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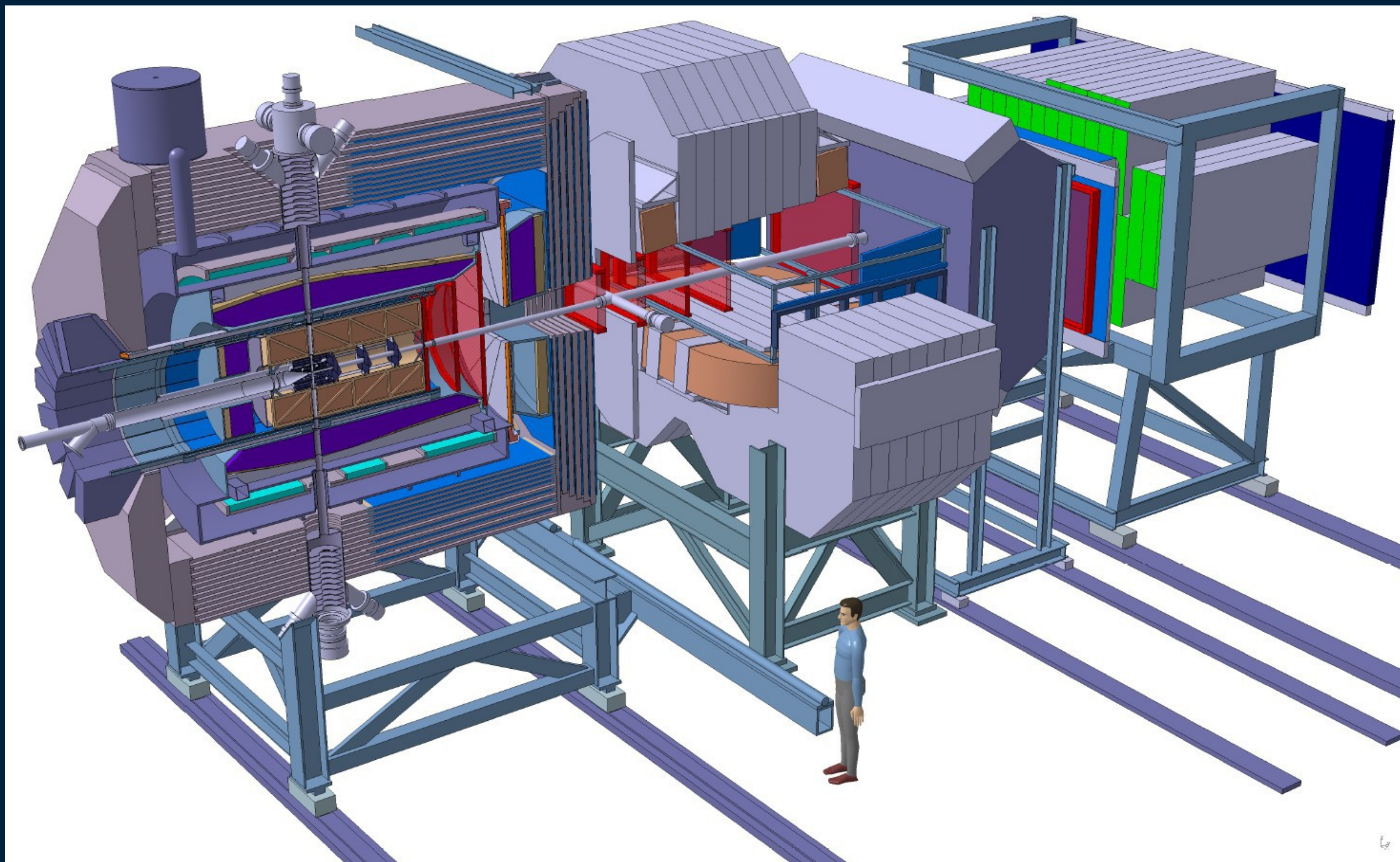
The $\bar{p}$anda detector at FAIR



Tibor Keri for the **$\overline{\text{P}}$ANDA collaboration** at the **Crimean Conference 2011**

