



L'esperimento ALICE

M. Bregant



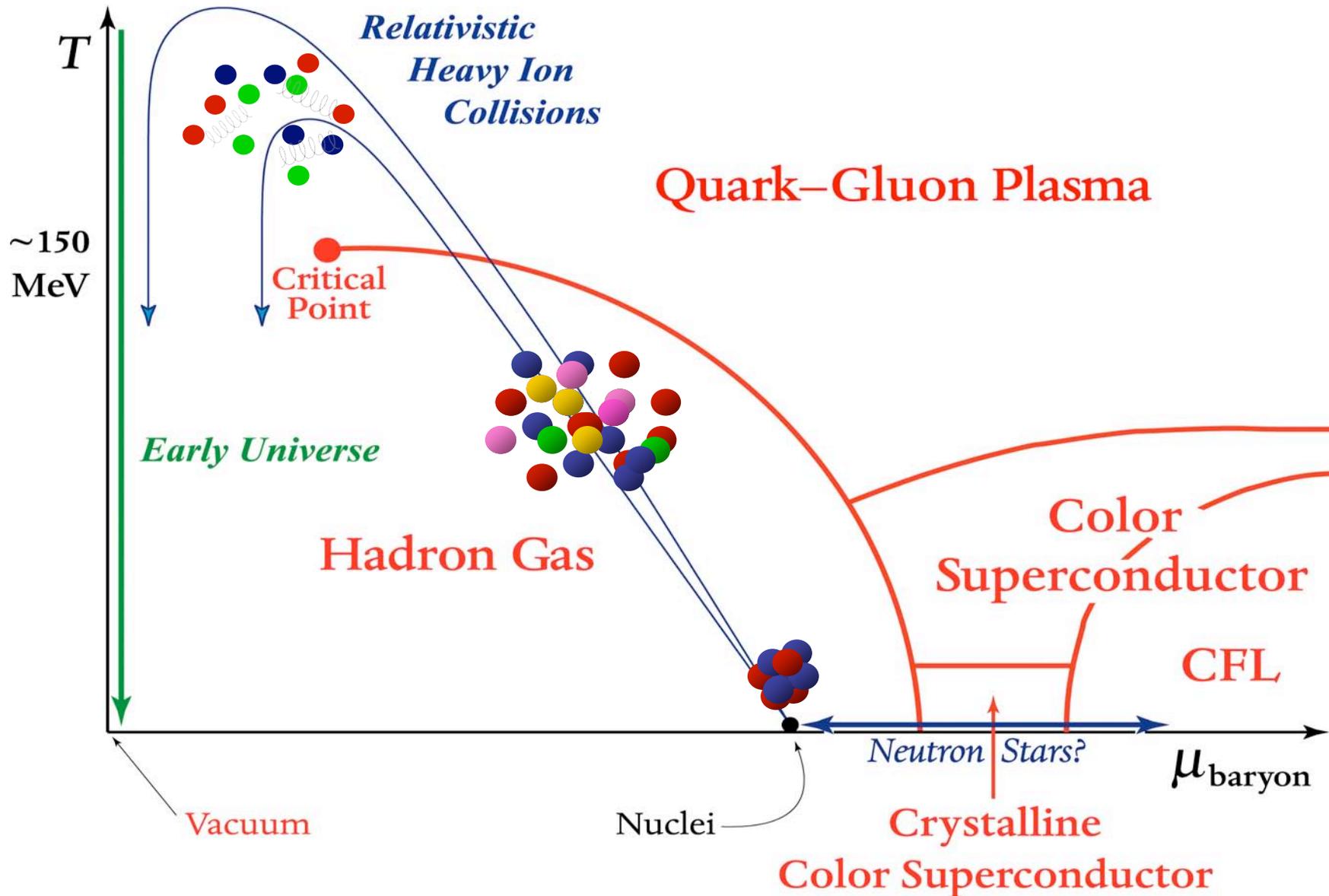
LCH, non solo p-p

- Energia dei fasci: $7 \times Z/A$ TeV (limitata dai magneti)
- Per fasci di Pb: 2.75 TeV per nucleone
- posso avere interazioni multiple, quindi una considerevole parte dell'energia “viene messa in gioco”

Nel caso di urto frontale centinaia di TeV e migliaia di partoni concentrati in $\sim 1000 \text{ fm}^3$!

Ho la possibilità di esplorare un nuovo stato della materia nucleare.

Le fasi della materia nucleare



linee guida teoriche: QCD su reticolo



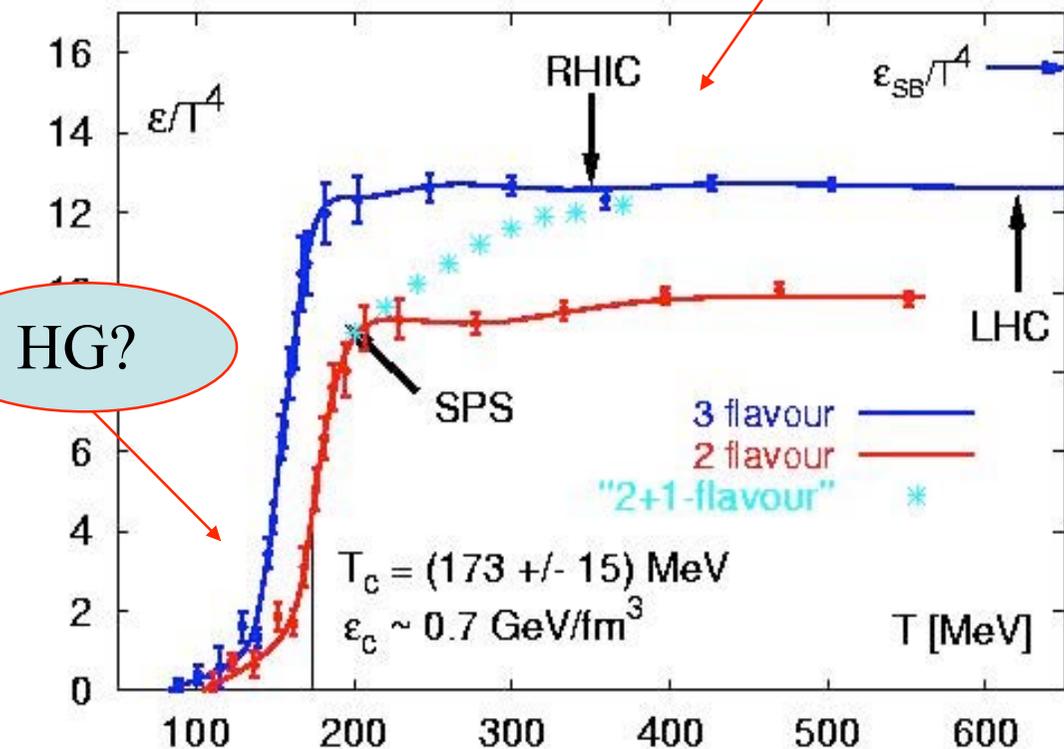
Nella QCD su reticolo, problemi non perturbativi sono trattati su un reticolo (spazio discreto, problema "trattabile")

Indicazione di una transizione da Hadron Gas a QuarkGluonPlasma a $T_c \approx 170 \text{ MeV}$ $\epsilon_c \approx 1 \text{ GeV}/\text{fm}^3$

QGP?

- vera transizione di fase o crossover?
- una fase intermedia di QCP fortemente interagente?
- Ripristino della simmetria chirale?

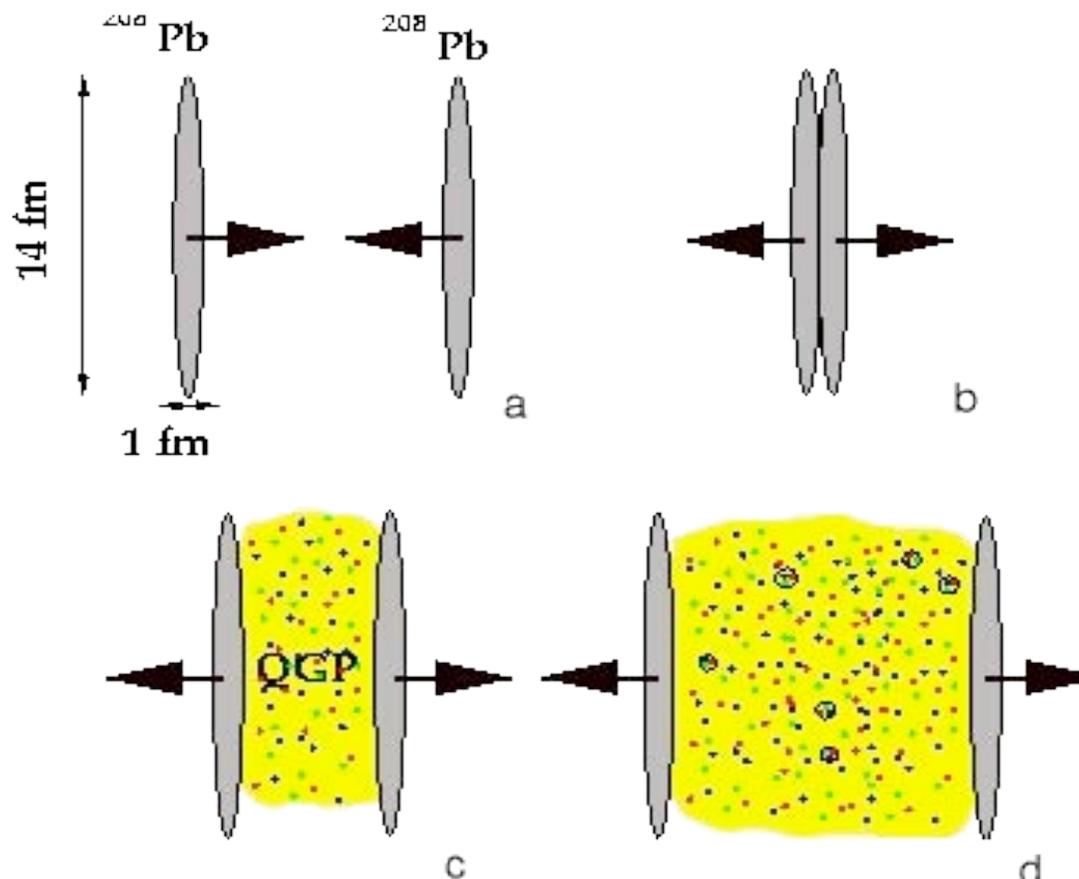
Constituent mass \rightarrow current mass



Heavy-ion collisions

- QCD predice che la materia adronica subisce una transizione di alla temperatura di critica $T \sim 150-180$ MeV, dando luogo a un nuovo stato deconfinato di quark e gluoni: il Quark Gluon Plasma (QGP).

- La densità di energia necessaria è molto elevata e può essere raggiunta solo con collisioni centrali di nuclei pesanti



- SPS, RHIC e LHC possono raggiungere tale energia, ma poi si deve cercare degli osservabili, degli “indicatori” caratteristici del fenomeno.

Nucleus-Nucleus collision: a process

Freeze-out:

- Chemical: particle composition is fixed (no more inel. Collisions)
- Thermal: momentum spectra are fixed (no more elastic collisions)

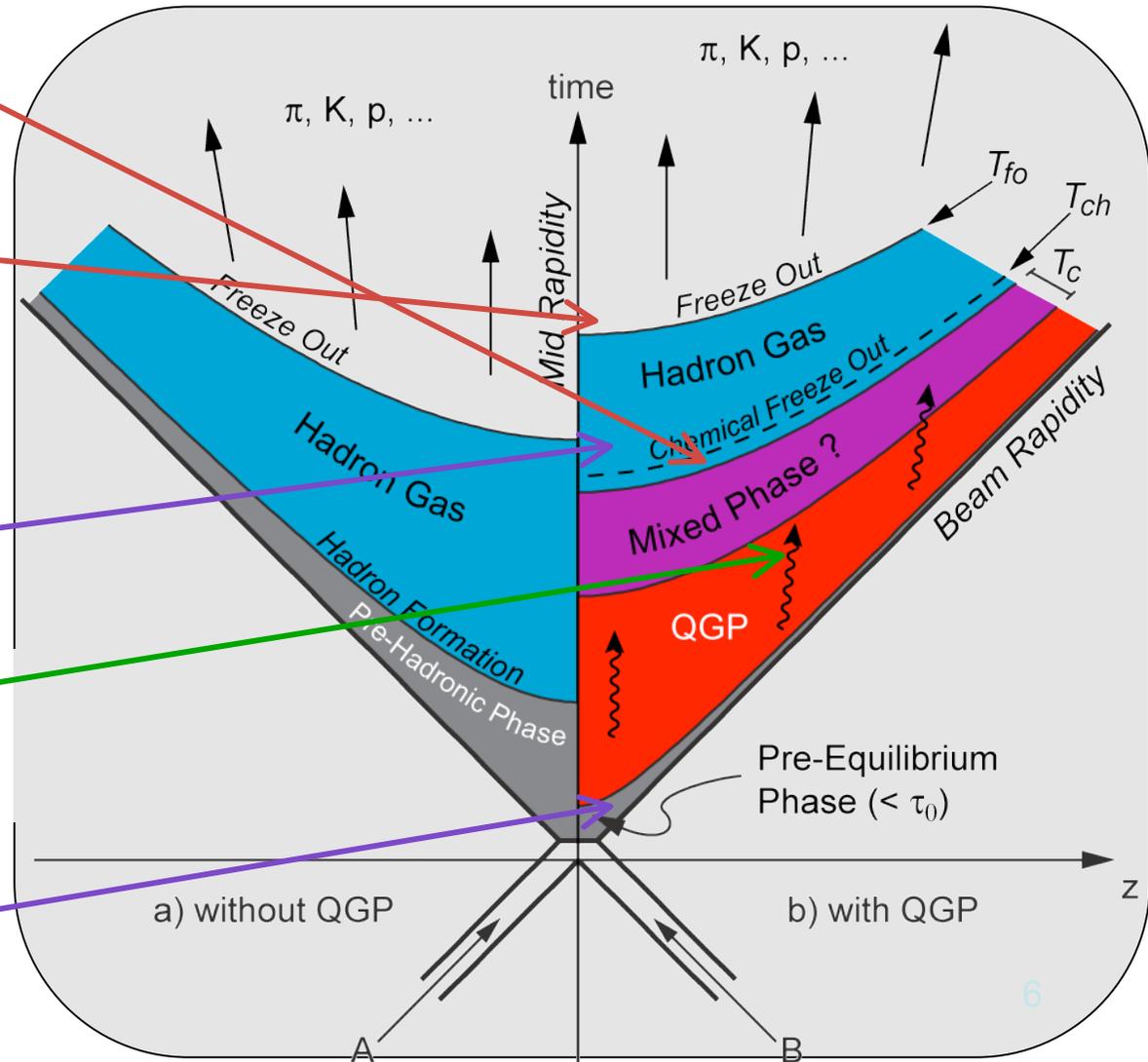
Soft processes:

- high cross section
- Decouple late - indirect signals for QGP

Photons (real and virtual): insensitive to the hadronization phase

Hard processes:

