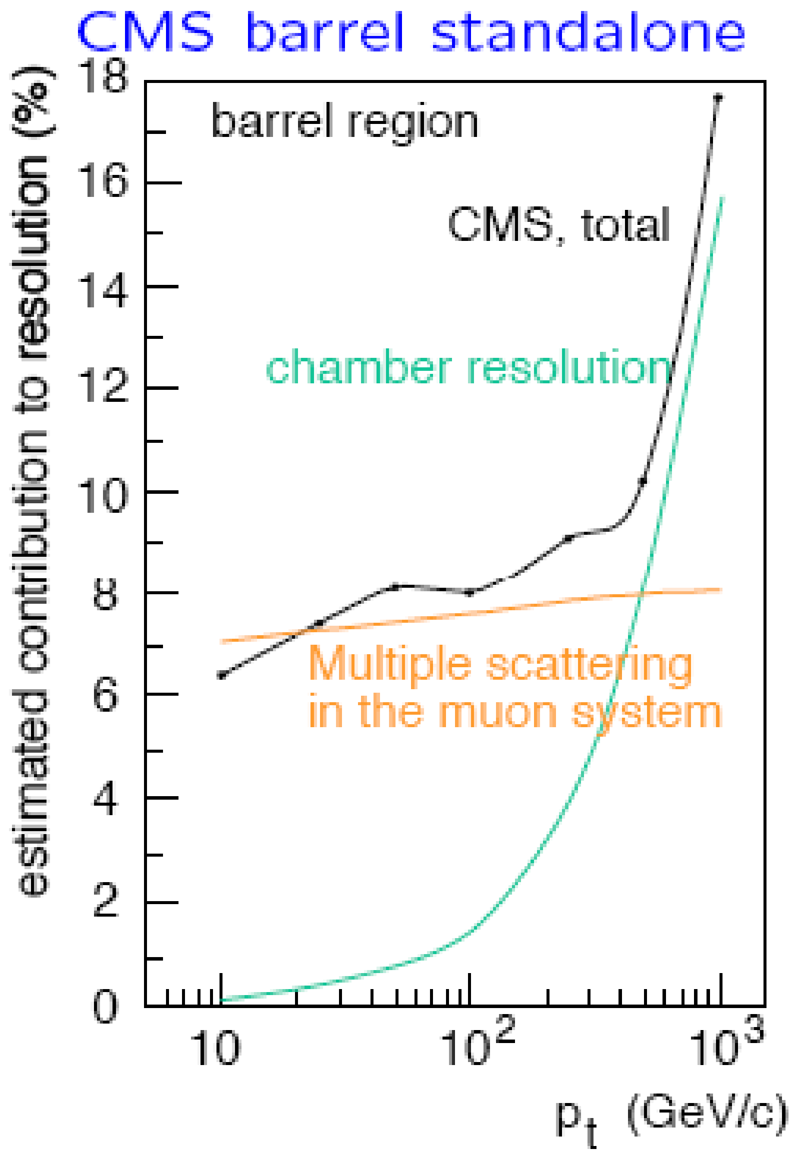
$\rightarrow$ $\approx 3\times$ worse p_t resolution in CMS.