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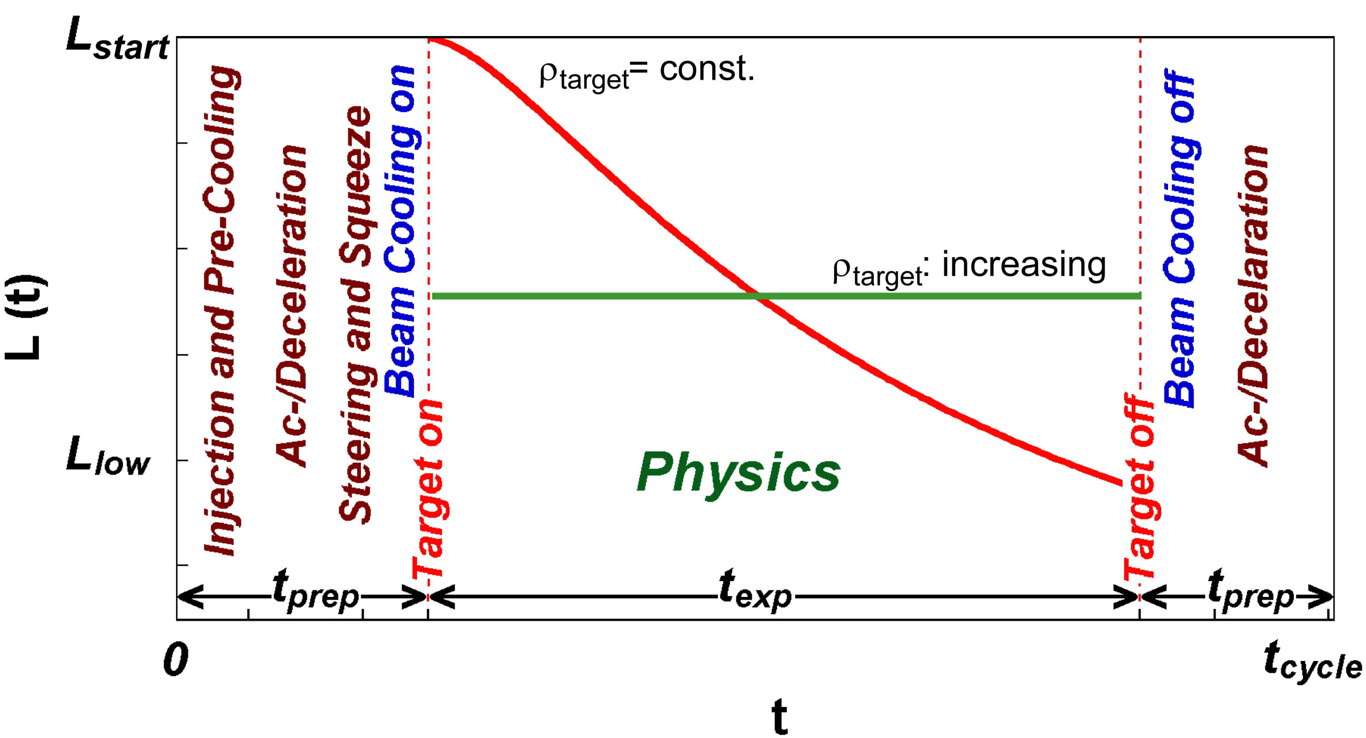
$\bar{p}$-beam setup

Variable beam momenta : 1-15 GeV/c (~2.25 < √s/GeV < ~5.47)

High resolution mode : dp/p ~10^{-5} @ L ~10^{31} cm^{-2} s^{-1} (electron cooling)

High luminosity mode : L ~2*10^{32} cm^{-2} s^{-1} @ dp/p ~10^{-4} (stochastic cooling)

$\bar{p}$-beam duty cycle (10^{11} $\bar{p}$ stored) : 2000 ns beam on / 400 ns beam off



t_{prep} :
~120 s … ~290 s

$t_{beam\ life}$ for 1/e decay :
~1540 s … ~35500 s

$t_{cycle} = t_{prep} + t_{exp}$:
~1280 s … ~4820 s

collider setup available : SIS18 versus SIS100/SIS300

Detector requirements

4π acceptance

→ partial wave analysis for exotics

High vertexing resolution

→ charmonium decays

High tracking resolution

→ event selection

Very good particle identification (γ,e,μ,π,K,p,...)/(redundant)