- Low cross section
- Probe the whole evolution of the collision

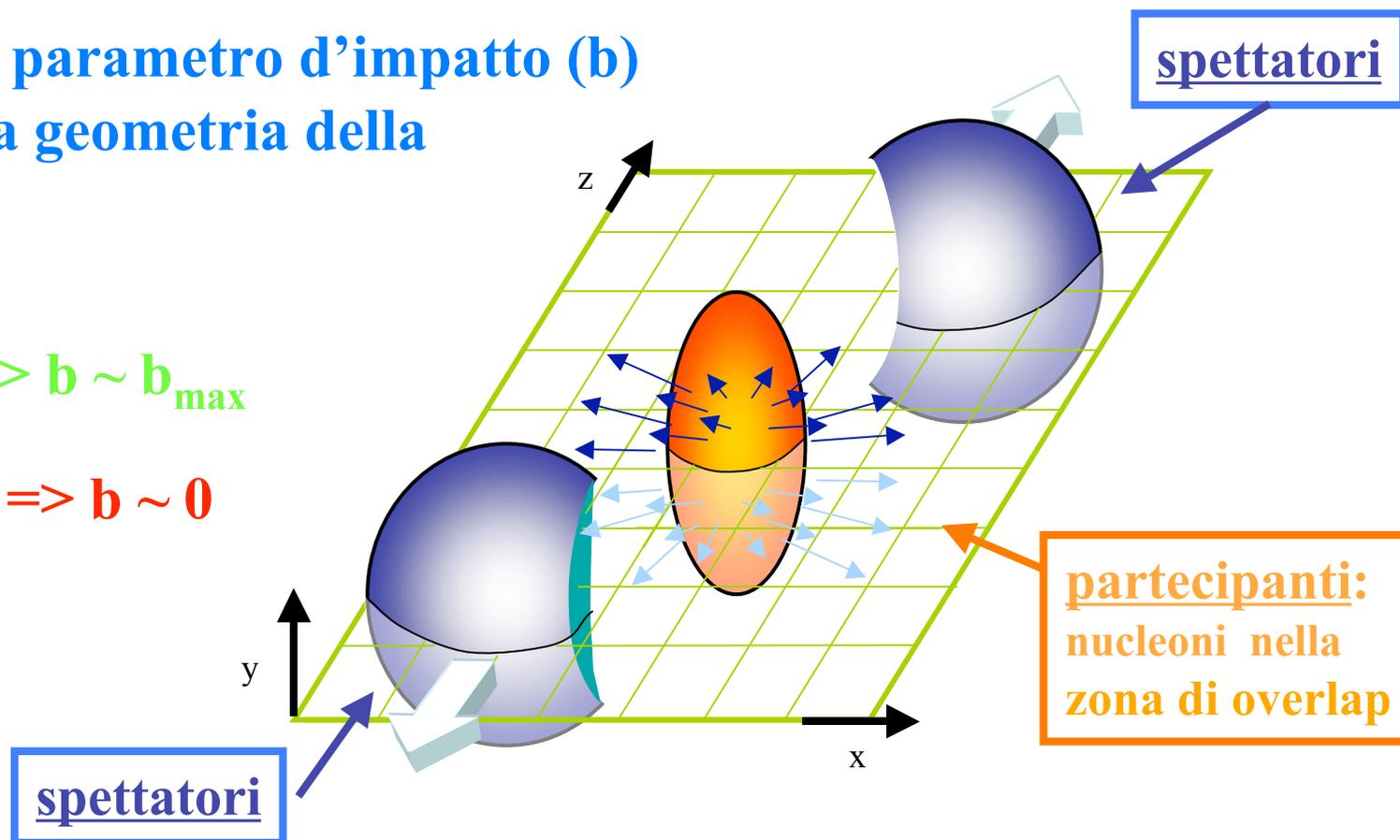


Condizioni iniziali: geometria della collisione

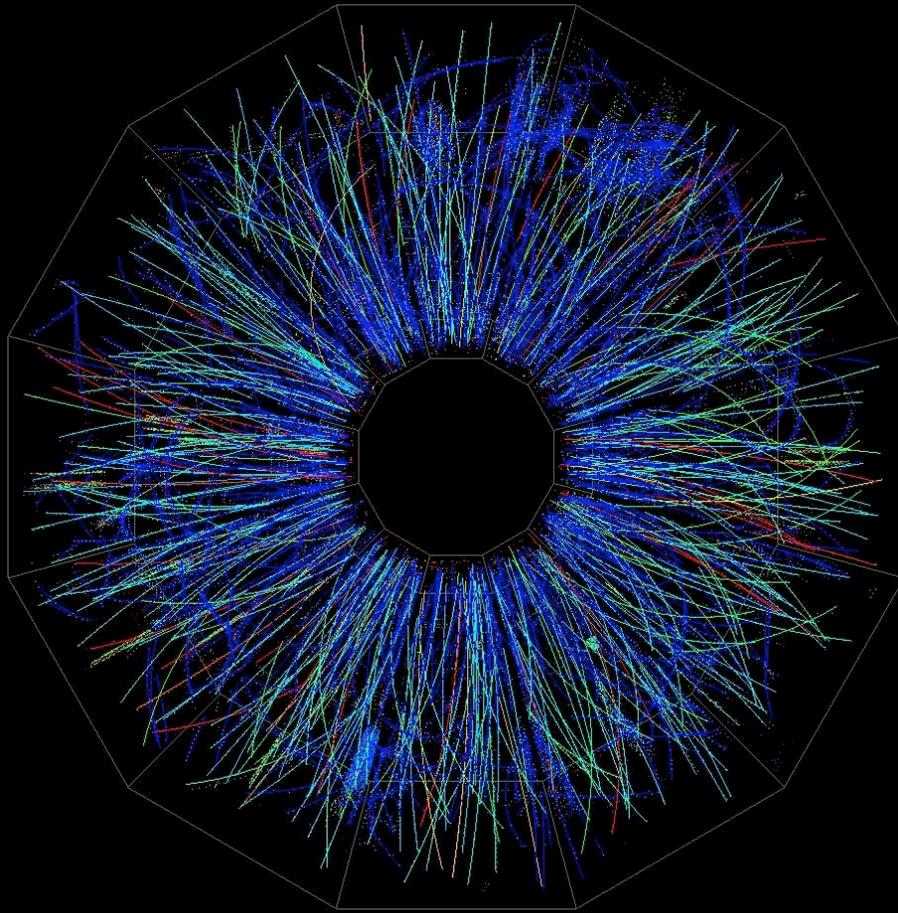
Centralità \rightarrow parametro d'impatto (b)
selezione sulla geometria della
collisione

“periferici” $\Rightarrow b \sim b_{\max}$

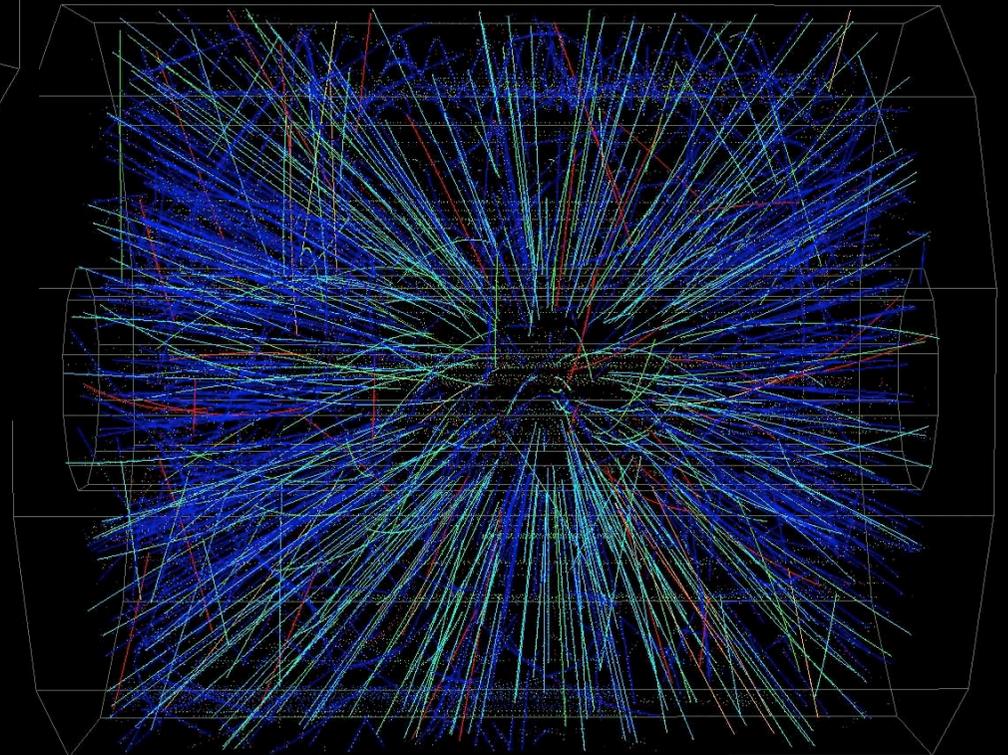
“centrali” $\Rightarrow b \sim 0$



Eventi Au-Au, Energia CM $E \sim 130$ A-GeV



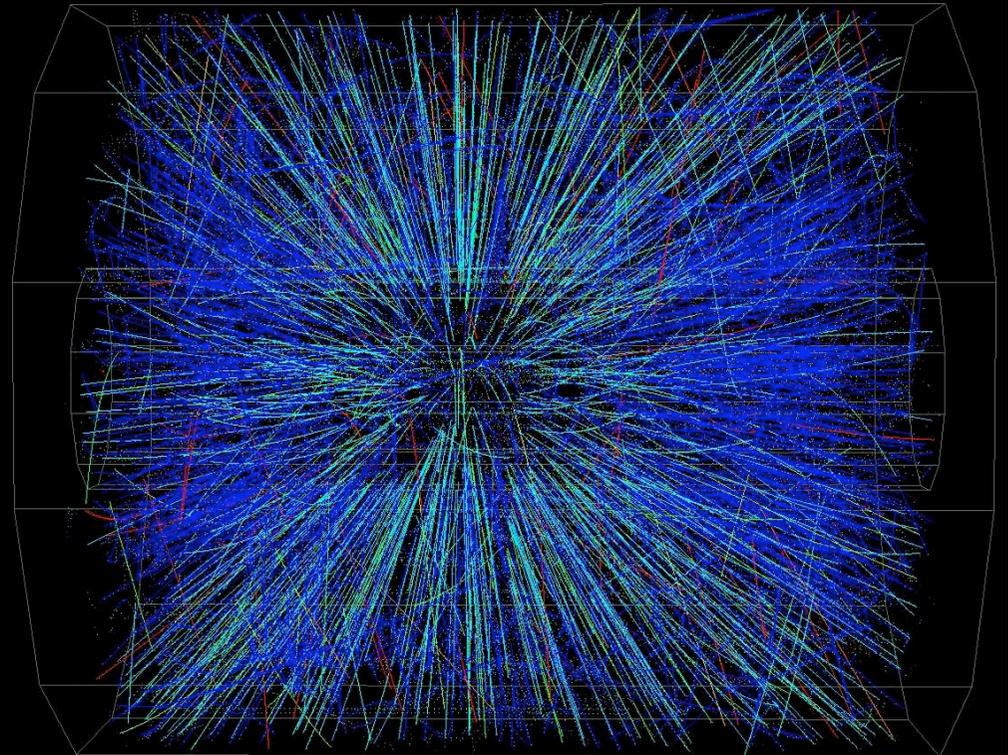
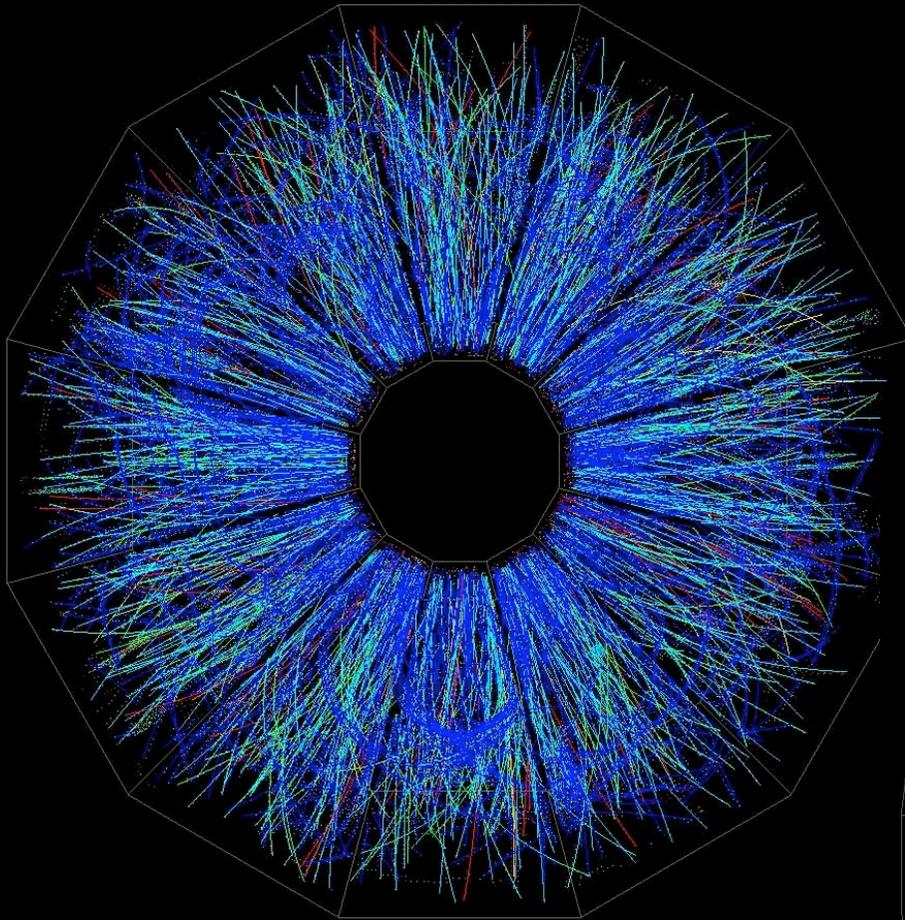
Evento periferico



color code \Rightarrow energy loss

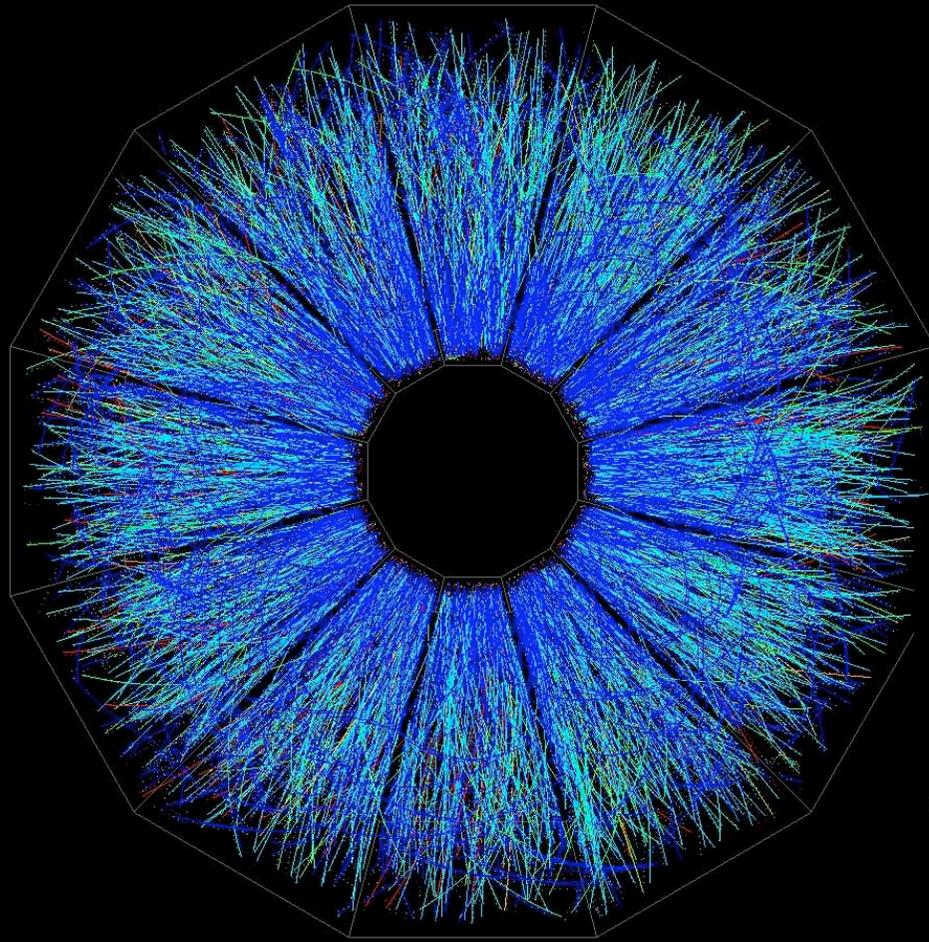
Eventi Au-Au, Energia CM $E \sim 130$ A-GeV

Evento semi-centrale

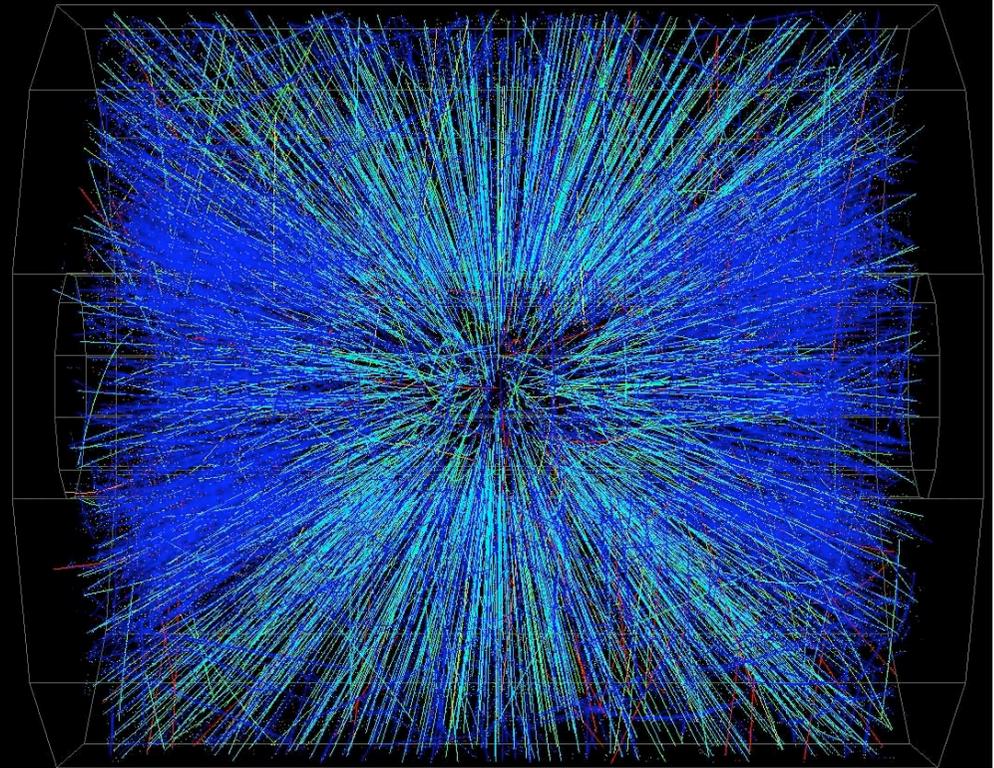


color code \Rightarrow energy loss

Eventi Au-Au, Energia CM $E \sim 130$ A-GeV



Evento Centrale



color code \Rightarrow energy loss

Cosa guardare??