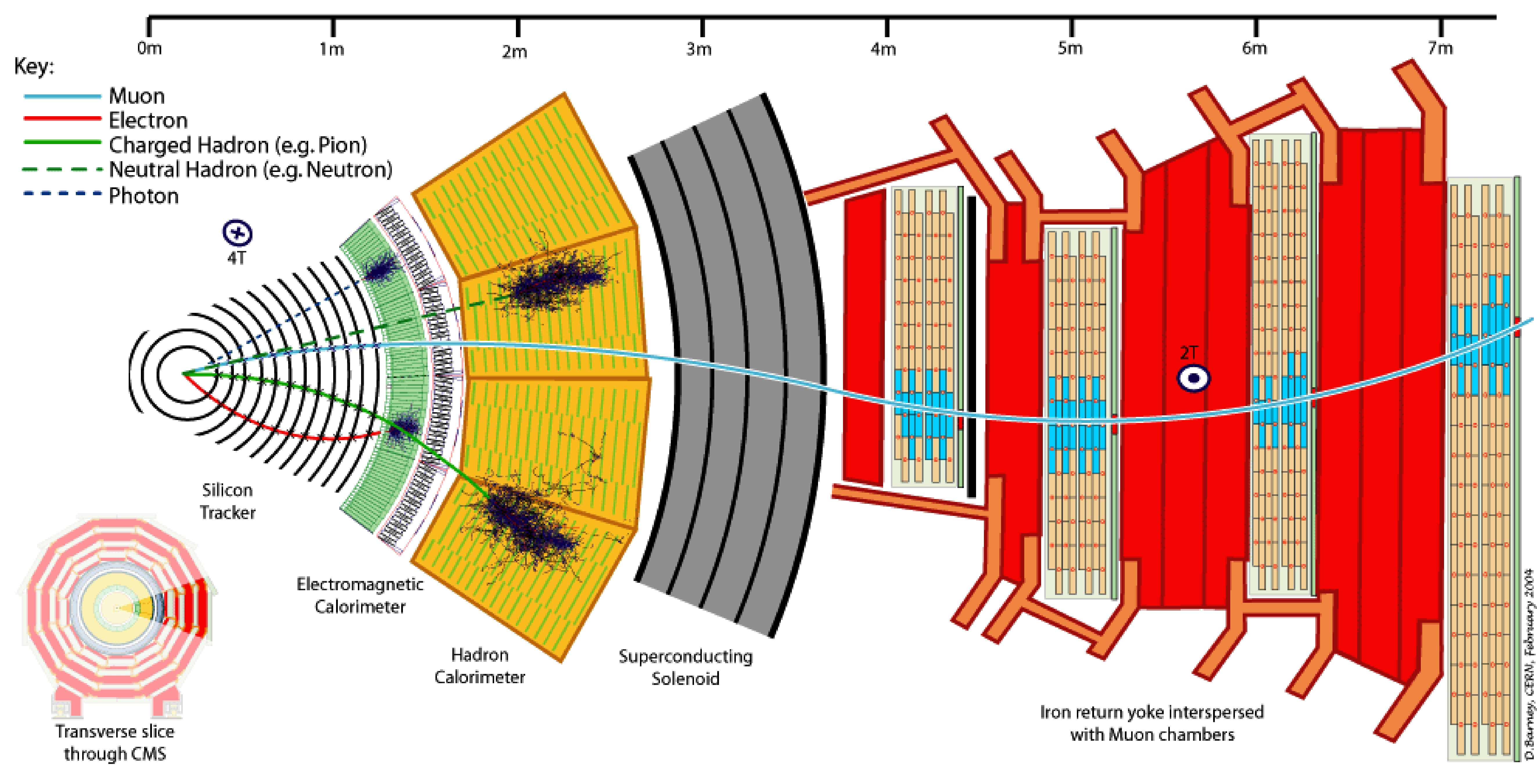
Endcap: similar bending powers, $\approx 10\times$ large multiple scattering.

$\rightarrow$ $\approx 5\times$ worse p_t resolution in CMS.