→ event selection

Variable trigger at high rates

→ low statistics reactions

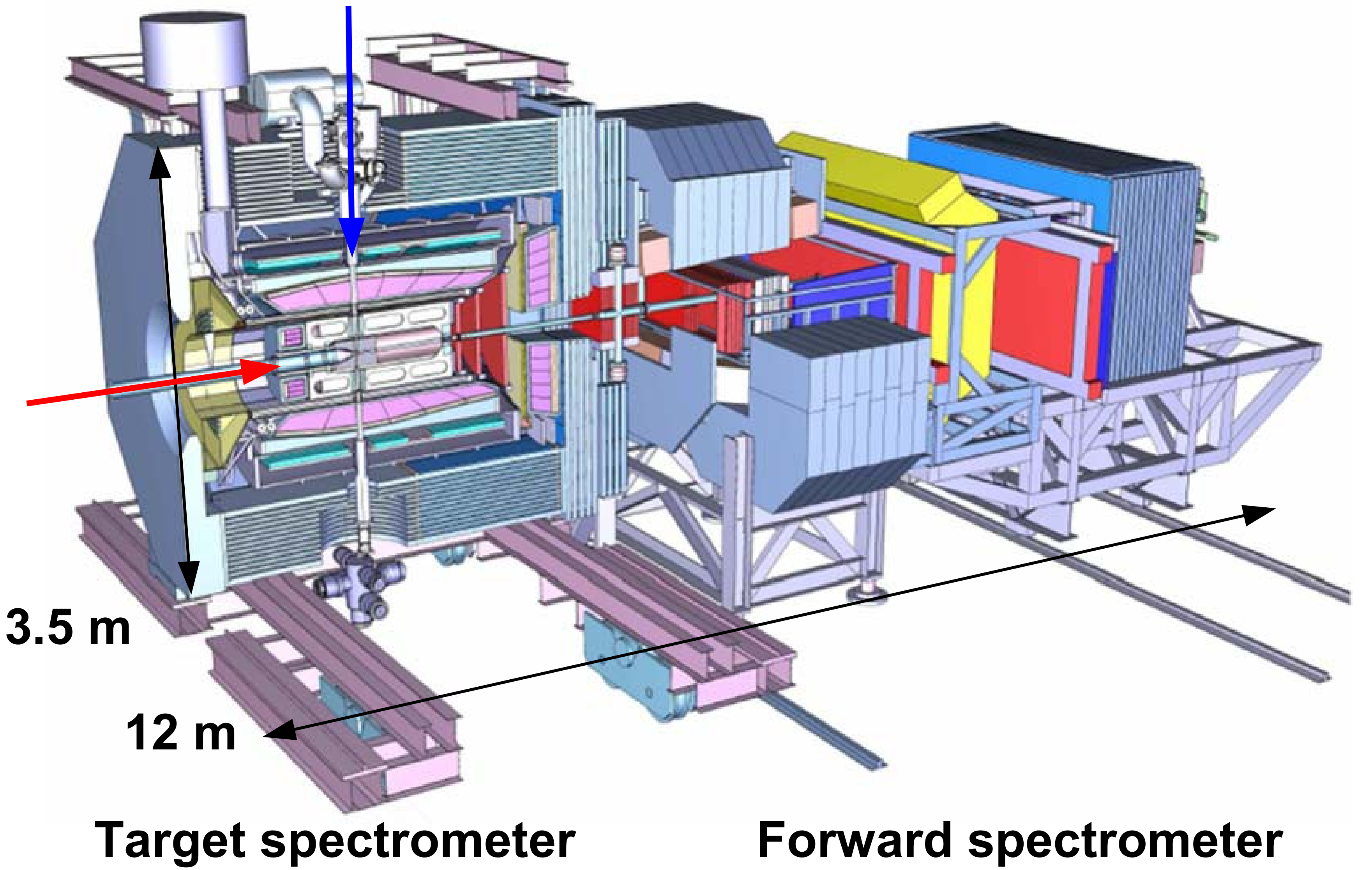
Variable targets and modular system

→ hypernuclei

=> Novel techniques in detector and readout design used

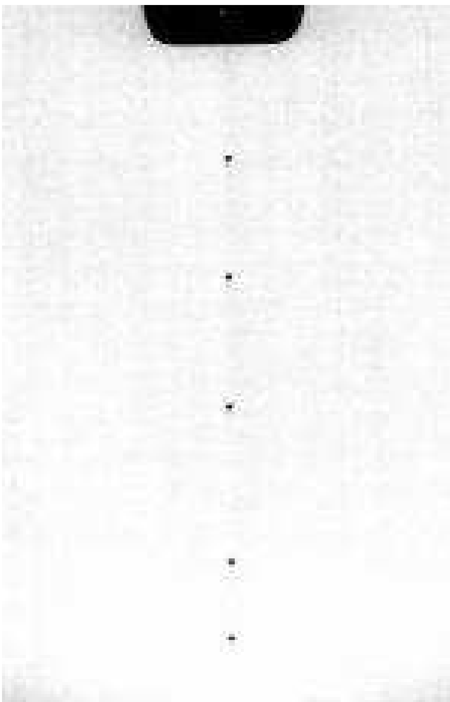
=> General purpose detector adjustable for future physics