Incremento di stranezza



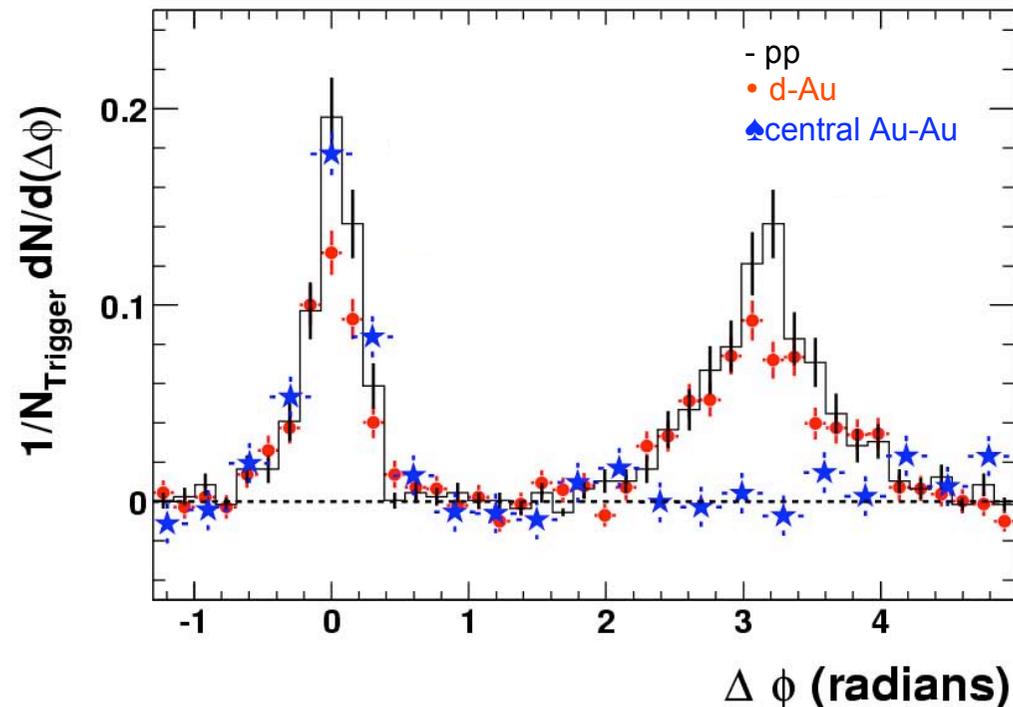
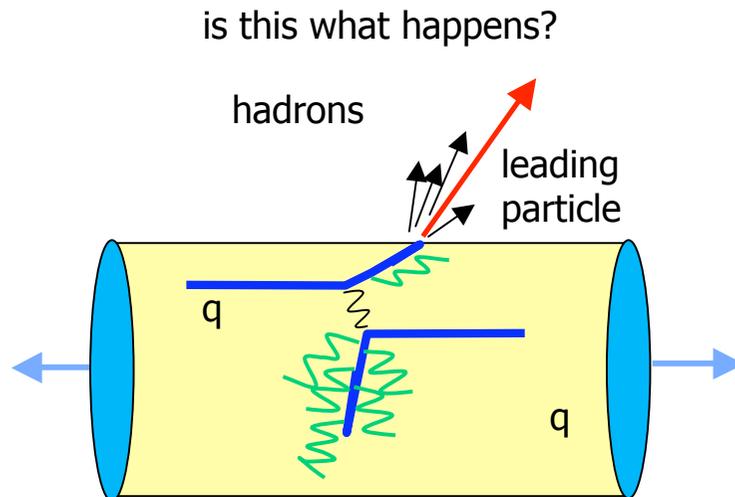
- la formazione di QGP dovrebbe causare un' aumento del numero (relativo) di particelle con stranezza, in quanto:
 - Pauli Blocking
 - Diminuizione della massa del quark s
- un incremento di stranezza single-strange (particelle con un' unico quark s) già osservate in collisioni A-A a relativamente bassa energia
- al SPS si è osservato un aumento delle particelle “Multi-strange”
- ciò è piuttosto difficile da spiegare senza QGP

Cosa guardare??

Correlazioni azimutali dei jet (jet quenching)

- la densità nella zona centrale è tale che quel volume è “opaco” (fortemente intergente).

Solo il partone più vicino alla superficie dà luogo a un Jet.
L'altro “viene riassorbito” nel mezzo.



ALICE Physics goals

(ovvero, vorremmo investigare tutto con un solo esperimento!)

● Osservabili globali:

Molteplicità, distribuzioni in η

● Gradi di libertà in funzione di T
rapporti tra adroni e loro spettro,
continuum dei dileptoni, fotoni diretti

● Prime evidenze di fenomeni
collettivi:

flusso ellittico

● Perdita di energia dei partoni nel
quark gluon plasma:
jet quenching, spettro ad alto p_t , open
charm and open beauty

• Deconfinamento:

spettroscopia del charmonium e
bottonium

• Ripristino della simmetria chirale:
rapporto neutri/carichi,

• Fenomeni di fluttuazione phenomena -
comportamento critico:

studio evento per evento di composizione
e spettro delle particelle

• collisioni p-p in un nuovo range di
energie.

➤ Grande accettazione

➤ Buone capacità di tracciamento

➤ Trigger selettivo

➤ Ottima granularità

➤ Ampia copertura in momento

➤ P.I.D. di adroni e leptoni

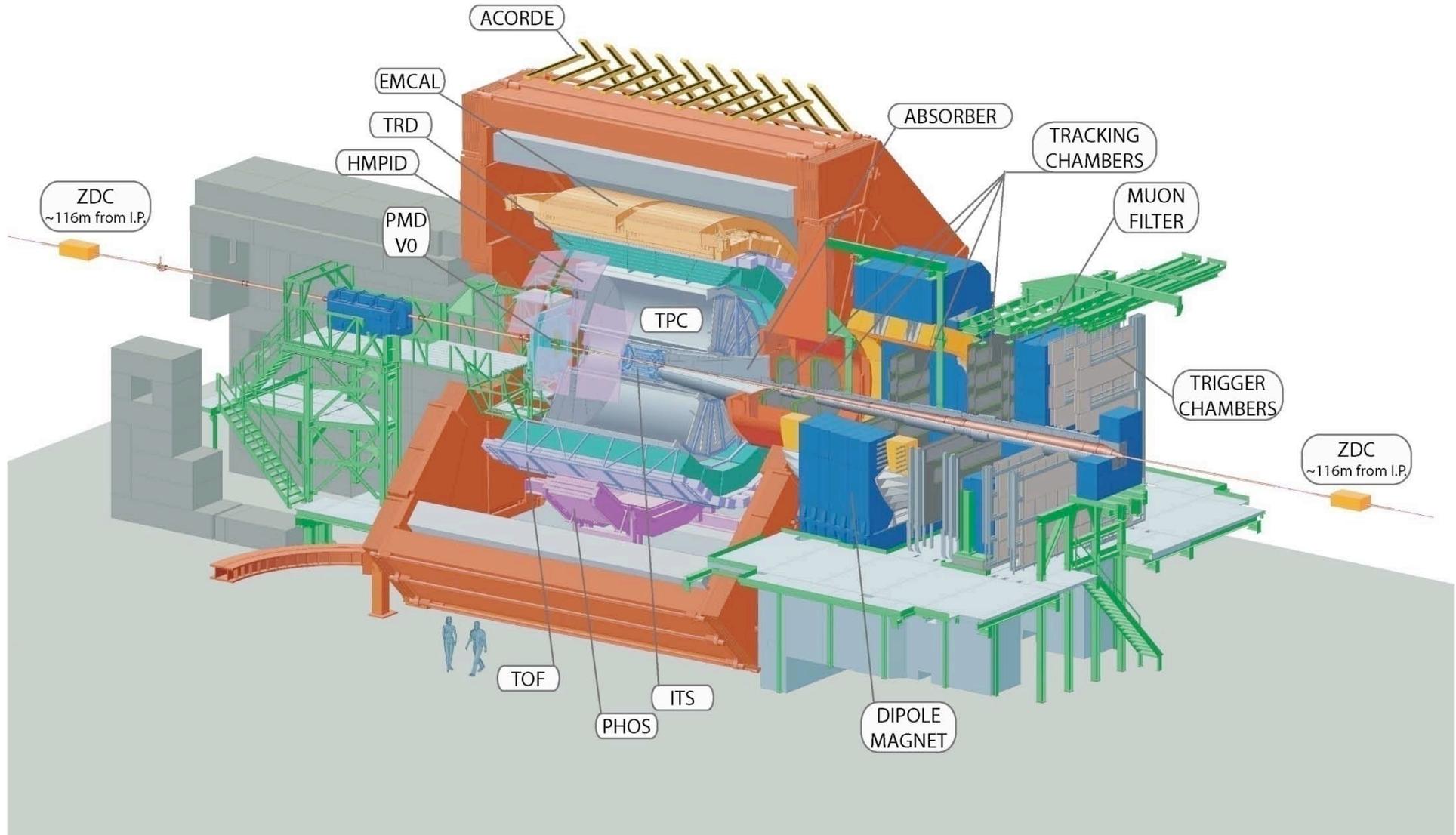
➤ Buona ricostruzione di vertici sec.

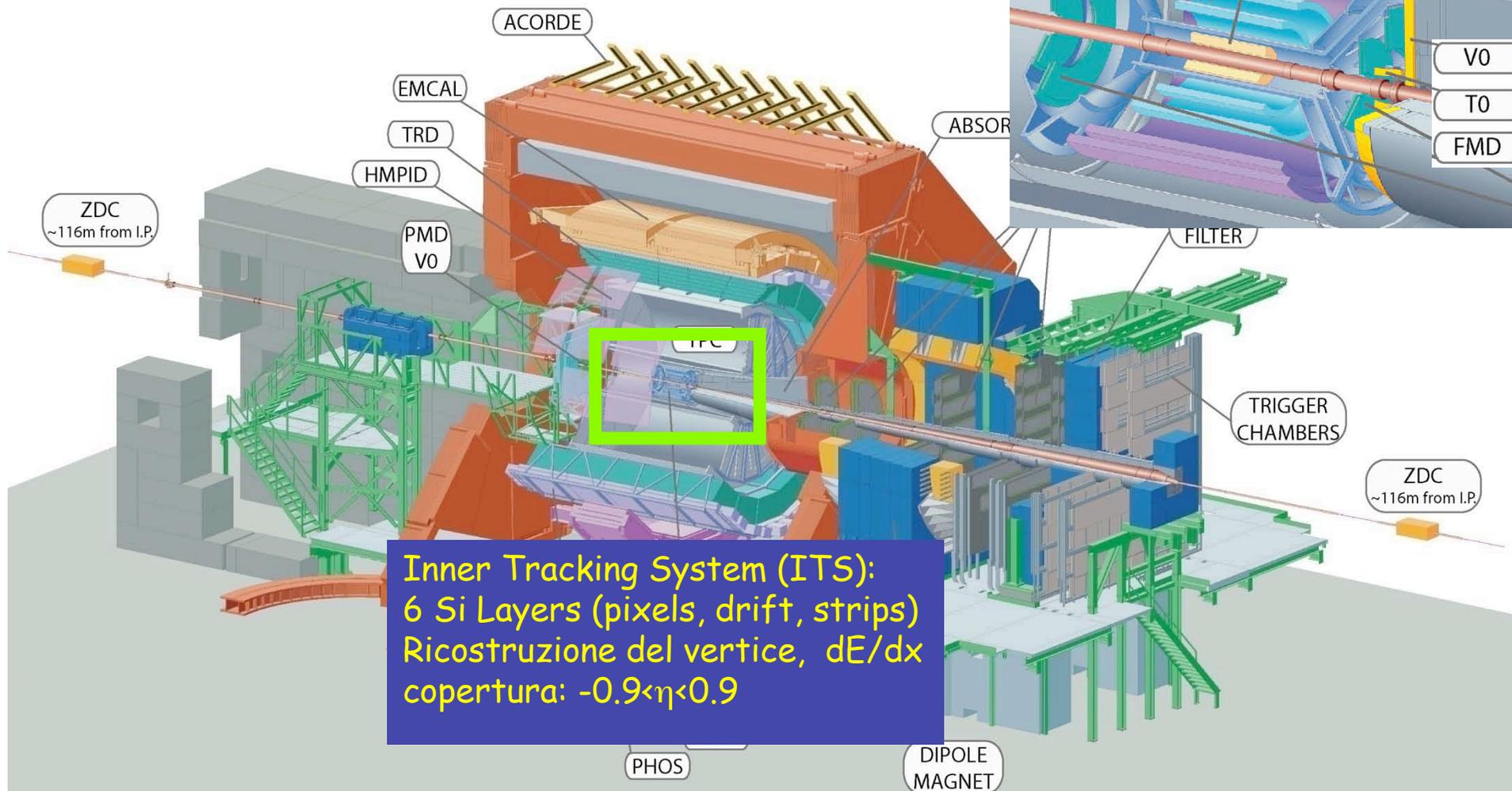
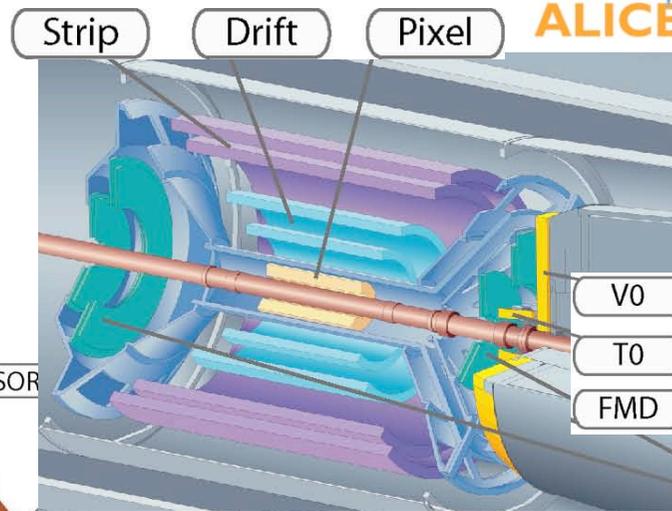
➤ Rivelazione di fotoni



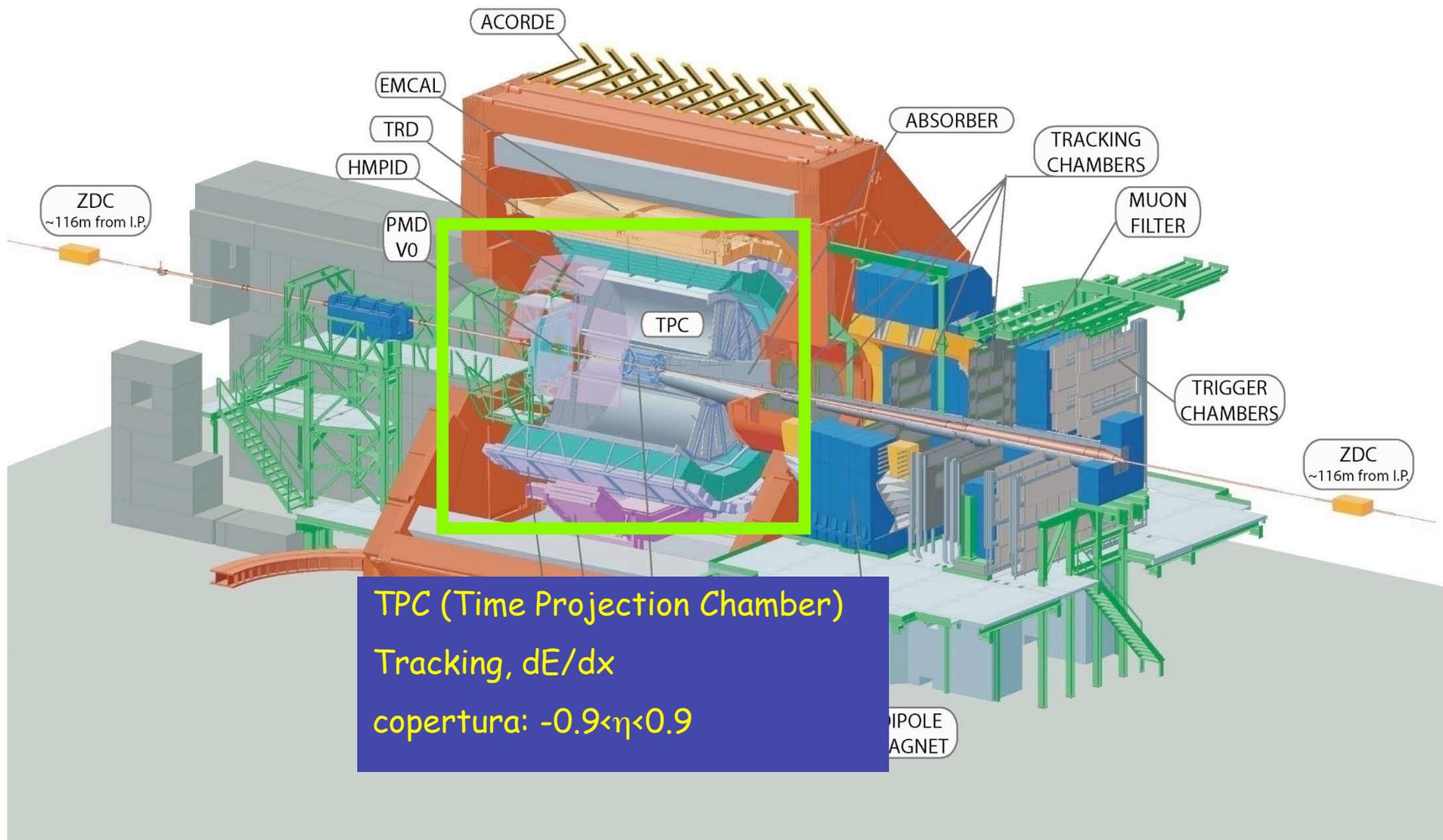
Uso di diverse tecniche sperimentali!