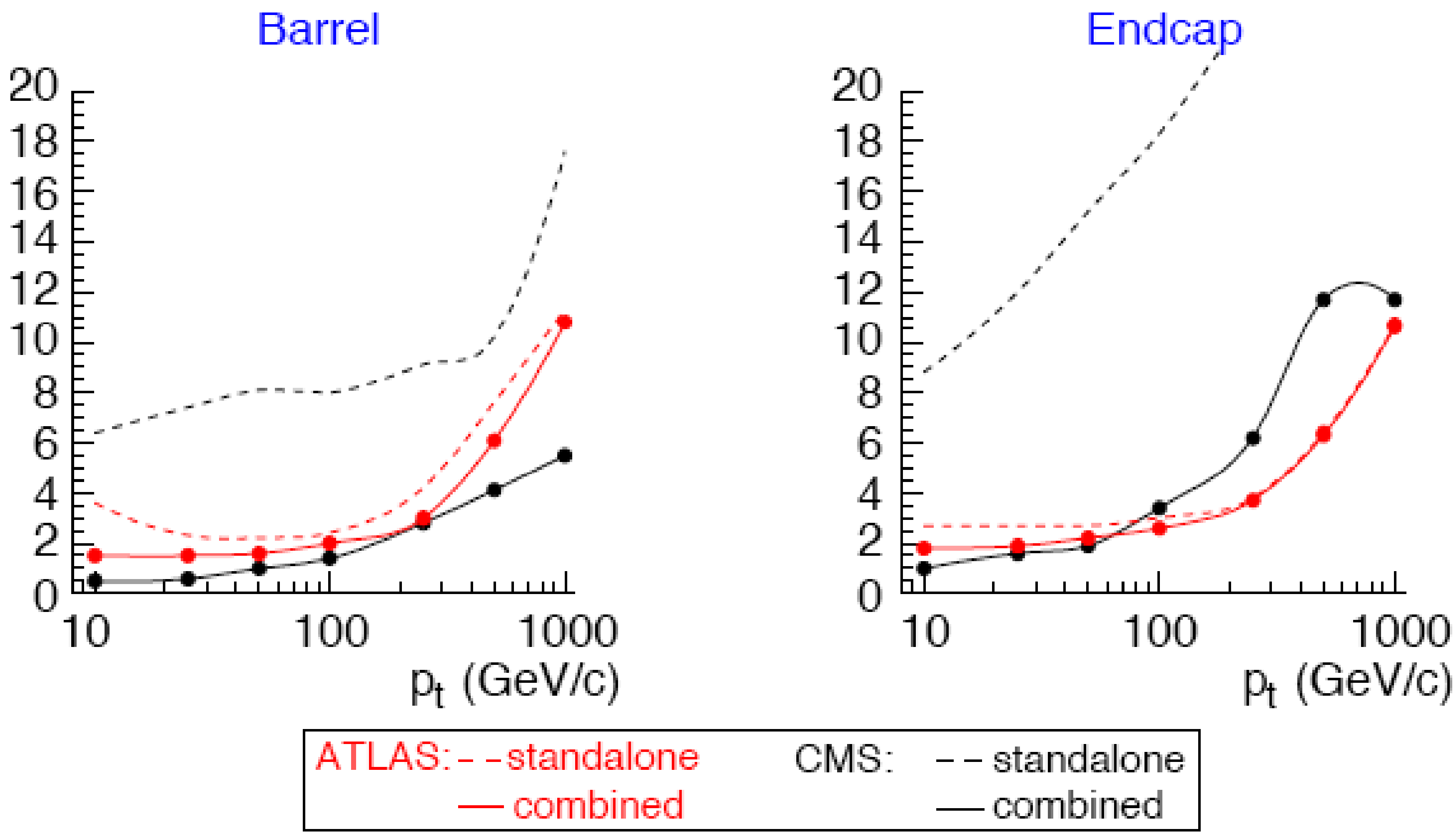
ATLAS/CMS: muon measurements






0m
1m
2m
3m
4m
5m
6m
7m
Key:
Muon
Electron
Charged Hadron (e.g. Pion)
Neutral Hadron (e.g. Neutron)
Photon
4T
2T
Silicon Tracker
Electromagnetic Calorimeter
Hadron Calorimeter
Superconducting Solenoid
Iron return yoke interspersed with Muon chambers
Transverse slice through CMS
D.Barney, CERN, February 2004

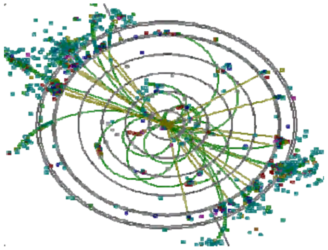
ATLAS/CMS: muon measurements



Optymalizacja detektora

Decydujące znaczenie mają, niestety, pieniądze...

Na przykładzie projektu SiD dla ILC.

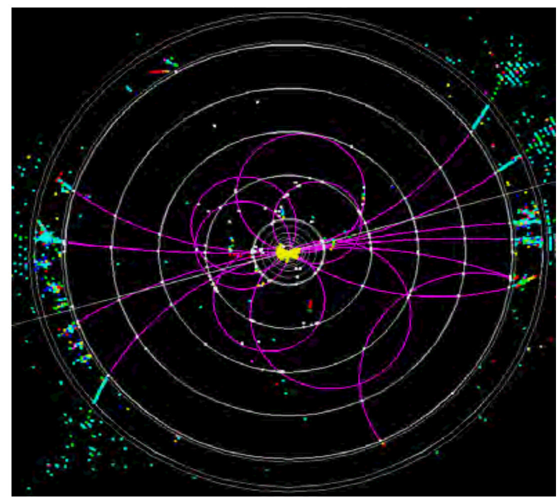


SiD (the Silicon Detector)