$\overline{\text{P}}$ANDA detector overview

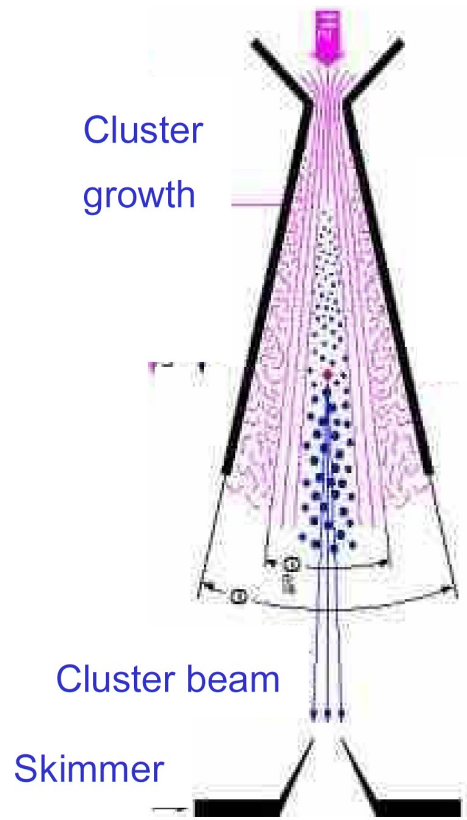


Targets (pellet, cluster jet, solid)

pellet



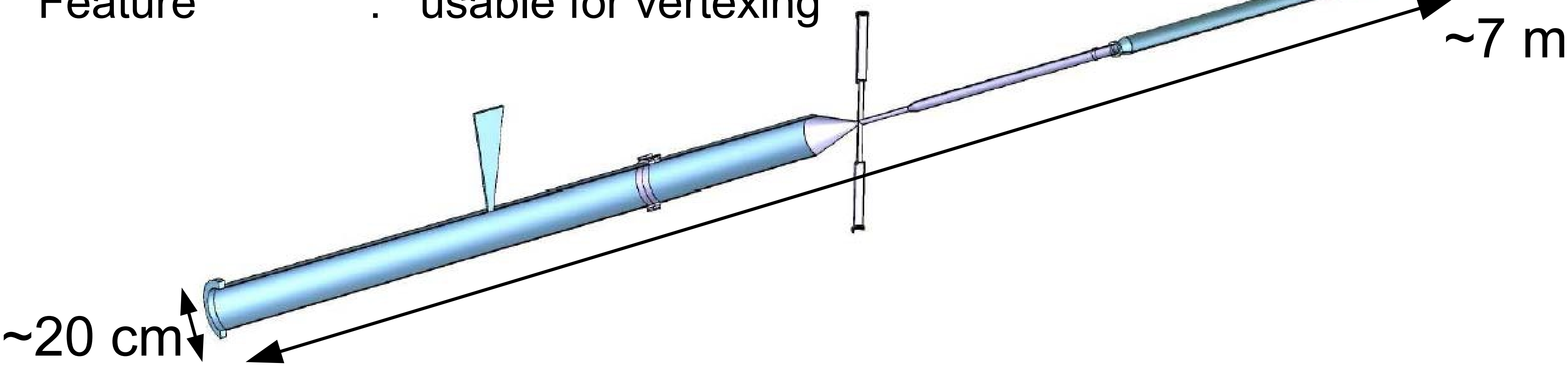
cluster jet



Other options : fiber targets (C,CH2,...)

Targets (pellet, cluster jet, solid)

		Pellet	Cluster	unit
Material	:	H2,D2,N2,Ne,Ar,...		
Density	:	$<4*10^{15}$	$<8*10^{14}$	atoms/cm^2
Interactions	:	~100 per pellet	adjustable	
Structure	:	~0.5 cm distance	no time structure	
Size	:	Diameter ~20-30 µm	10^3-10^5 atoms	
Flow rate	:	10k pellets/s	continuous	
Feature	:	usable for vertexing		



=> Interaction rate : ~20 MHz at $2*10^{32}$ cm^{-2} s^{-1} Luminosity with 10^{11} $\bar{p}$ stored

Vertex detectors

Design

4 Barrels

- 2 inner : Si-hibrid pixel (cell size 100 x 100 μm^2)
- 2 outer : double sided Si-strips (pitch size 130 μm)