Size: 16 x 26 meters
Weight: 10,000 tons
Detectors: 18

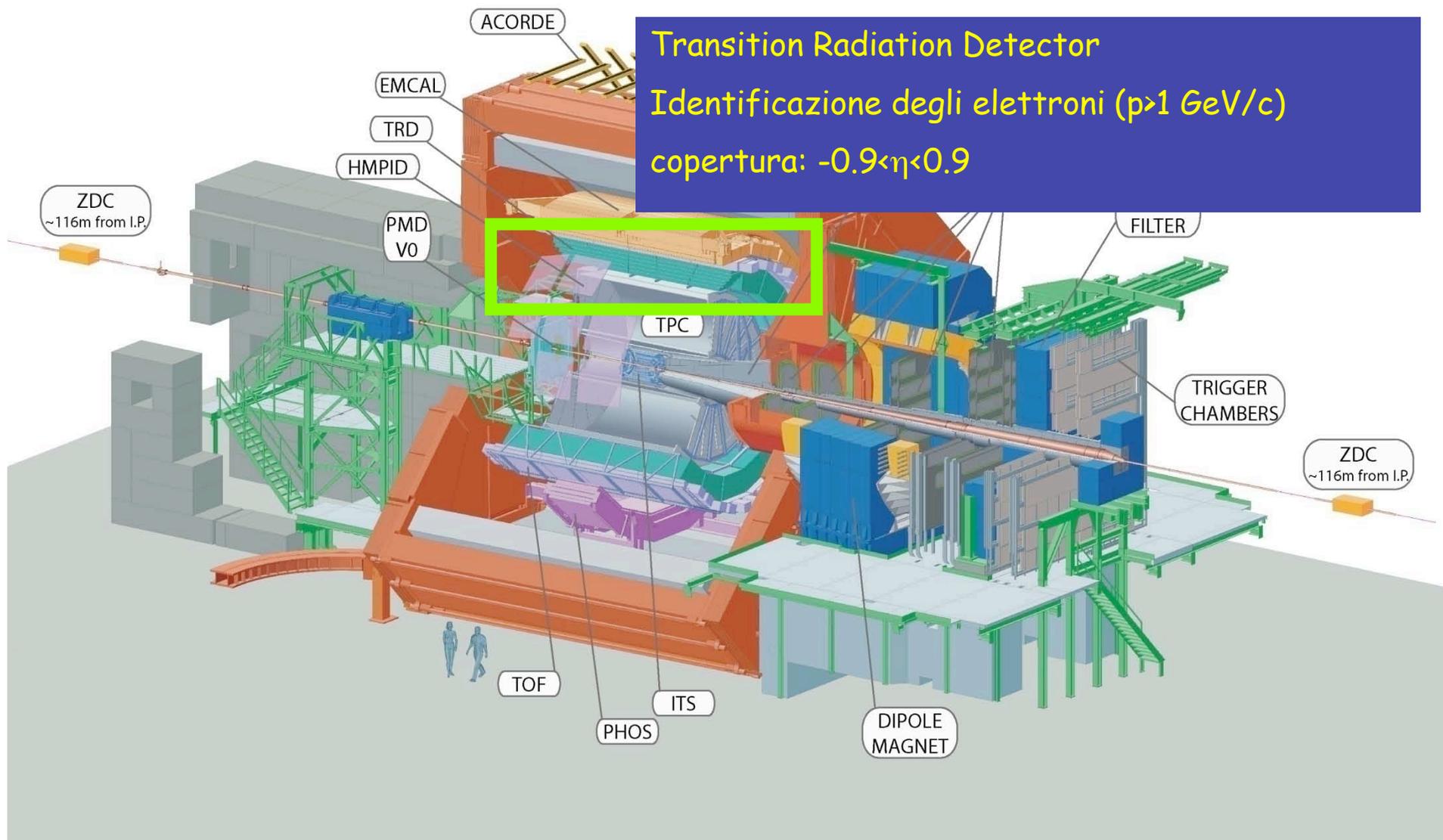




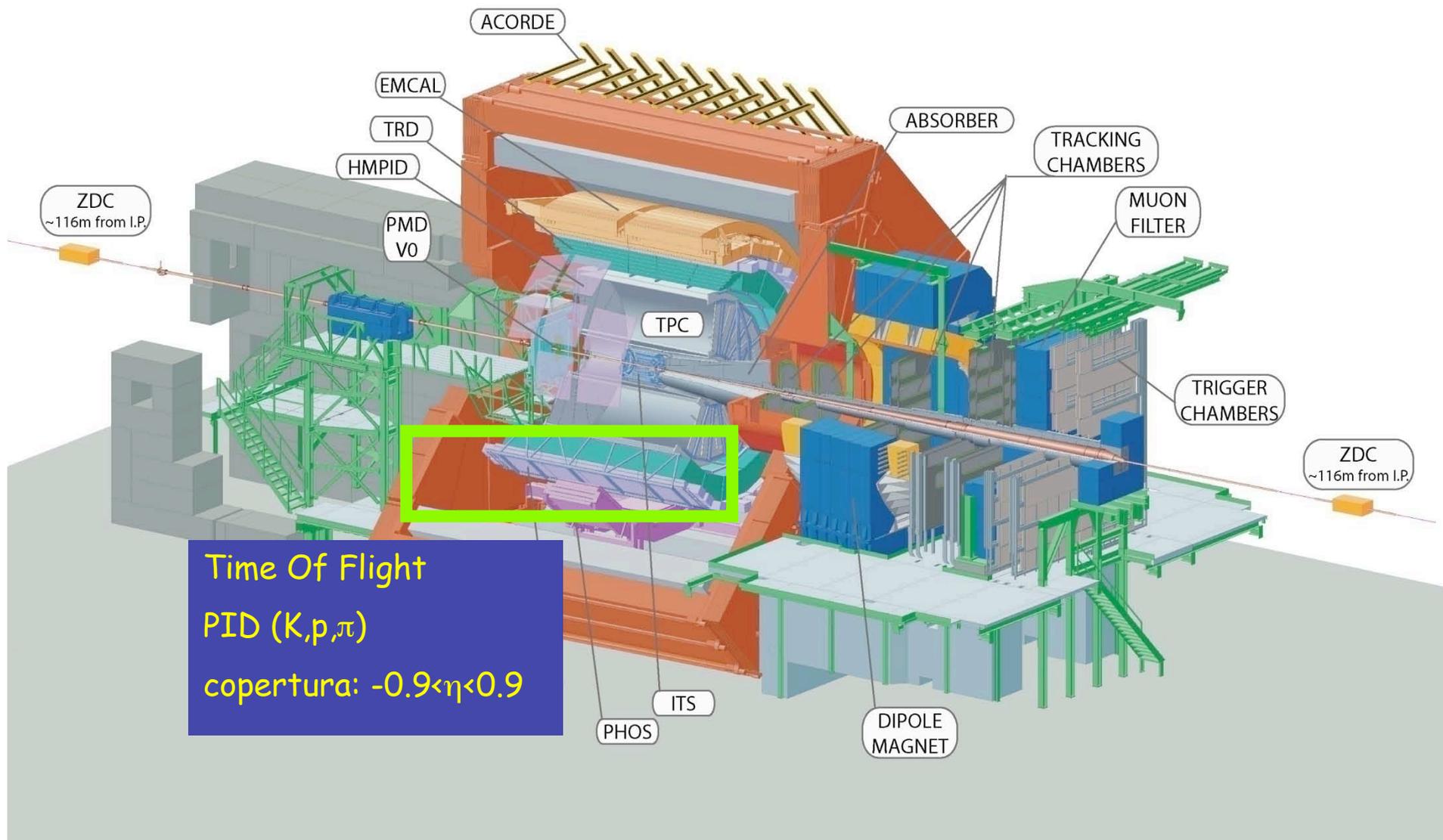
Inner Tracking System (ITS):
 6 Si Layers (pixels, drift, strips)
 Ricostruzione del vertice, dE/dx
 copertura: $-0.9 < \eta < 0.9$

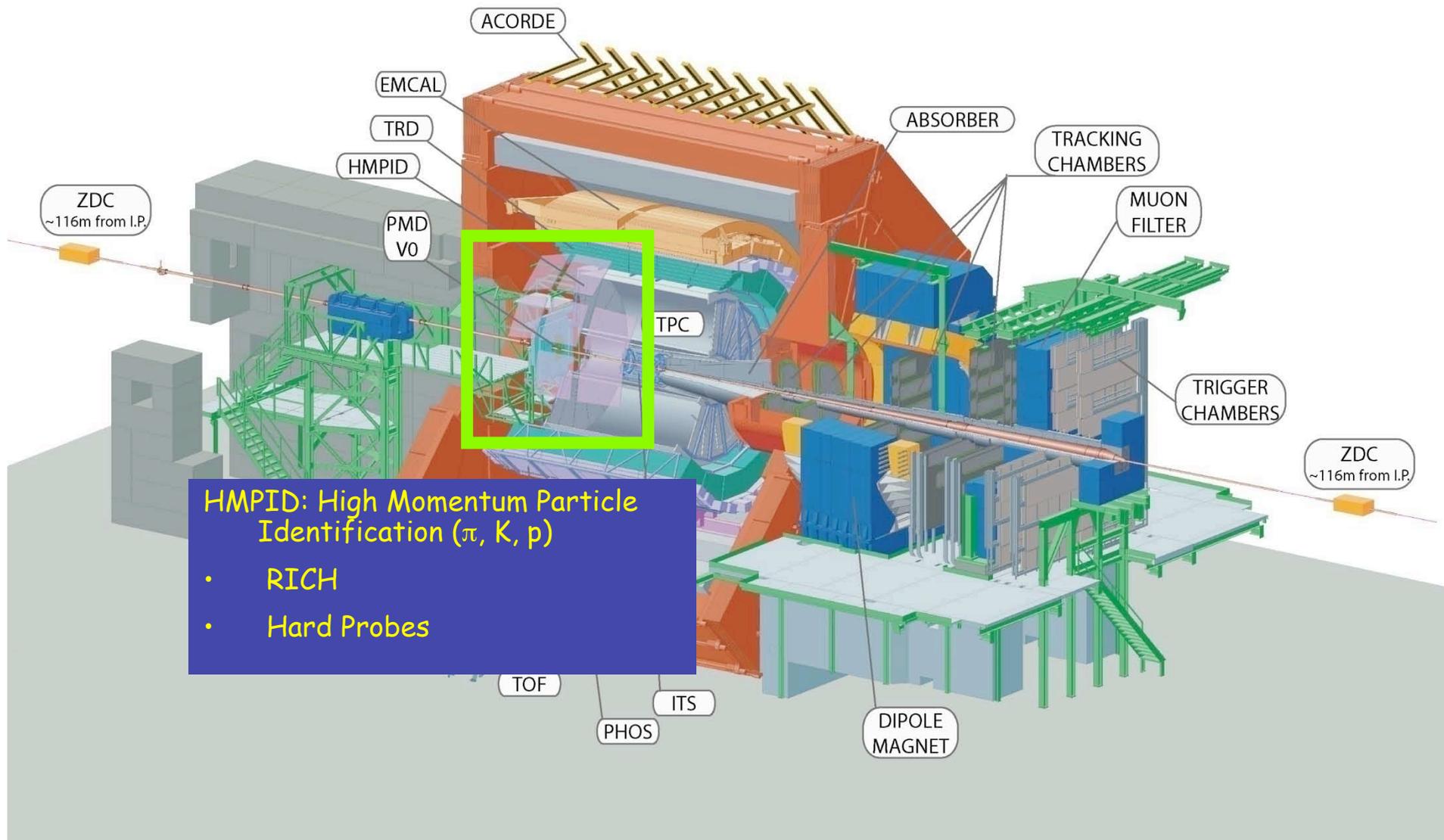


TPC (Time Projection Chamber)
Tracking, dE/dx
copertura: $-0.9 < \eta < 0.9$



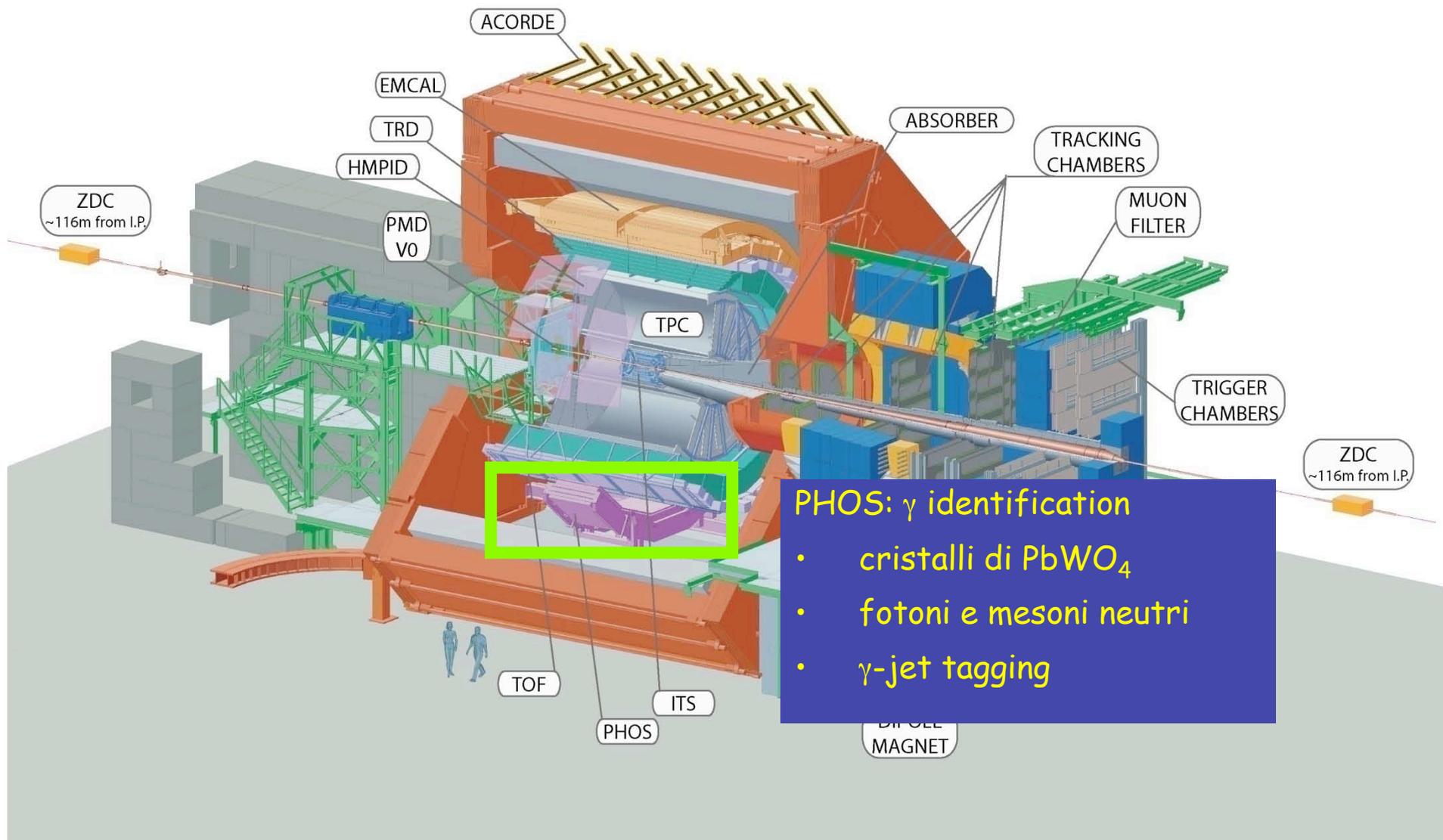
Transition Radiation Detector
Identificazione degli elettroni ($p > 1 \text{ GeV}/c$)
copertura: $-0.9 < \eta < 0.9$





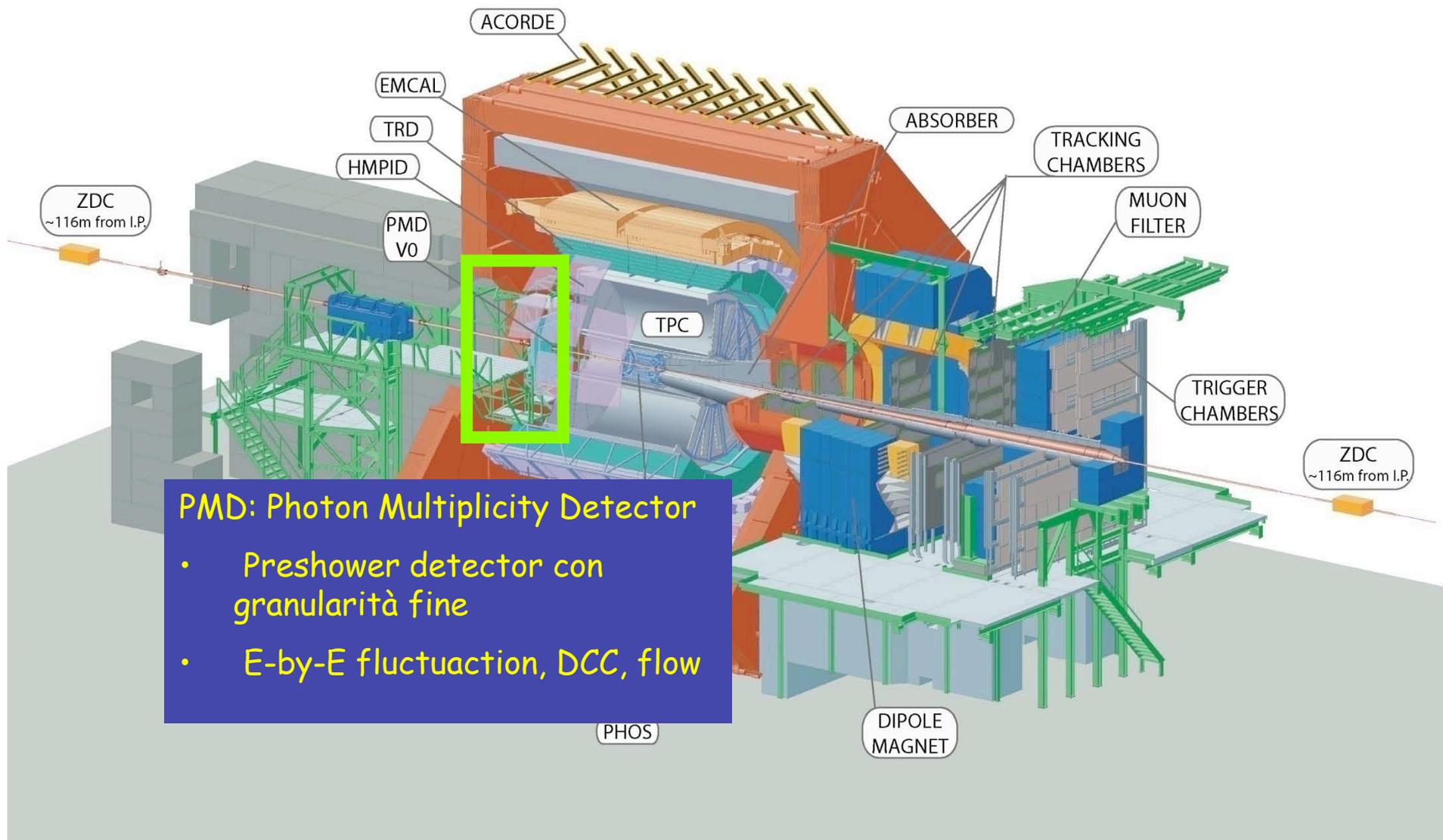
HMPID: High Momentum Particle Identification (π , K, p)