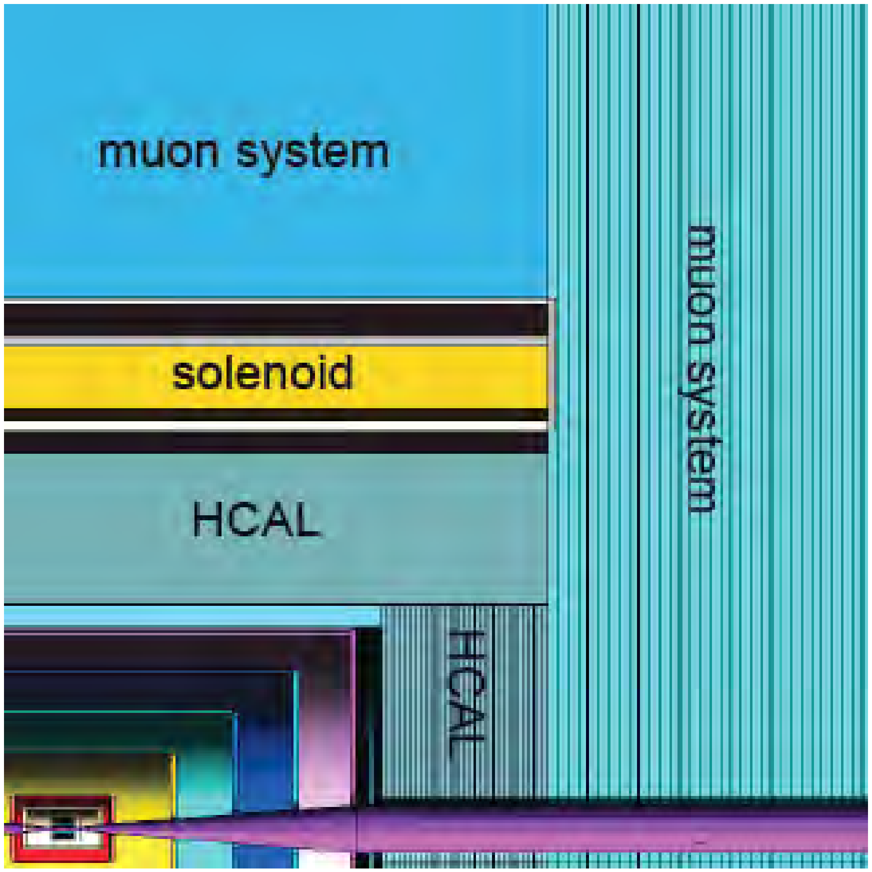
CALORIMETRY IS THE STARTING POINT IN THE SiD DESIGN

<u>assumptions</u>

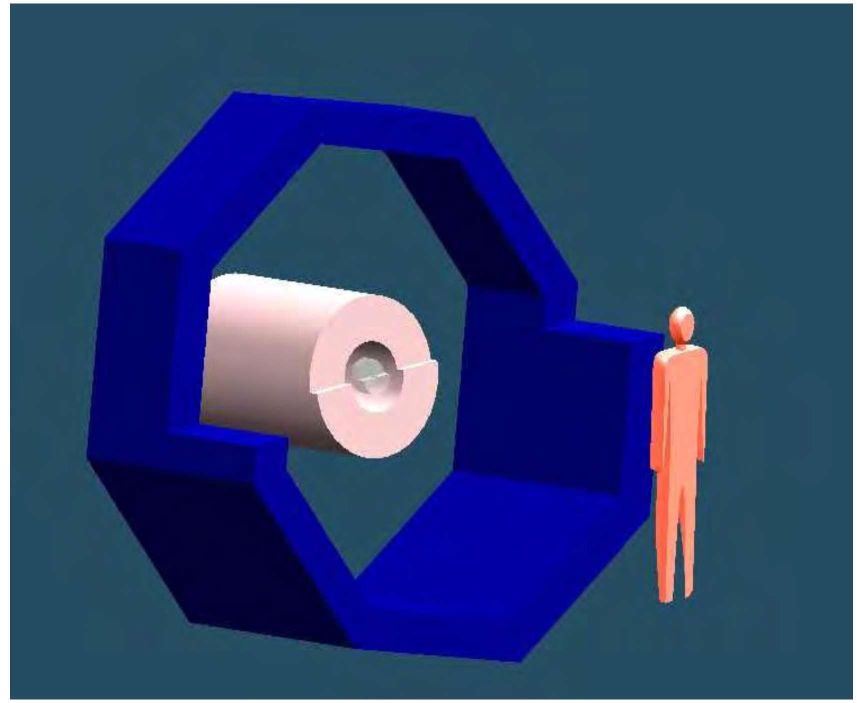
- Particle Flow Calorimetry will result in the best possible performance
- Silicon/tungsten is the best approach for the EM calorimeter
- Silicon tracking delivers excellent resolution in smaller volume
- Large B field desirable to contain electron-positron pairs in beamline
- Cost is constrained