6 forward discs

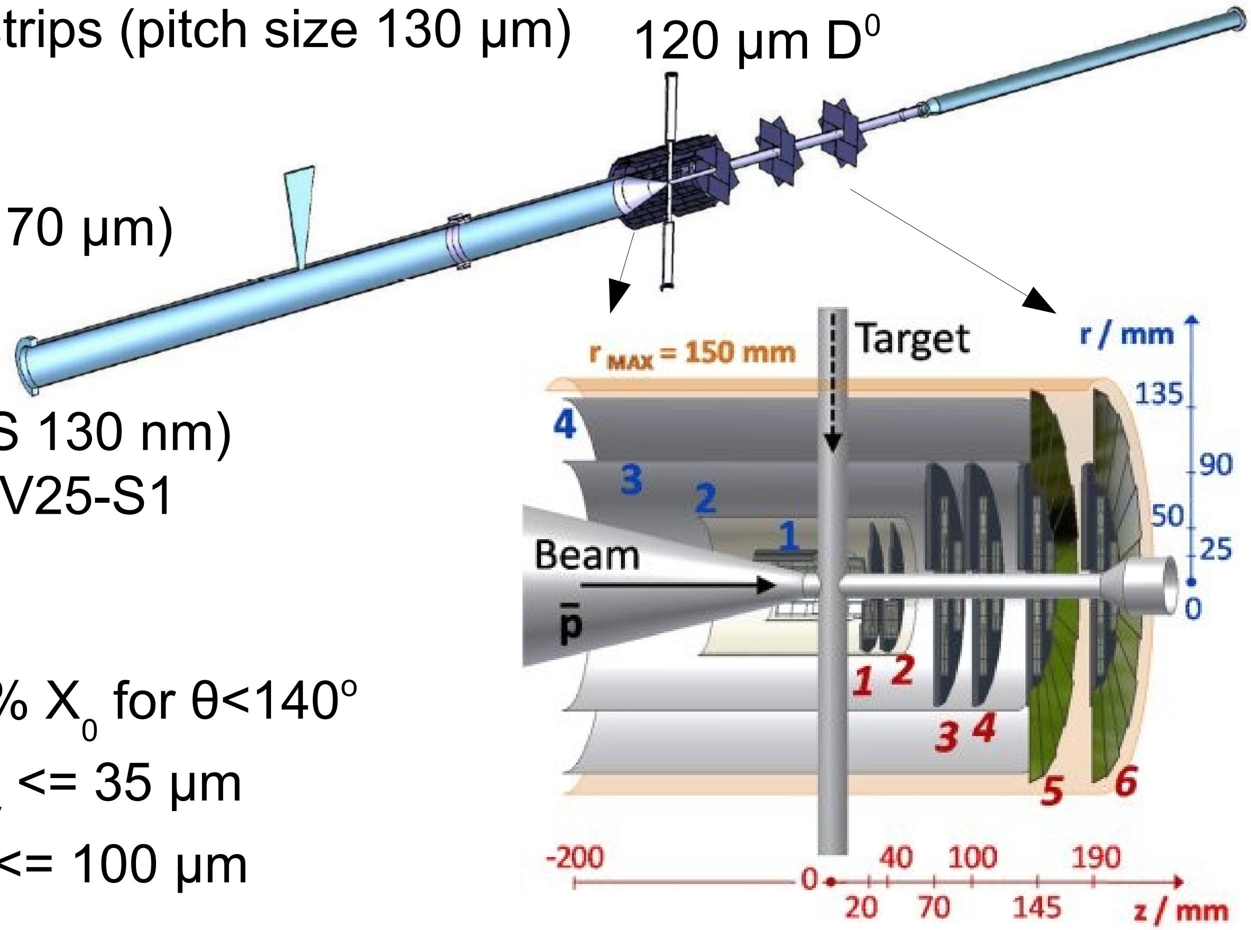
- 4 discs : Si-hibrid pixel
- 2 discs : mixed (pitch size 70 μm)

Goal : vertexing D,K,Λ,...