- RICH
- Hard Probes



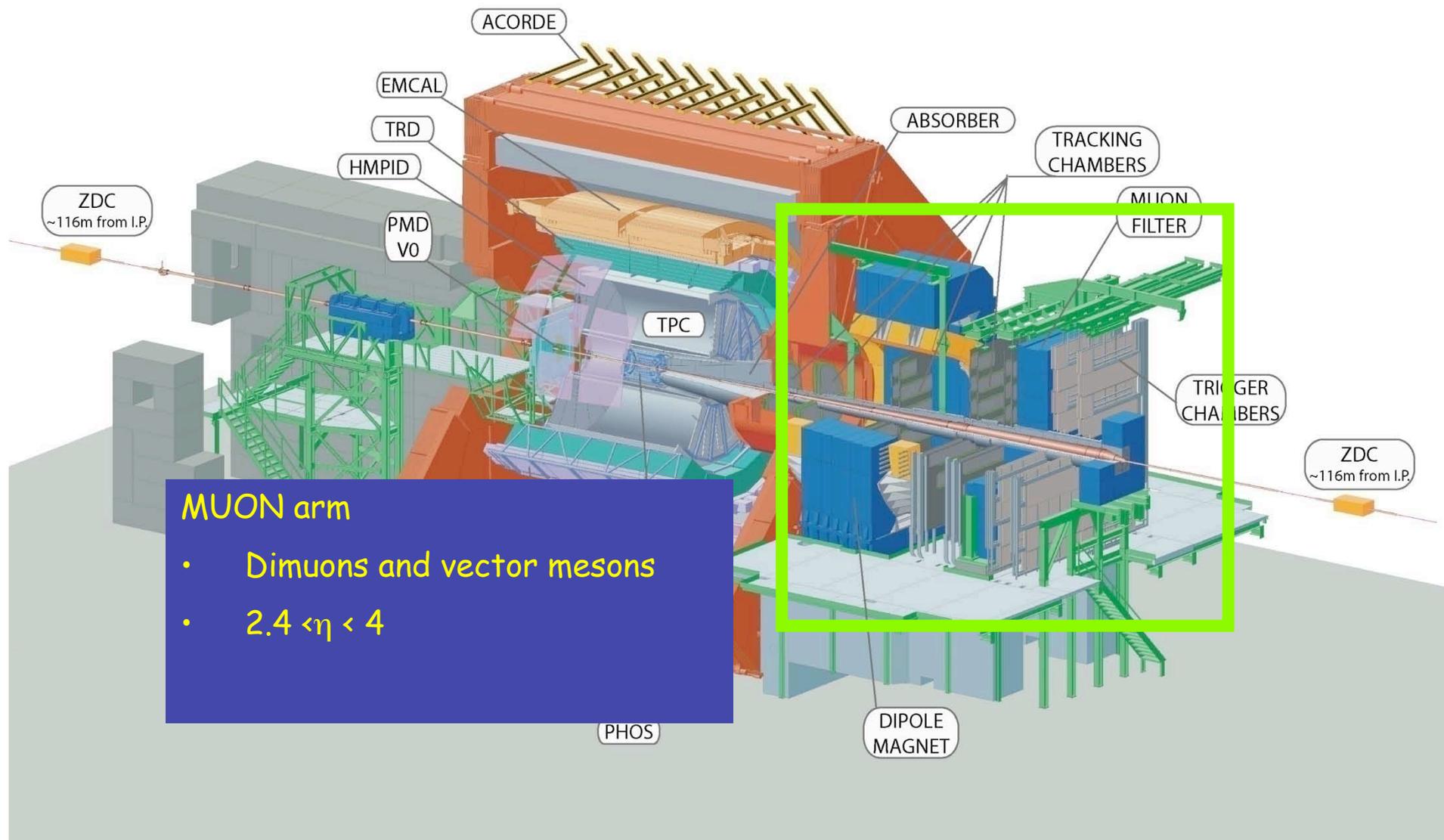
PHOS: γ identification

- cristalli di PbWO_4
- fotoni e mesoni neutri
- γ -jet tagging



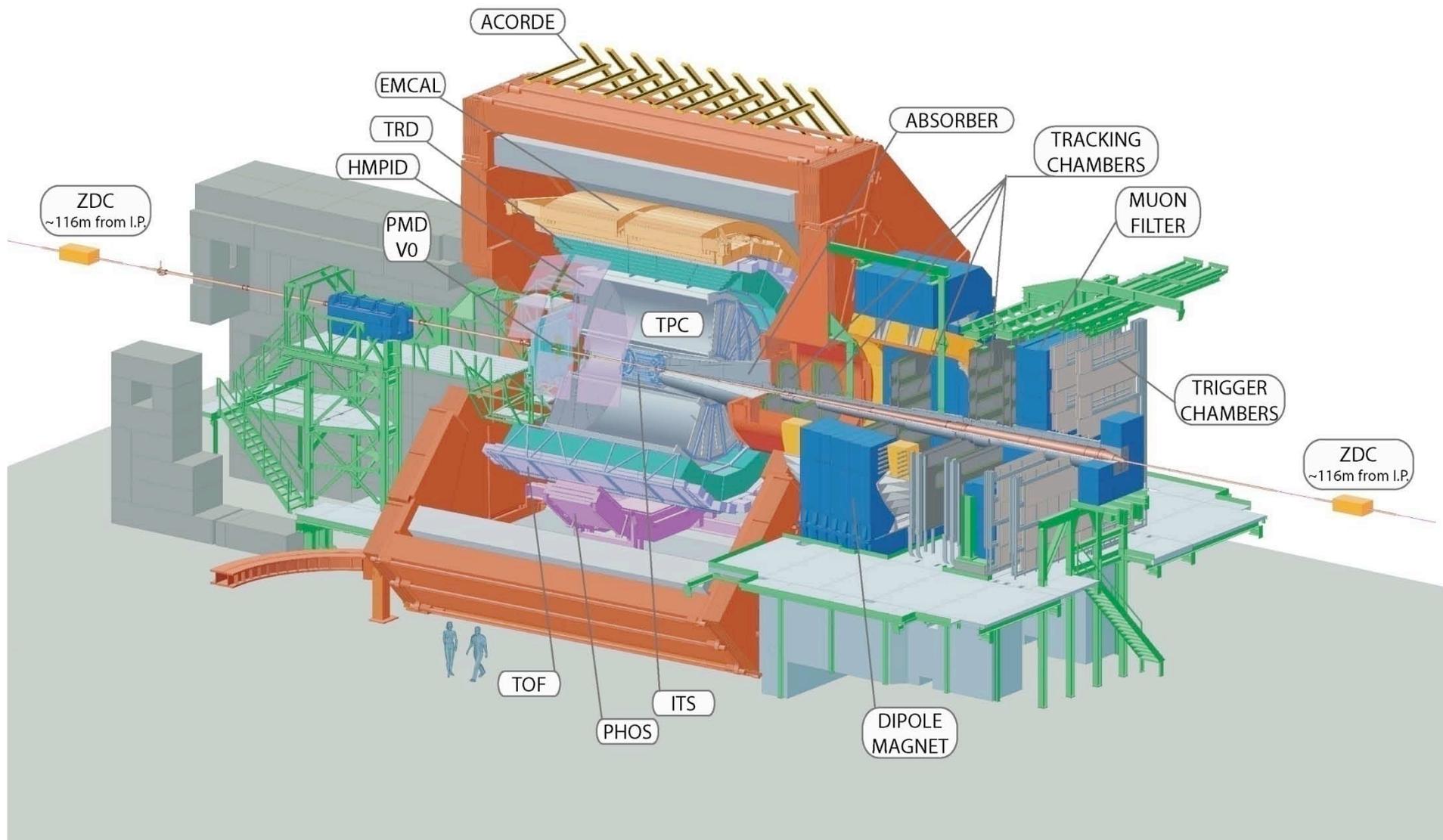
PMD: Photon Multiplicity Detector

- Preshower detector con granularità fine
- E-by-E fluctuaction, DCC, flow



MUON arm

- Dimuons and vector mesons
- $2.4 < \eta < 4$

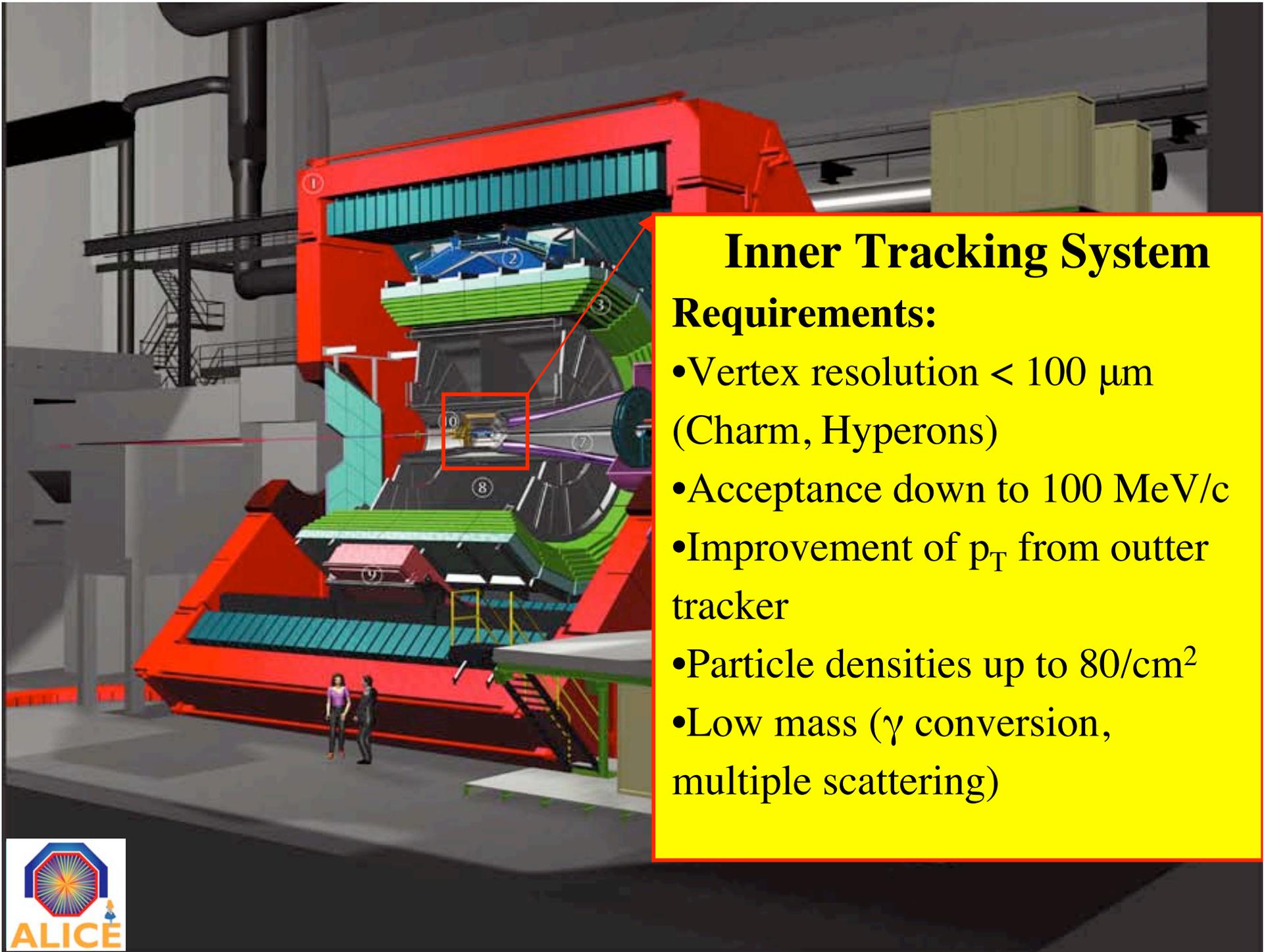


Tracciamento



- $dN/d\eta|_{\max} \sim 4000$ ➔ il tracciamento è la sfida principale!
- Requirements (TPC+ITS):
 - ❖ Buona efficienza ($> 90\%$) per $p_T > 0.1$ GeV/c
 - ❖ Risoluzione in momento (dp/p):
 - $\sim 1\div 2\%$ per bassi momenti,
 - alcuni % a 5 GeV/c
 - e ancora $O(10\%)$ a 50 GeV/c o più (per i Jets)
 - ❖ Buona ricostruzione del vertice: V0, charm
 - ❖ Identificazione delle particle (dE/dx , kinks)

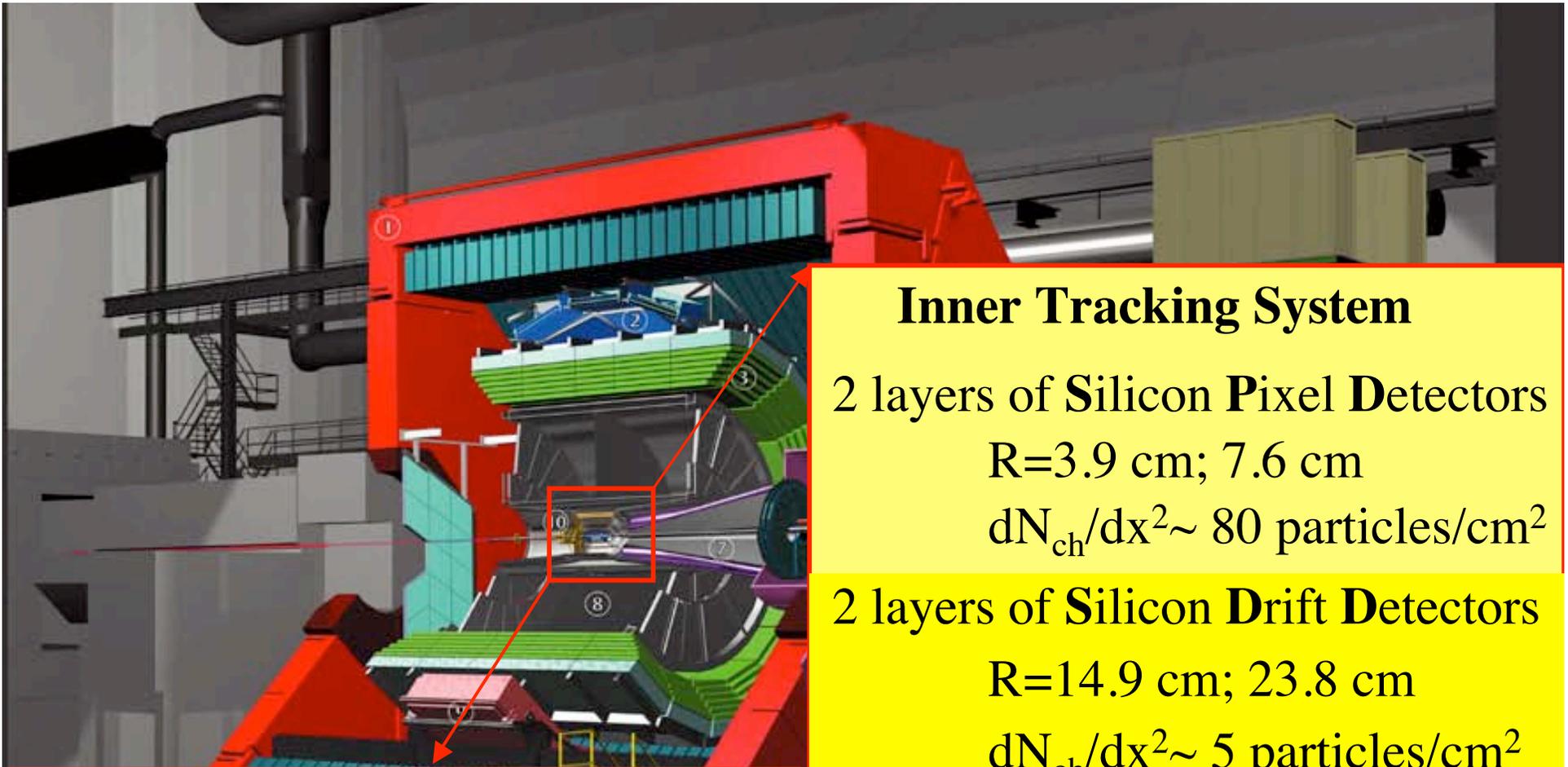
Quindi: molti punti ad alta risoluzione, vero 3D,
tracce lunghe, in un campo magnetico moderato,
usando meno materiale possibile



Inner Tracking System

Requirements:

- Vertex resolution $< 100 \mu\text{m}$
(Charm, Hyperons)
- Acceptance down to $100 \text{ MeV}/c$
- Improvement of p_T from outer tracker
- Particle densities up to $80/\text{cm}^2$
- Low mass (γ conversion, multiple scattering)