SiD Configuration



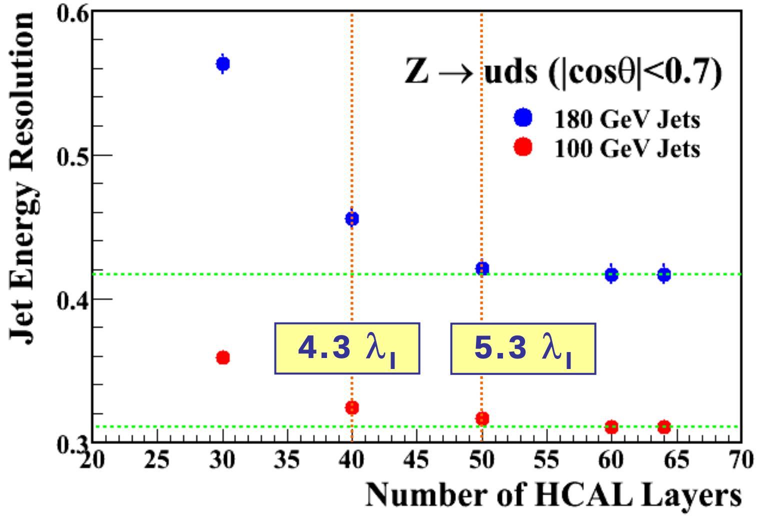
5 Tesla

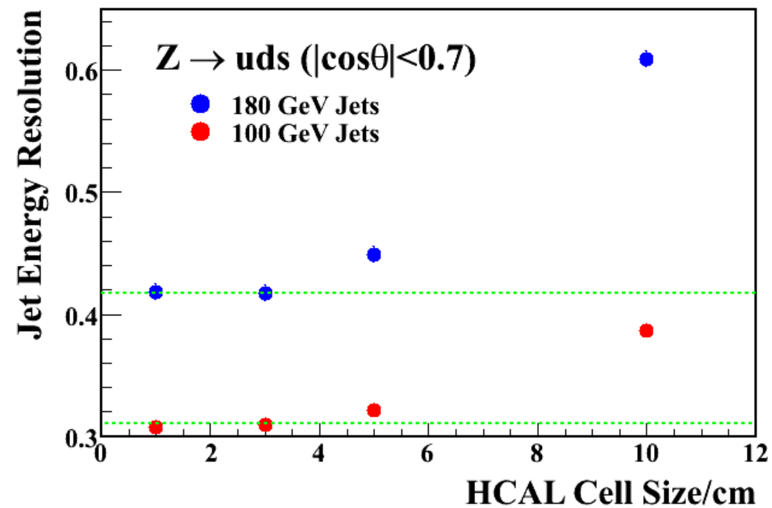


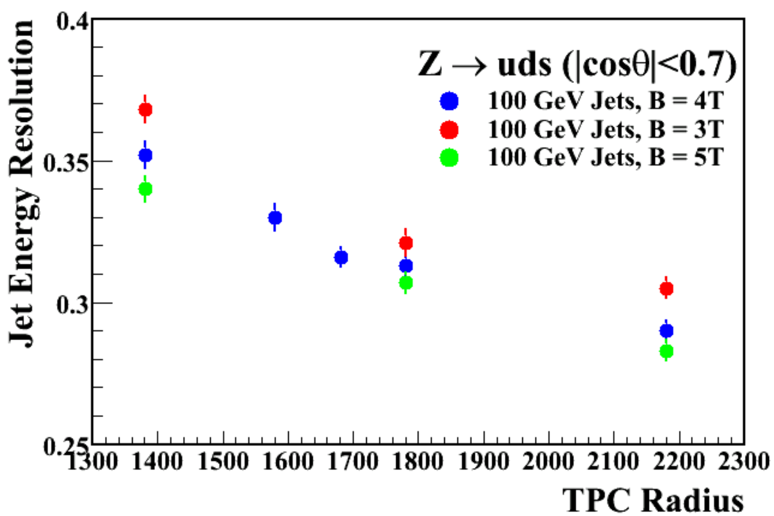
Scale of EMCal & Vertex Detector

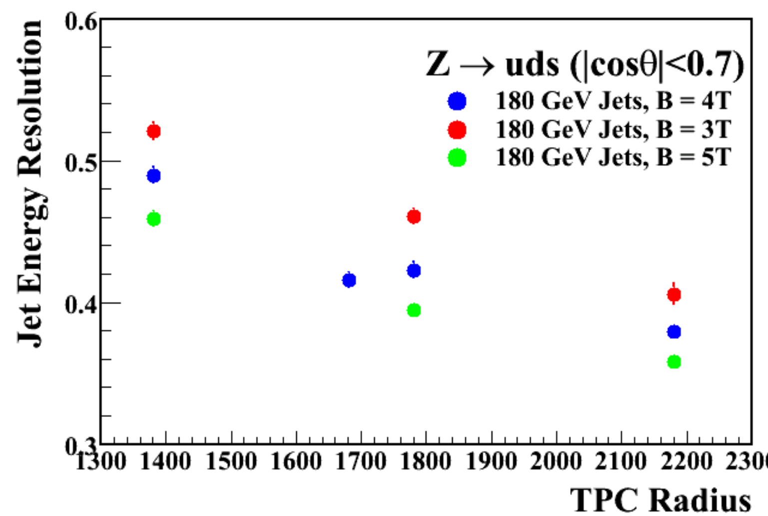