cτ : 320 μm $D^{\pm}$

150 μm $D^{\pm}_{s}$

120 μm D^{0}



Continuous readout

- ~11M pixels ToPiX (CMOS 130 nm)
- ~200k strips n-XYTER/APV25-S1

Challenges

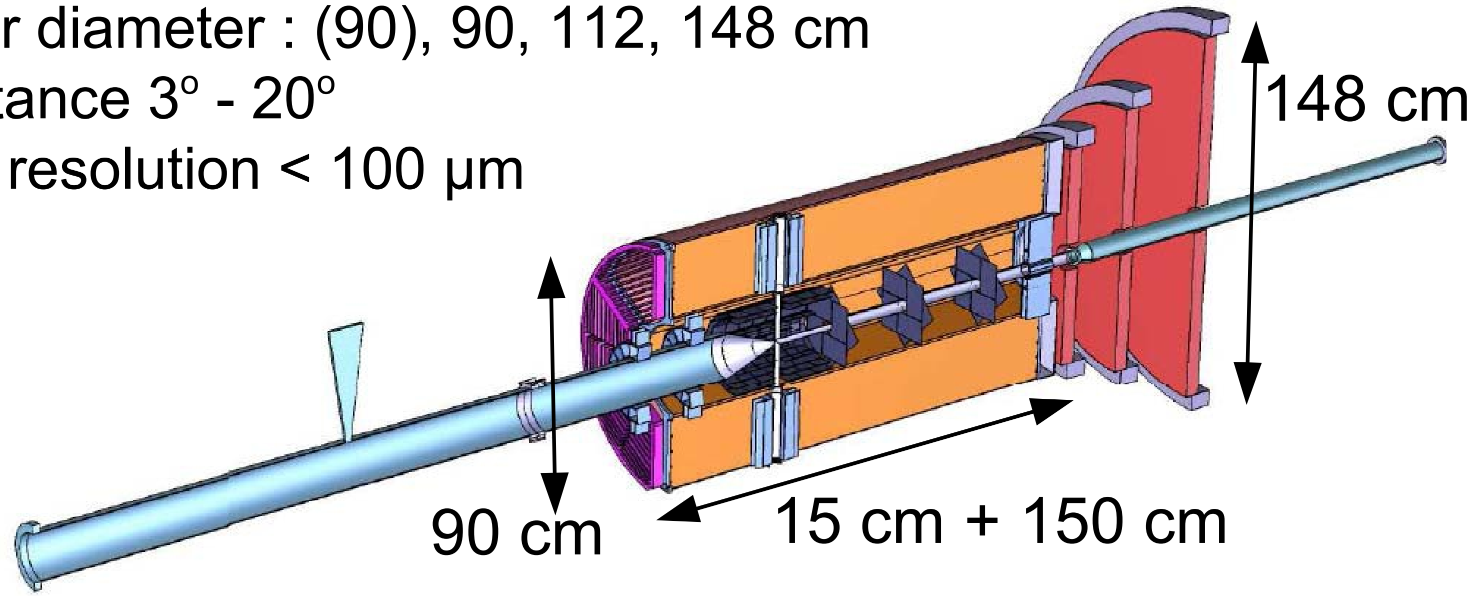
- Low material budget <10% X_0 for θ<140°
- High vertex resolution $\sigma_{x,y}$ <= 35 μm
  σ_z <= 100 μm

Tracking detectors

Design

Forward tracker
- Gas Electron Multiplier detectors (GEMs)
  - 3-4 Discs
    - IP : (81),117,153,189 cm
    - Outer diameter : (90), 90, 112, 148 cm
  - Acceptance 3° - 20°
  - Space resolution < 100 μm

Goal :
- Momentum resolution 1%
- Low material budget
- Support for PID (dE/dx)



Central tracker
- Straw Tube Tracker / Time Projection Chamber

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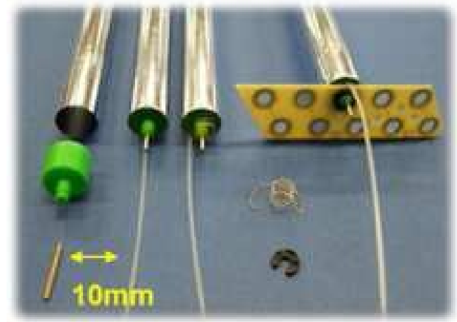
Tracking detectors
Straw Tube Tracker

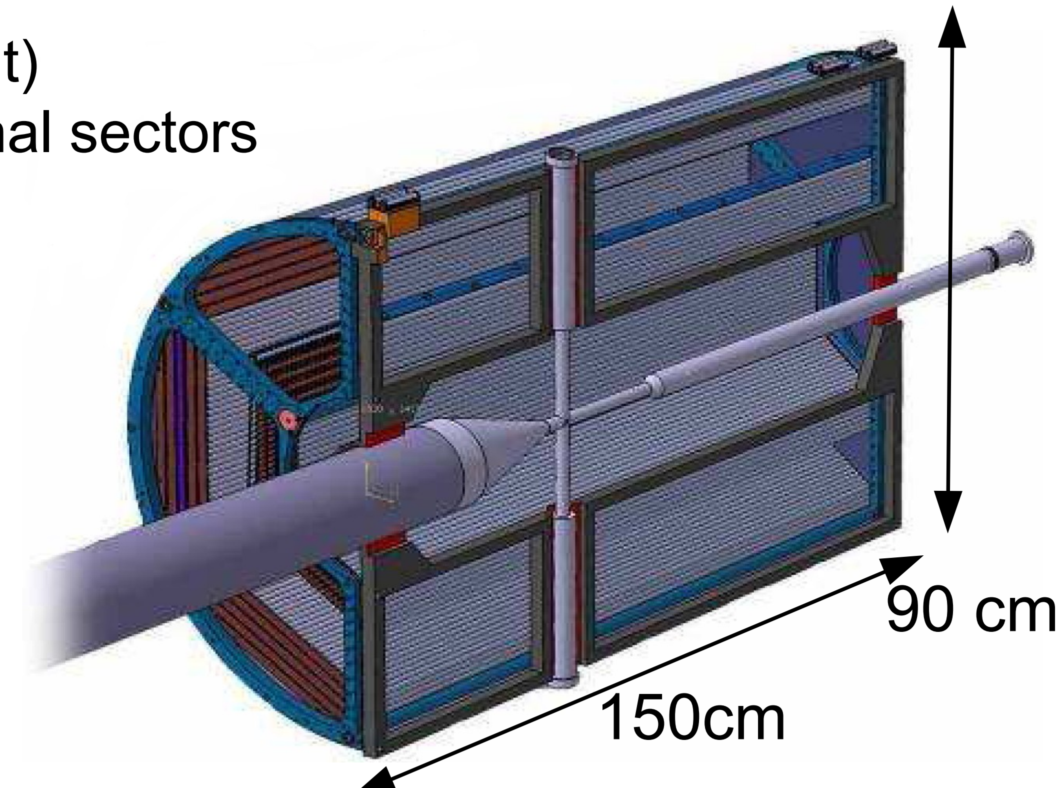
4636 pressure stabilized straw tubes +1 bar
Gas mixture : Ar/CO_2 (90/10) at 2 bar
X/X_0 ~ 1.2% (2/3 tube wall + 1/3 gas)