Inner Tracking System

2 layers of **Silicon Pixel Detectors**

$R=3.9\text{ cm}; 7.6\text{ cm}$

$dN_{\text{ch}}/dx^2 \sim 80\text{ particles/cm}^2$

2 layers of **Silicon Drift Detectors**

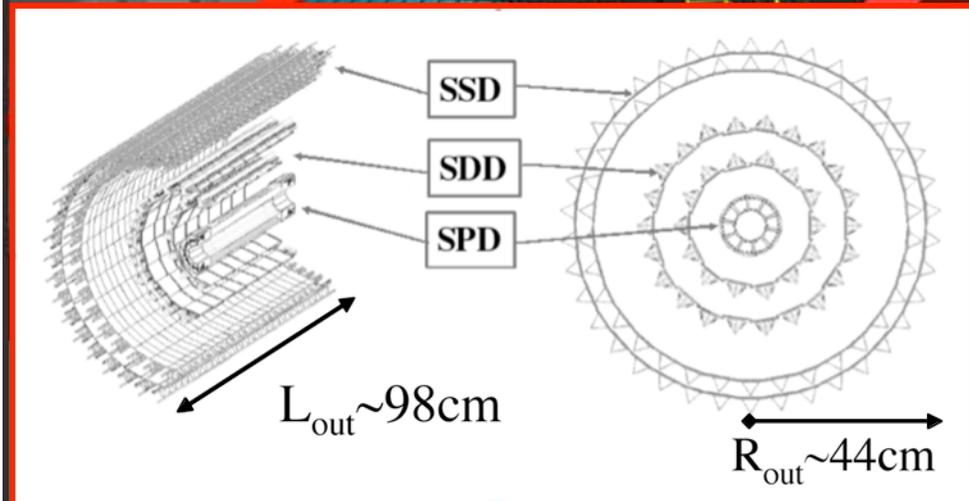
$R=14.9\text{ cm}; 23.8\text{ cm}$

$dN_{\text{ch}}/dx^2 \sim 5\text{ particles/cm}^2$

2 layers of **Silicon Strip Detectors**

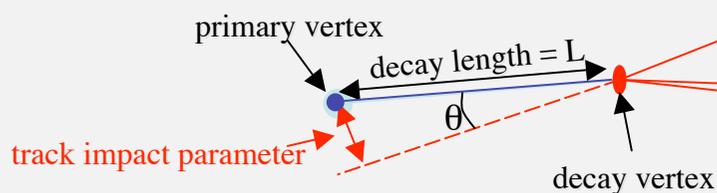
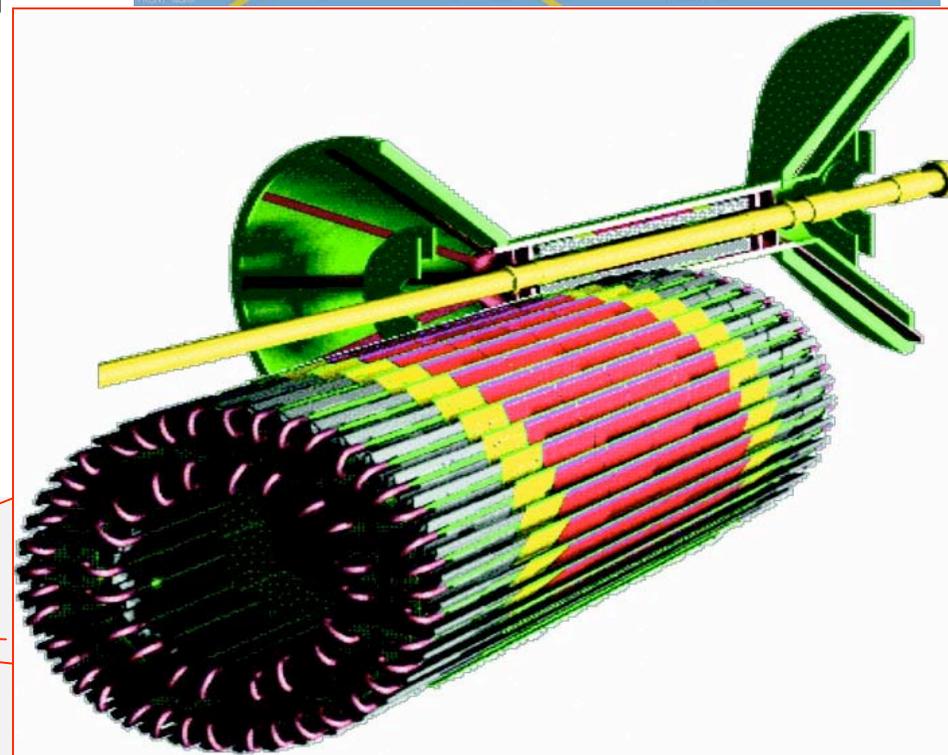
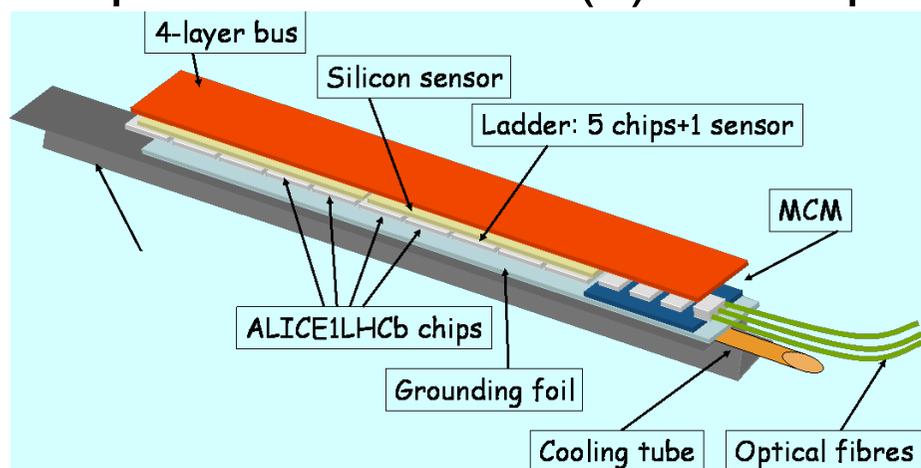
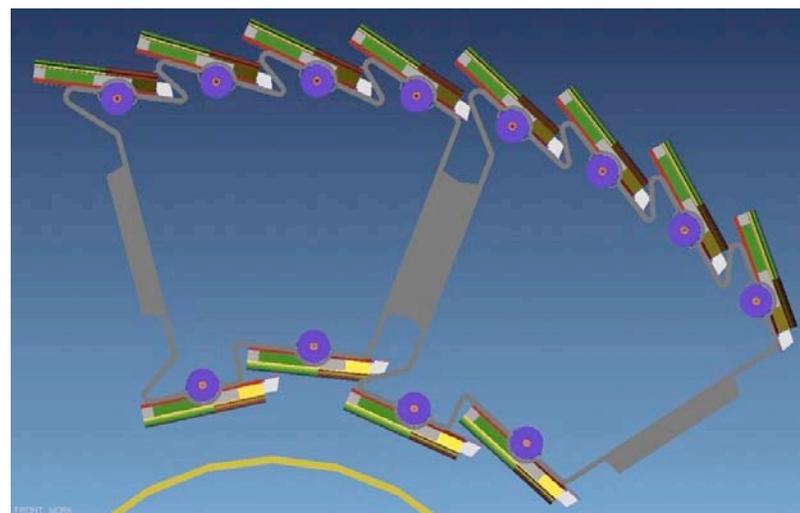
$R=38.5\text{ cm}, 43.6\text{ cm}$

$dN_{\text{ch}}/dx^2 \sim 1\text{ particle/cm}^2$



L1,L2: Silicon Pixel Detector

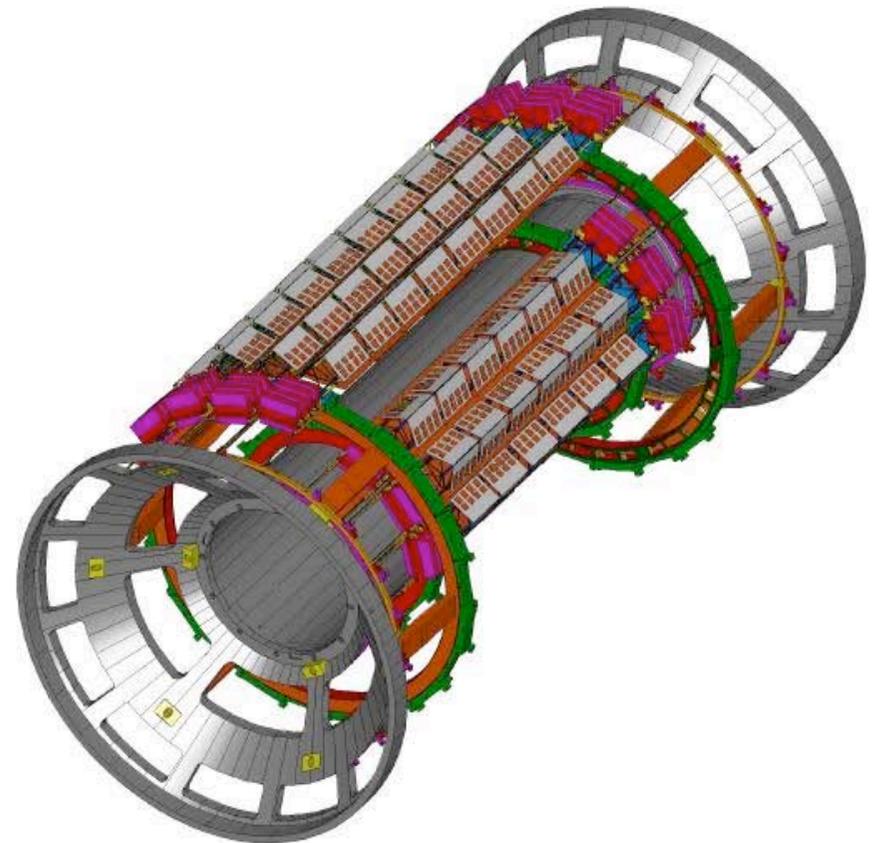
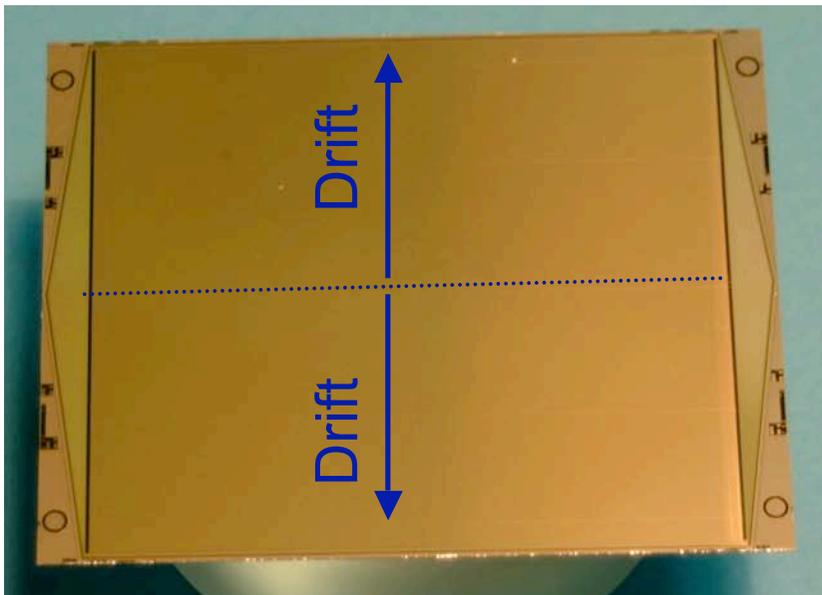
- 60 staves, 240 modules
- 40960 chs. per module
- cell size ($r_{\phi,z}$): 50 x 425 μm^2
- spatial resolution (r_{ϕ}) 12 μm
- spatial resolution (z) 100 μm



L3,L4: Silicon Drift Detector



- 36 ladders, 260 modules
- 2 x 256 chs. per module
- cell size ($r_{\phi,z}$): 294 x 150 μm^2
- spatial resolution (r_{ϕ}) 35 μm
- spatial resolution (z) 23 μm