❻ Detector Optimisation Studies

★ Lots of progress… …no time





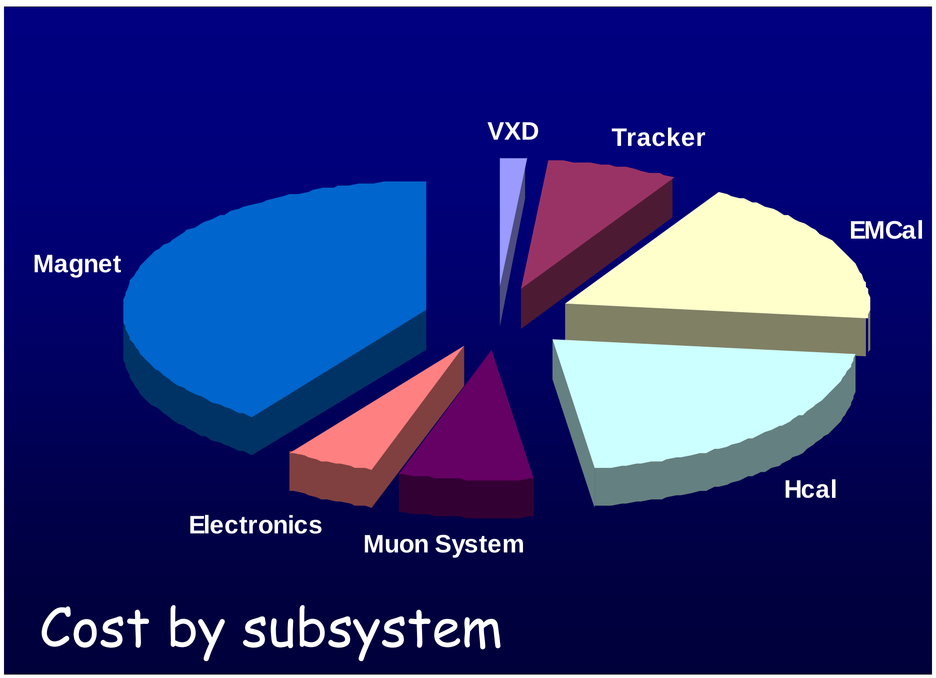


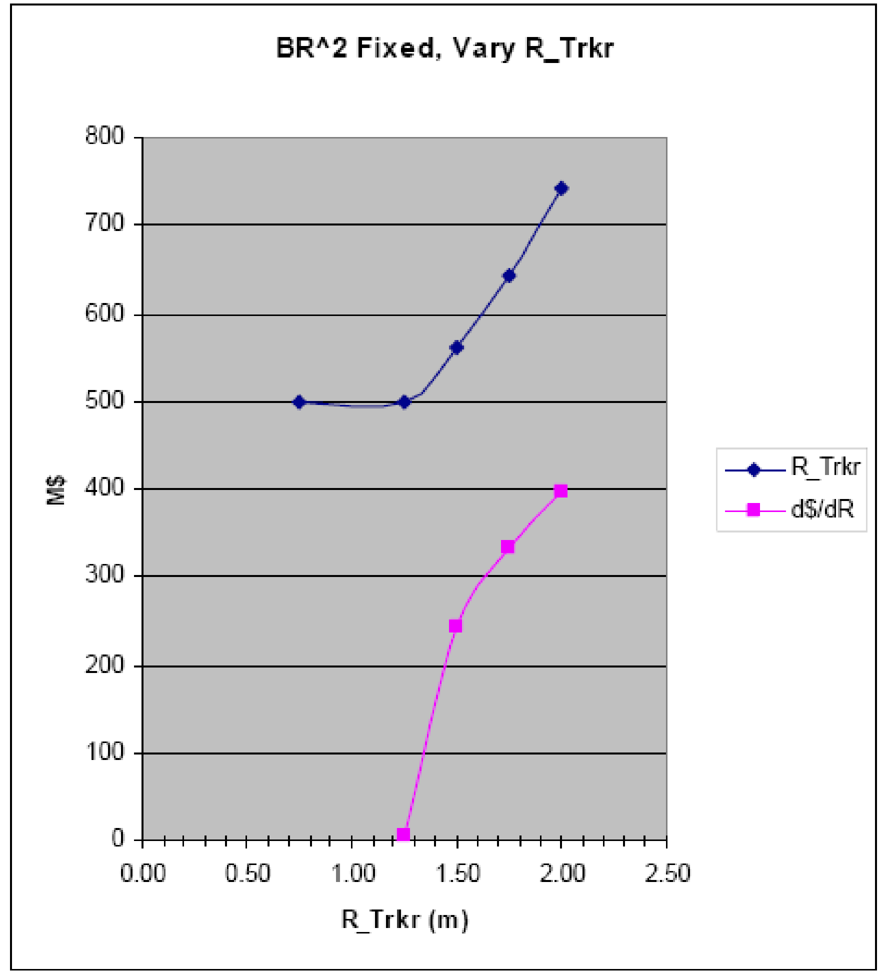


Cost

Parametric Cost Model

Cost = f (B-field, R_{TRK}, ….)