Material:
27 µm Mylar
2x30 nm Al
Anode wire:
20 µm W/Re

Two half cylinders R_{in}/R_{out} : 150 mm / 418 mm
Length : 150cm + 15 cm (readout)
23-27 planar layers in 6 hexagonal sectors
- 15-19 axial layers
- 4 stereo double layers
- ±2.89° skew angle

$\sigma_{r,\varphi} <= 150$ µm
$\sigma_z <= 1.0$ mm
$\sigma_p <= 1.2\%$ (B = 2 T)



Tracking detectors
Time Projection Chamber

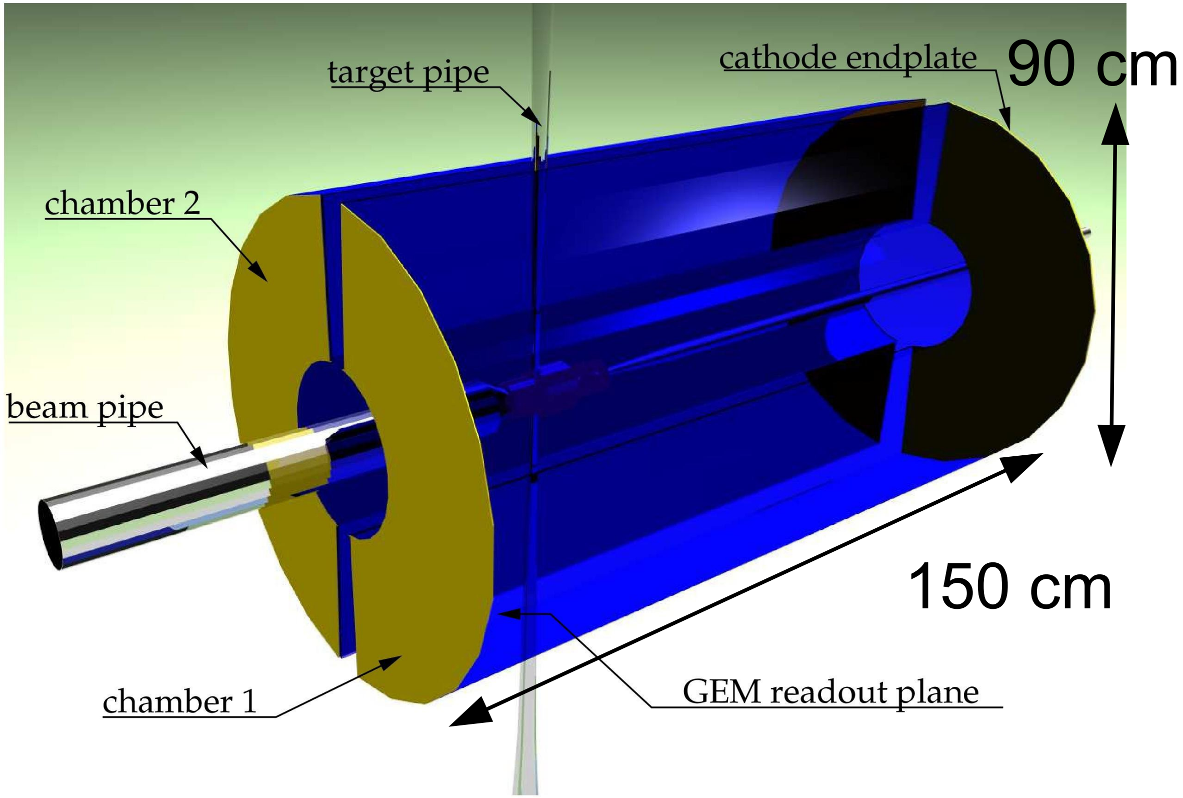
Multi-GEM for gas amplification and ion backflow suppression
Gas mixture (700 l) : Ne/CO2 (+CH4/CF4)