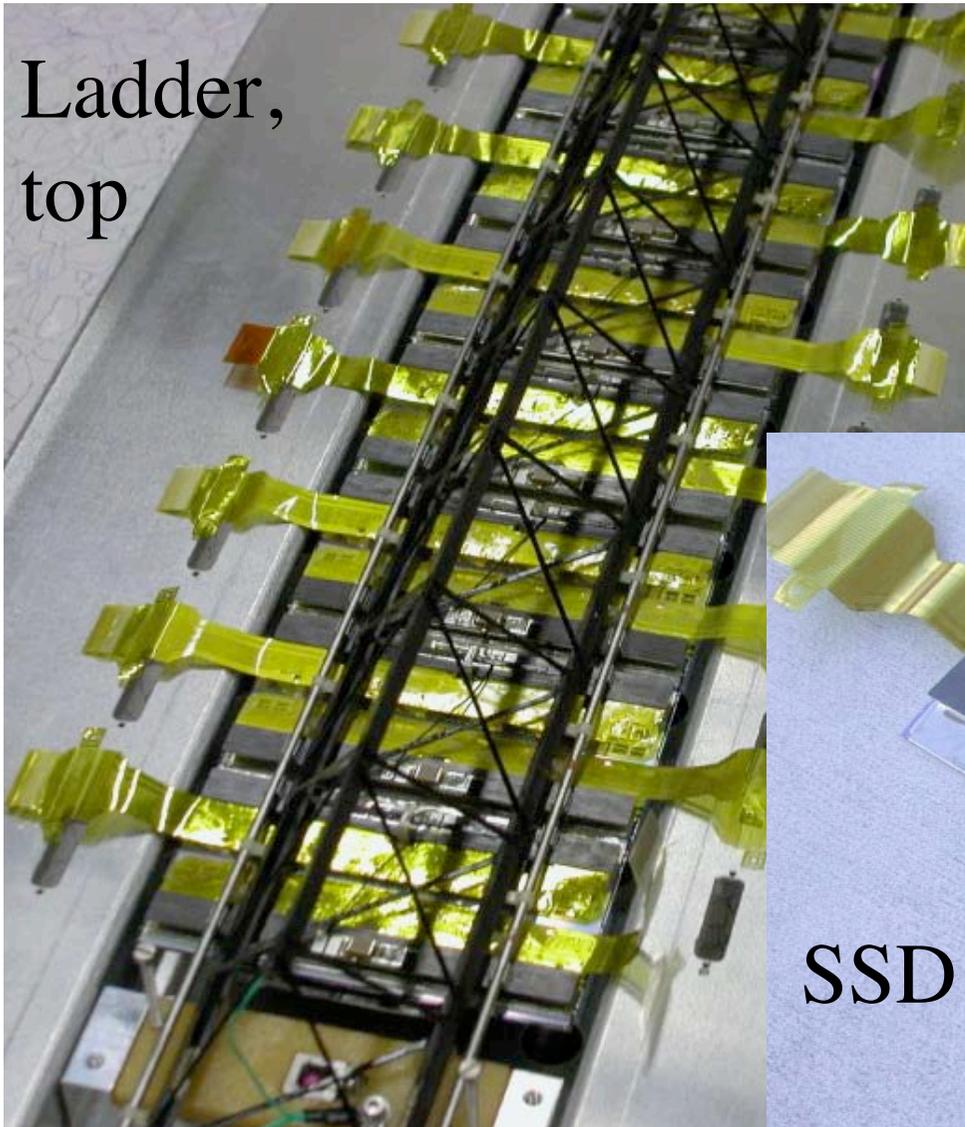


L5,L6: Silicon Strip Detector

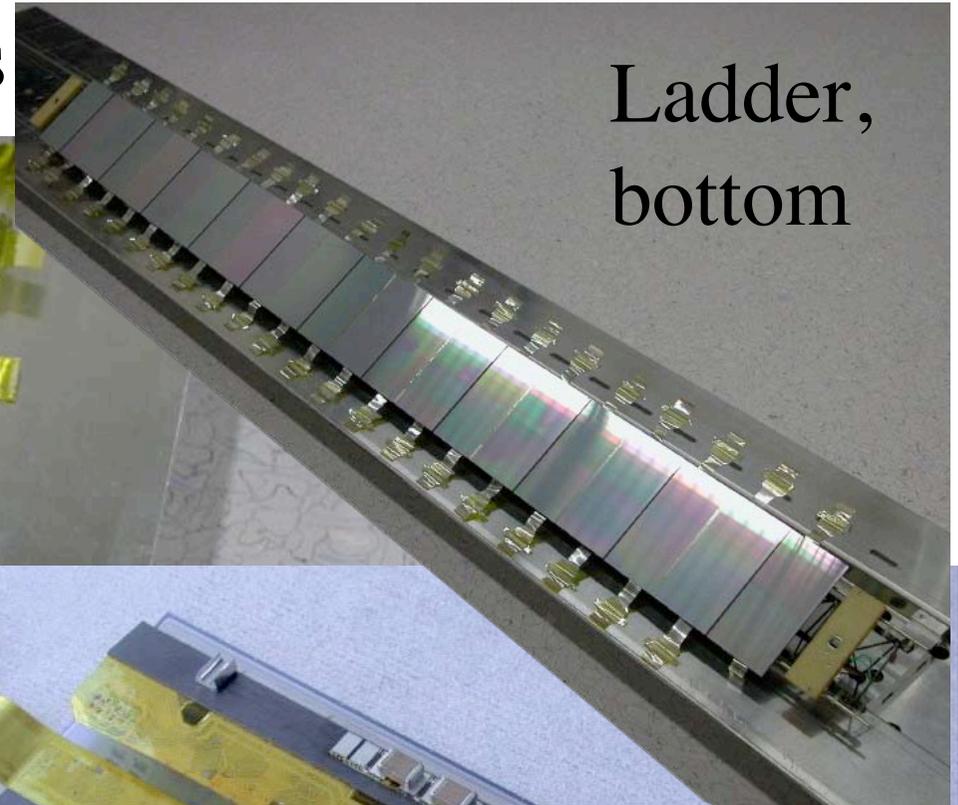


- 72 ladders, 1698 modules

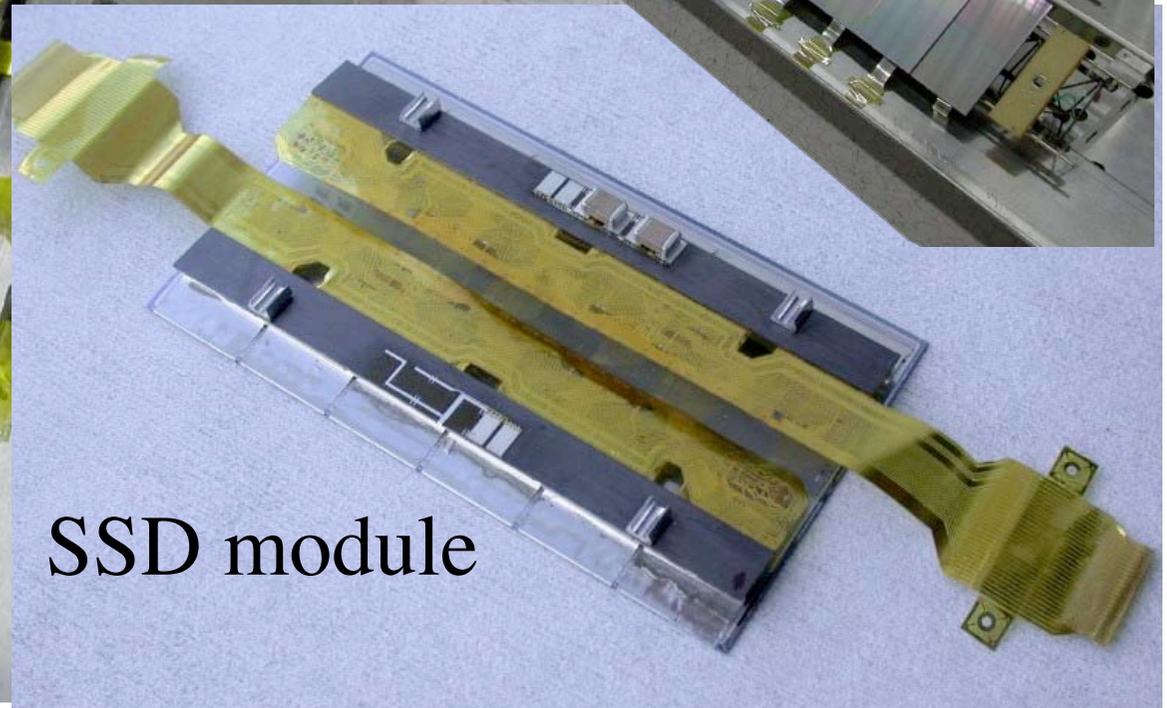
Ladder,
top



Ladder,
bottom



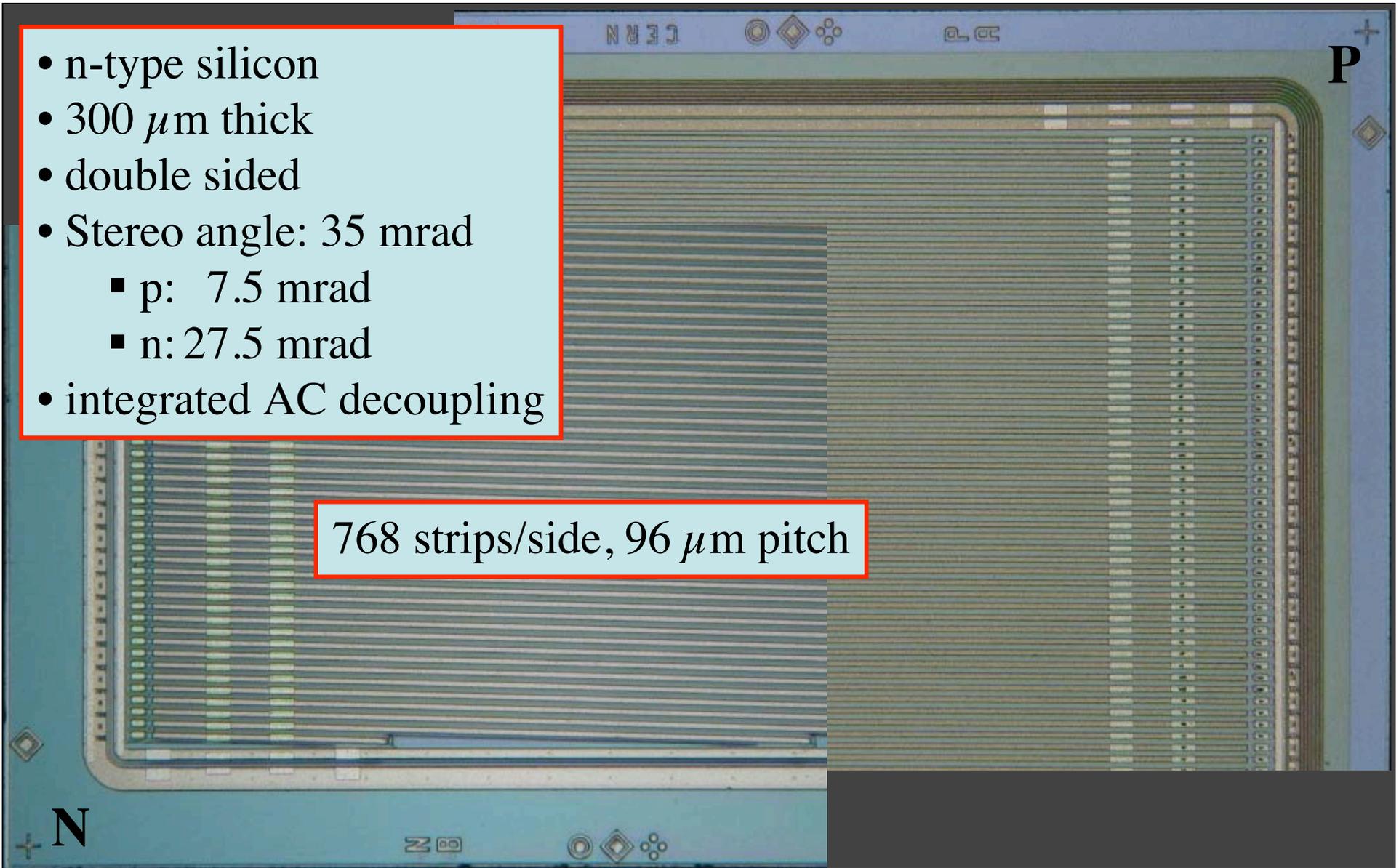
SSD module



sensore a microstrip

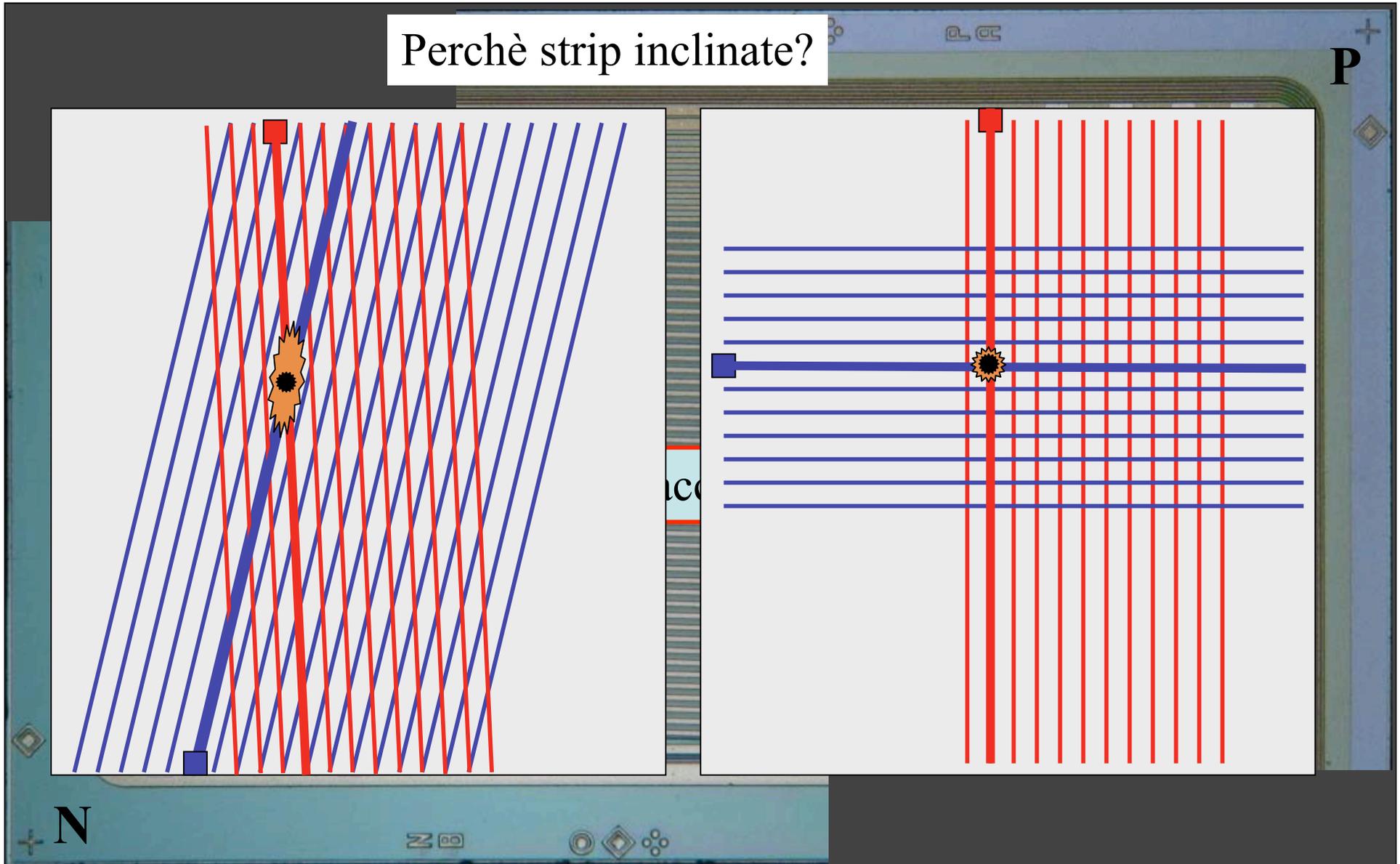
- n-type silicon
- 300 μm thick
- double sided
- Stereo angle: 35 mrad
 - p: 7.5 mrad
 - n: 27.5 mrad
- integrated AC decoupling

768 strips/side, 96 μm pitch



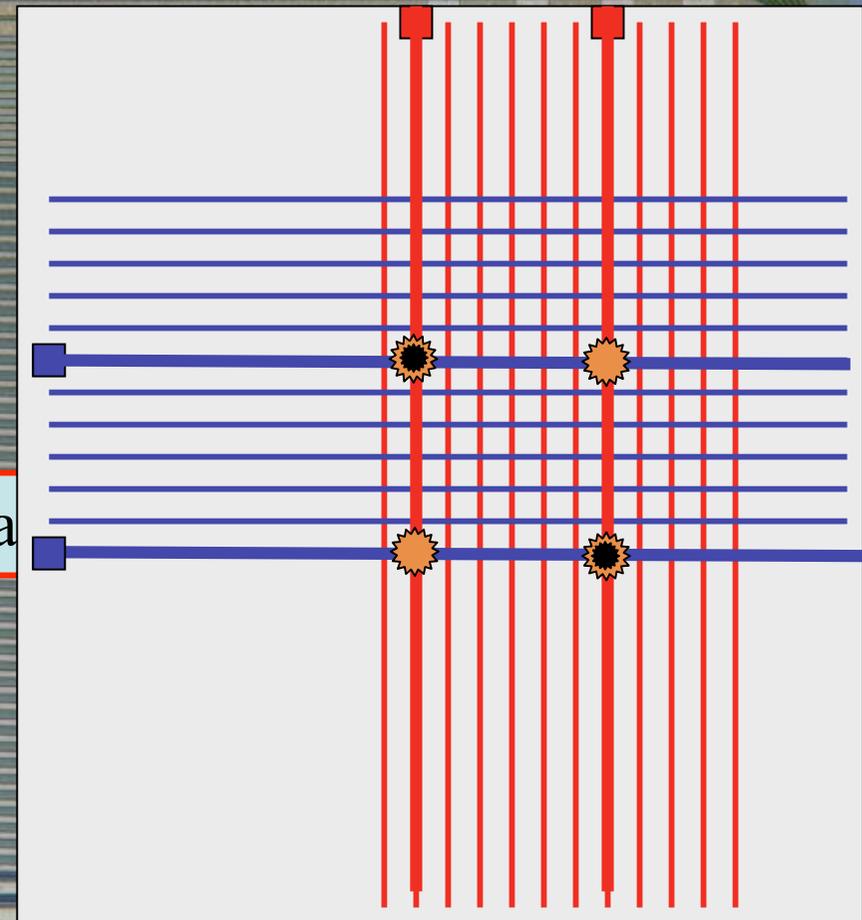
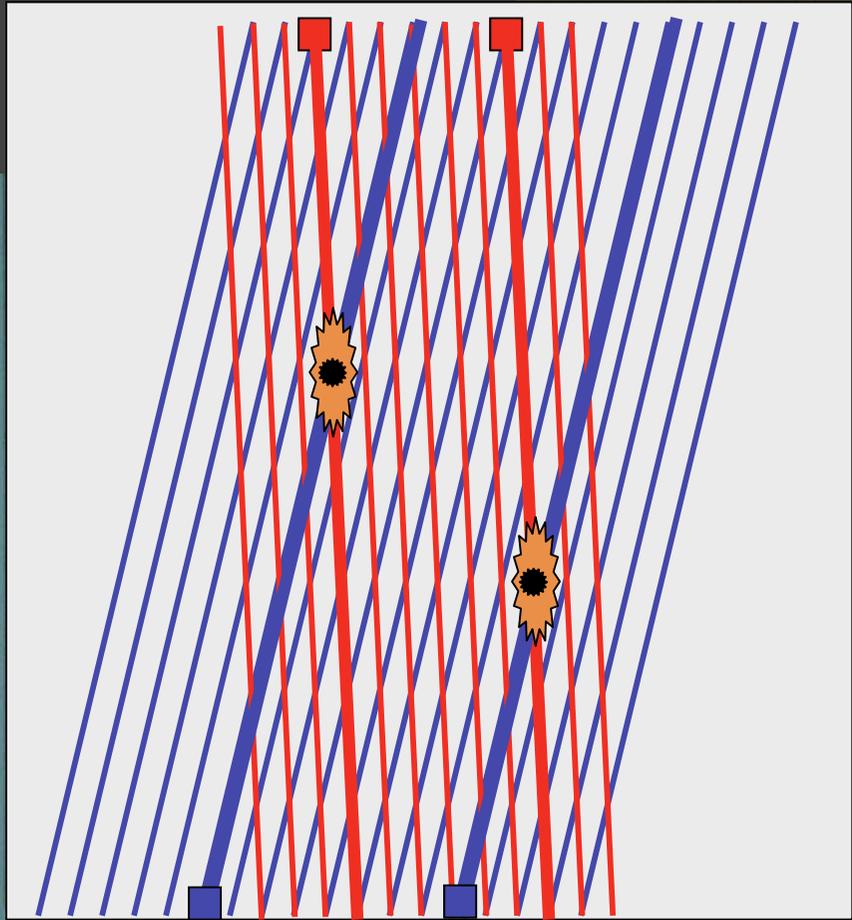
seniore a microstrip

Perchè strip inclinate?



seniore a microstrip

Con strip a 90° ho problemi



cia

P

N

20

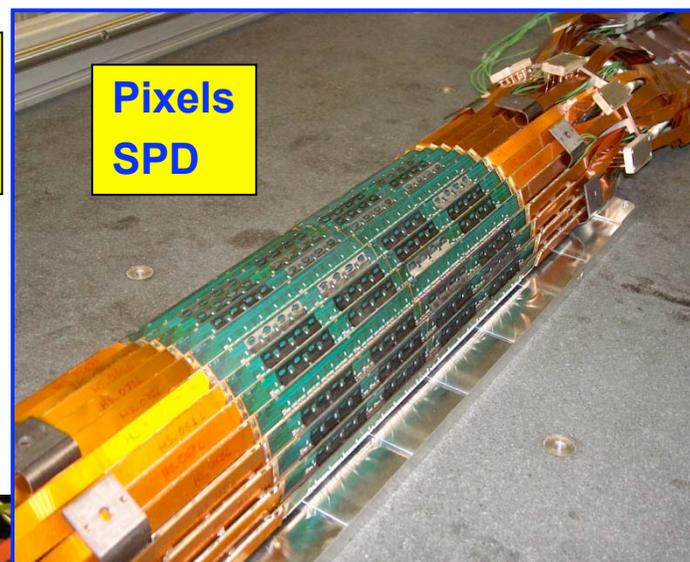


Inner Silicon Tracker



Inner Tracking System
~ 10 m² Si detectors, 6 layers
Pixels, Drift, double sided Strips