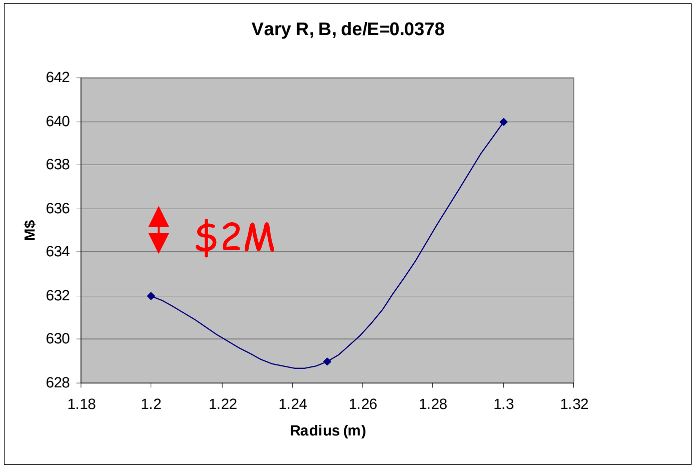


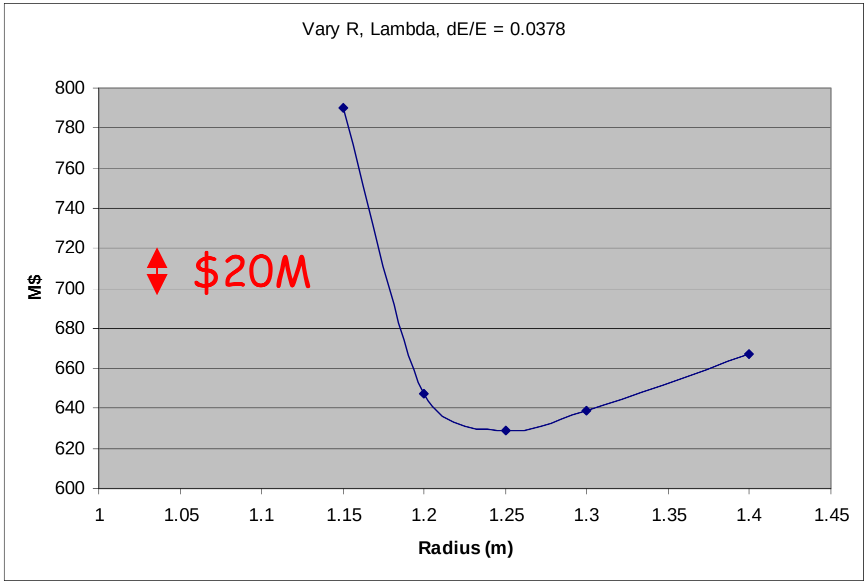


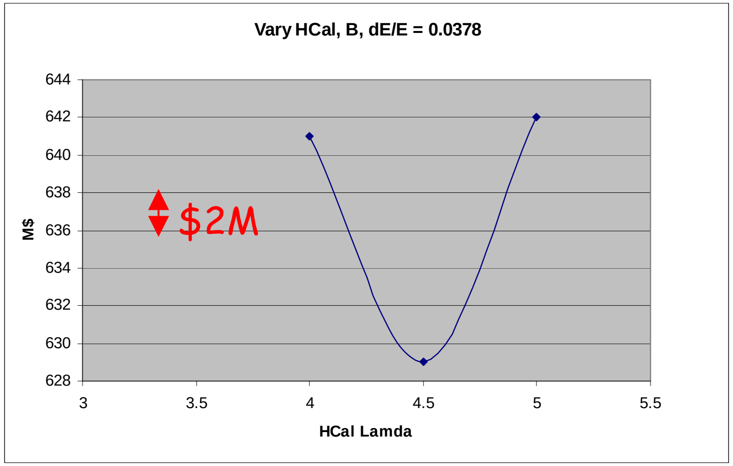
Cost vs. tracker radius

SiD "Baseline"

- Rtrkr = 1.25 m
- B = 5 T
- HCalλ = 4.5
- ΔE/E(180 Gev) = 0.0378

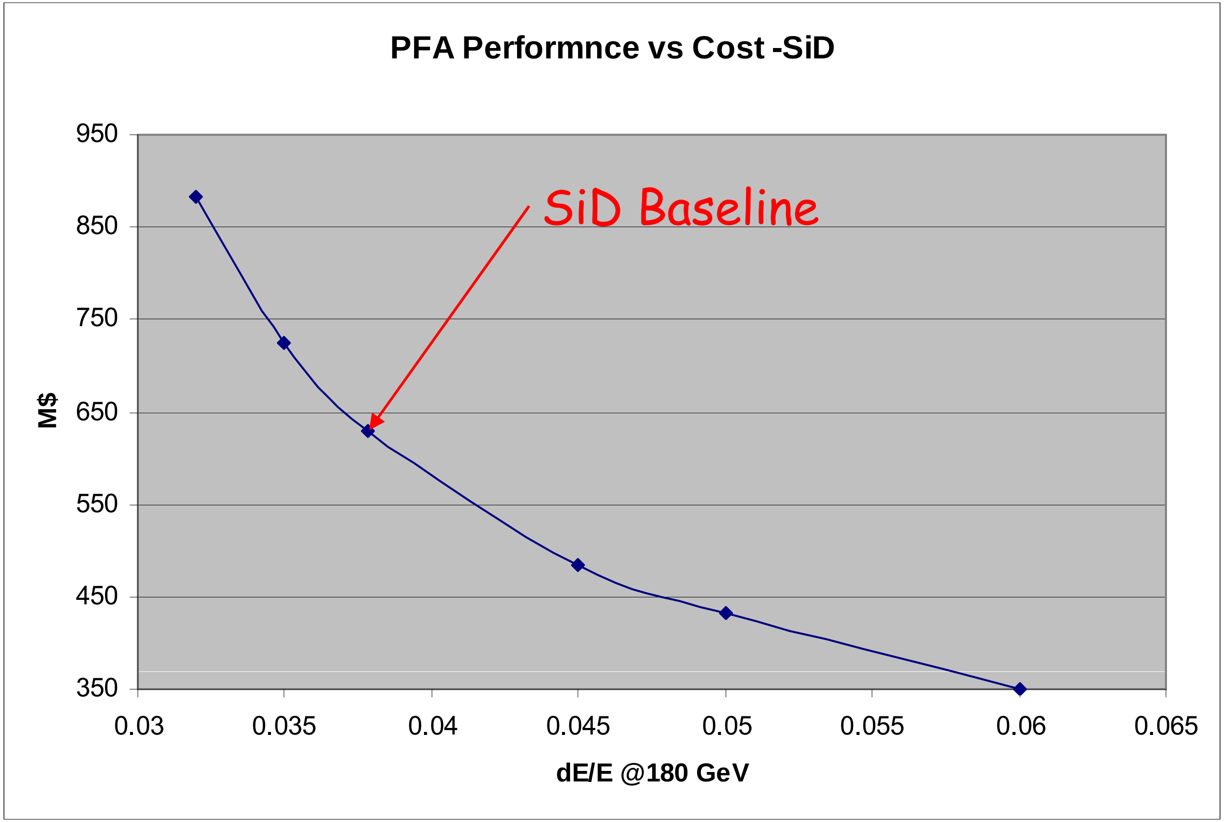






SiD "Baseline" is optimal for this value of ΔE/E(180 Gev) (Pandora parameterization, Checked with Pandora version of SiD, SiD PFA)

A sequence of "Optimized SiD's"



Selected Physics Process Errors vs Cost