**Strips
SSD**

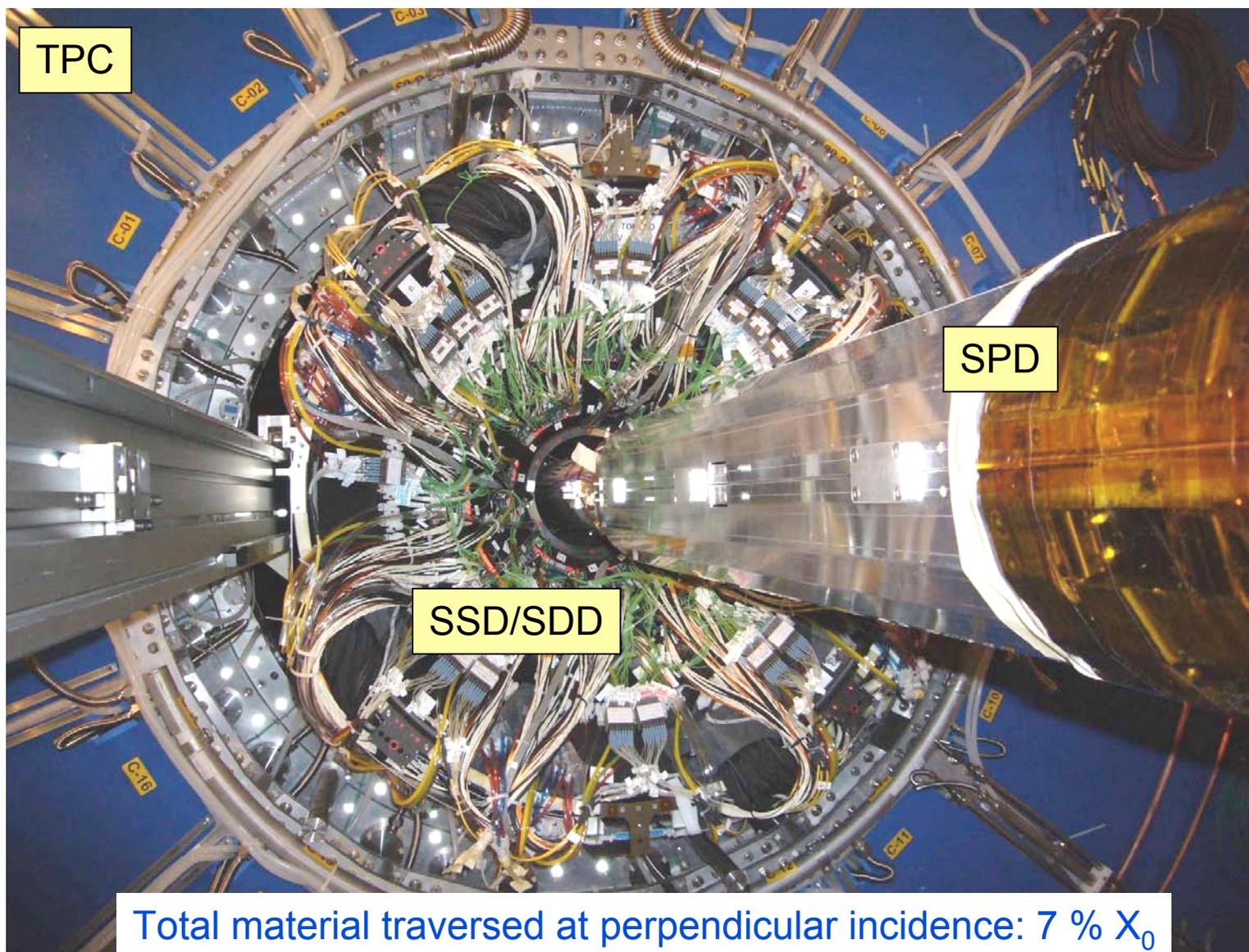


**Pixels
SPD**



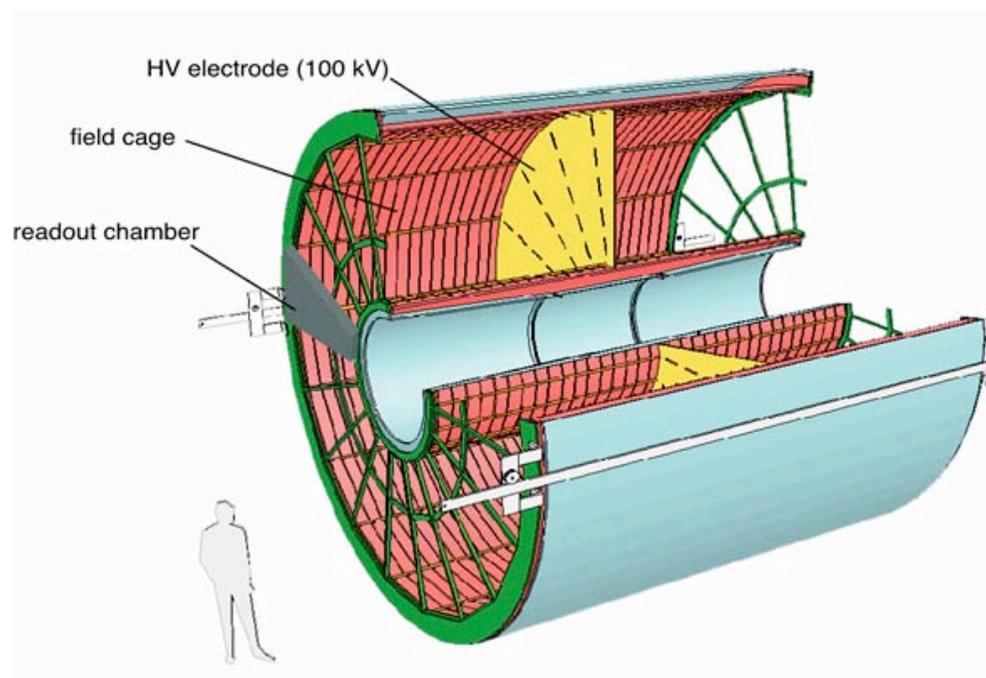
**Drift
SDD**

ITS Russian Dolls - Sliding the SSD/SDD over the SPD

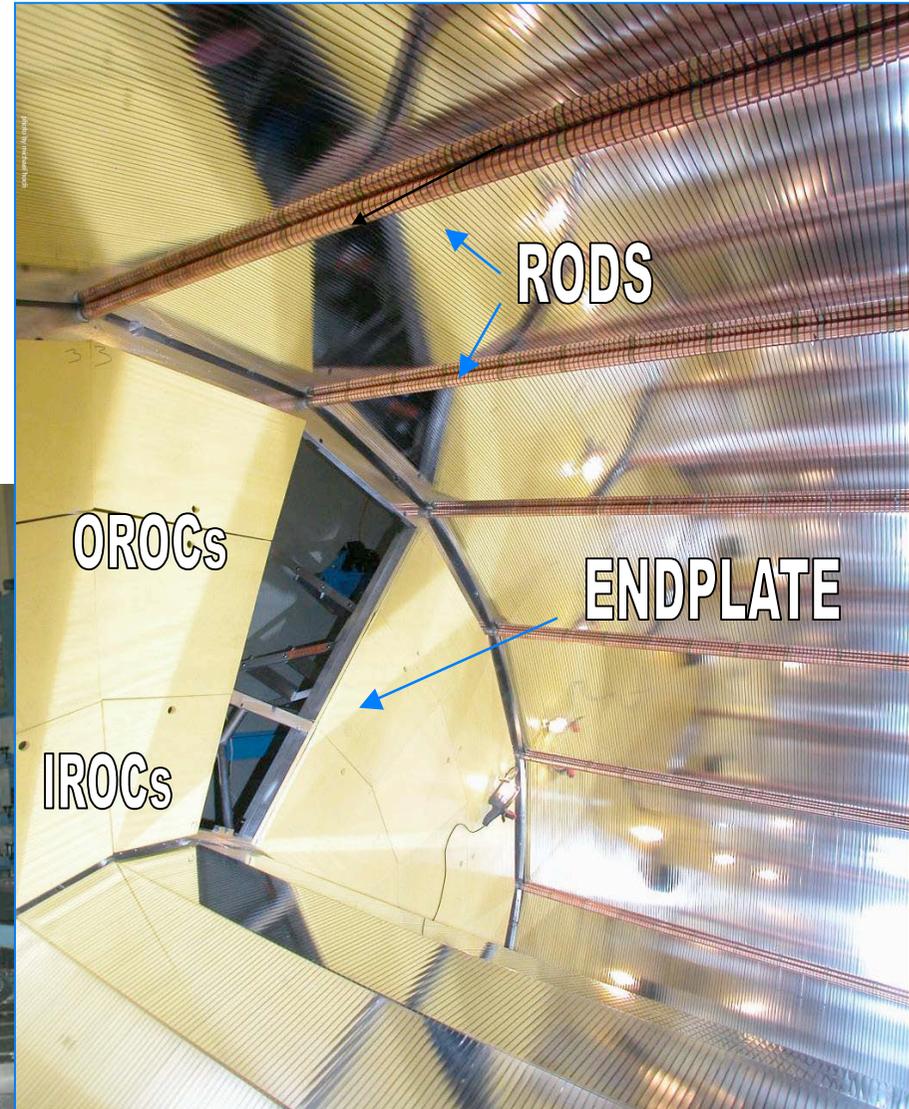


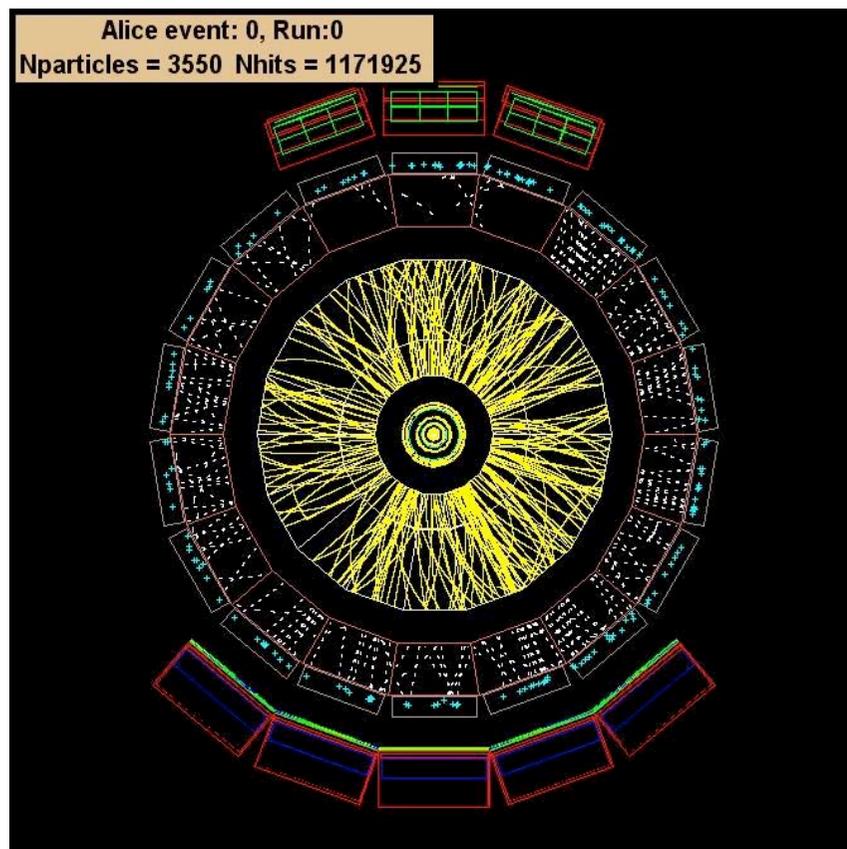
ALICE TPC

- Optimized for $dN/d\eta \approx 8000$
 - $l = 5 \text{ m}$, $\varnothing = 5.6\text{m}$, 88 m^3 , 570 k channels,
 - up to 80 Mbytes/event (after 0 suppression)
- Features:
 - lightweight: $3\% X_0$ total material for perpendicular tracks
 - Drift gas: Ne (86) / CO₂ (9.5) / N₂ (4.5) + $\sim 1\text{ppm O}_2$
 - novel digital electronics (ALTRO)
 - highly integrated, digital shaping; tail cancellation; 0-suppression; Baseline restoration
 - Powerful laser calibration system

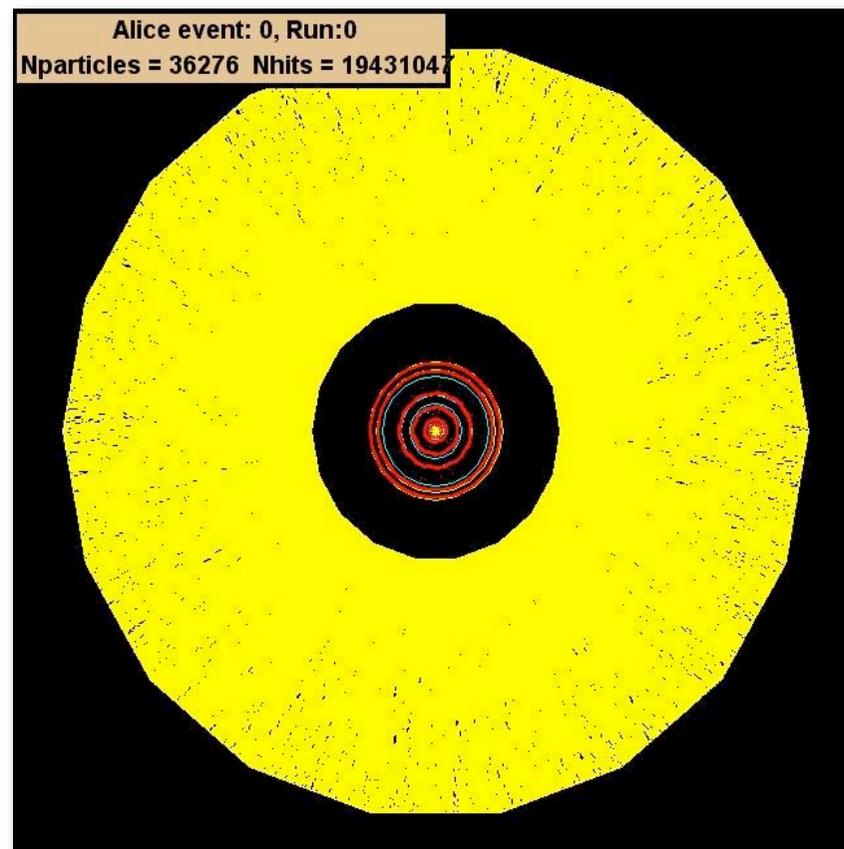


ALICE TPC: 5 years construction





$60^\circ < \vartheta < 62^\circ!$



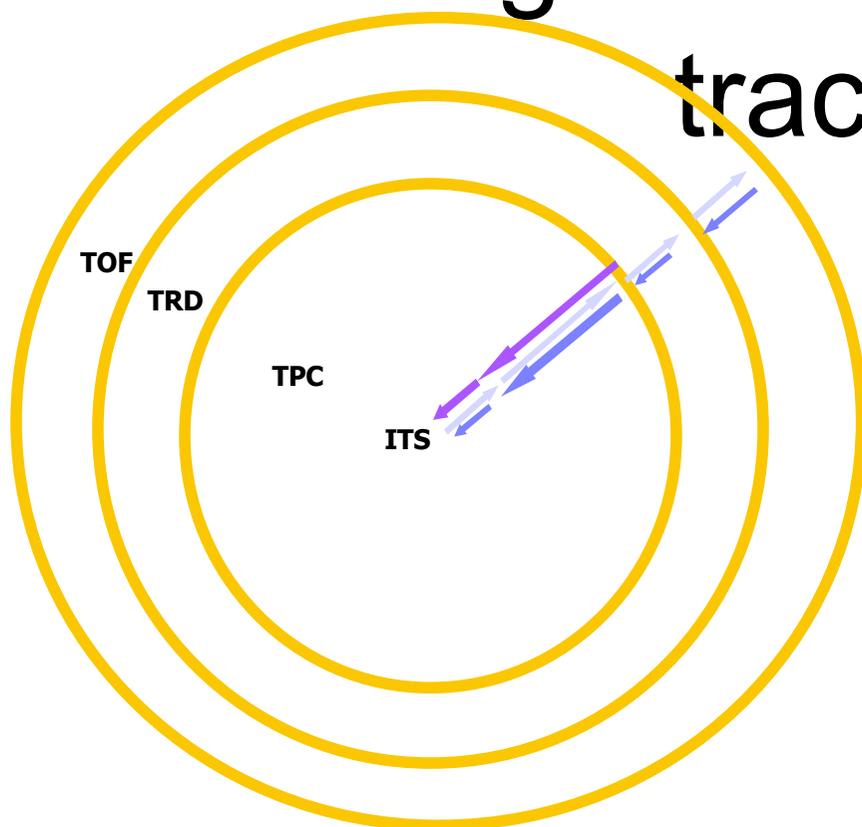
One collision :
Pb+Pb @ 5.5 TeV



Reconstruction strategy

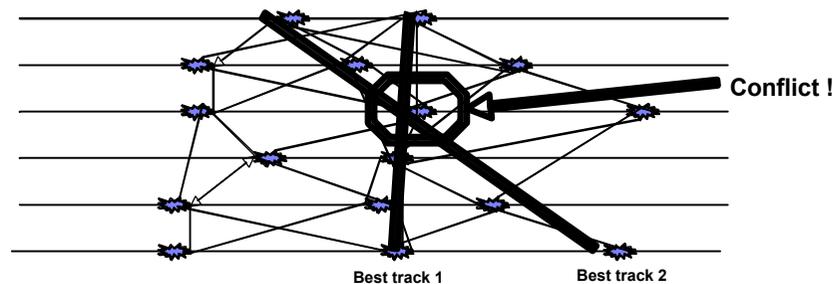
- Main challenge - Reconstruction in the high flux environment (occupancy in the TPC up to 40%) requires a new approach to tracking
- Basic principle – Maximum information approach
 - Use everything you can, you will get the best
- Algorithms and data structures optimized for fast access and usage of all relevant information
 - Localize relevant information
 - Keep this information until it is needed

Tracking strategy – Primary tracks



- Incremental process
 - Forward propagation towards to the vertex
TPC⇒ITS
 - Back propagation ITS⇒TPC⇒TRD⇒TOF
 - Refit inward TOF⇒TRD⇒TPC⇒ITS
- Continuous seeding
 - Track segment finding in all detectors

- Combinatorial tracking in ITS
 - Weighted two-tracks χ^2 calculated
 - Effective probability of cluster sharing
 - Probability not to cross given layer for secondary particles





Allineamento e calibrazione

- La risposta dei rivelatori va “calibrata”
 - Al momento della costruzione
 - Durante il funzionamento della macchina
- La posizione dei rivelatori non è perfettamente determinata
 - Misurazioni al momento dell’installazione
 - Correzioni tramite le tracce ricostruite
- La gestione dei files è un problema in sè

I dati di LHC



- 40 milioni di collisioni al secondo
- Dopo il filtraggio, 100 collisioni interessanti al secondo
- Da 1 a 12 MB per collisione \dot{P} da 0.1 a 1.2 GB/s
- 1010 collisioni registrate ogni anno
- ~ 10 Petabytes (10^{15} B) per anno
- I dati di LHC data corrispondono a 20 milioni di CD all'anno!