Two half cylinders
- R= 15.5 – 42.5 cm
- Max drift path : 1.5 m
- Max drift time : 50 – 70 μs

Pads (2 mm x 2mm) : 100k
PASA/Altro or AFTER T2K

σ_p <= 1% (B = 2 T)
Good PID (dE/dx)

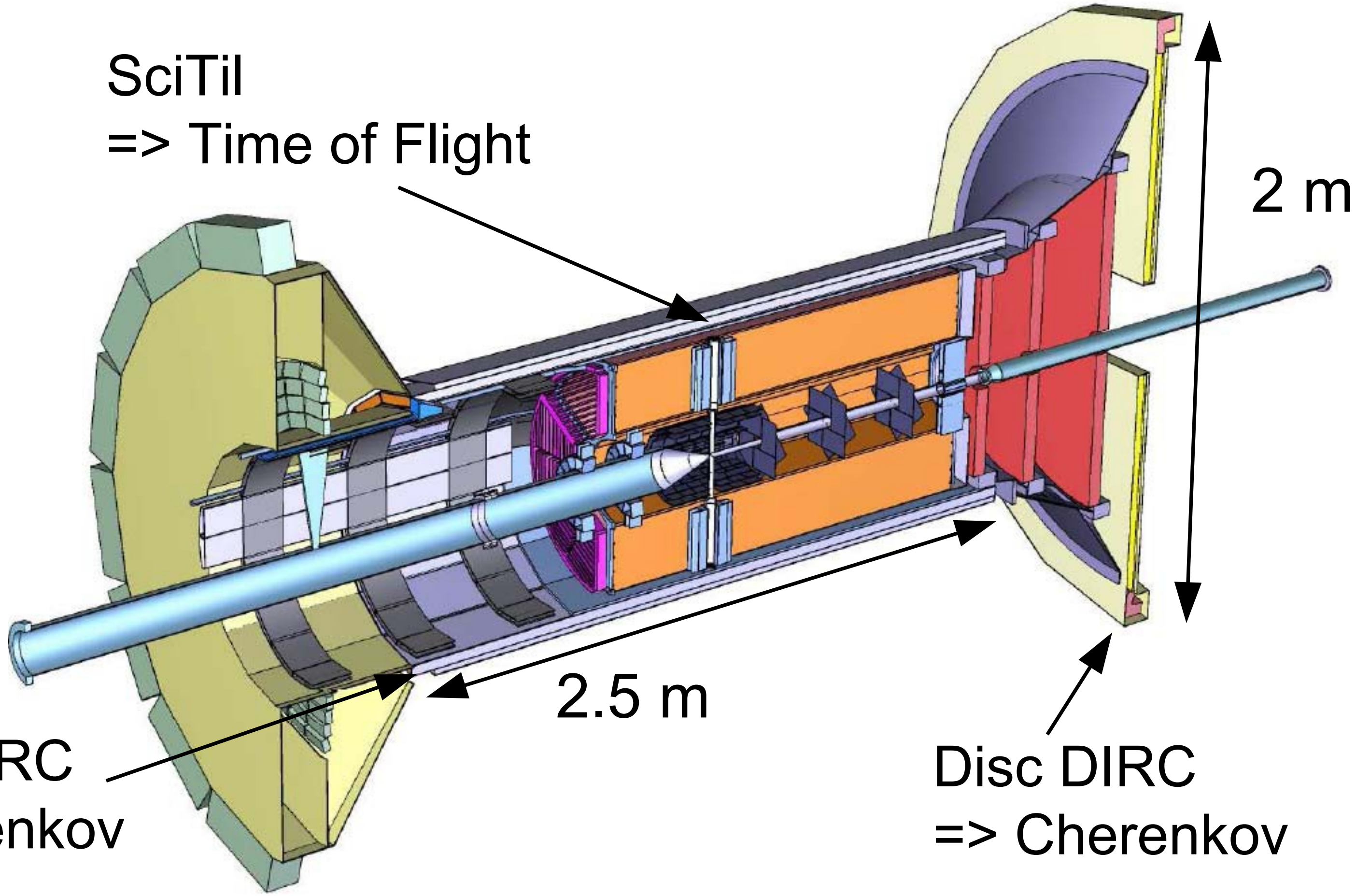
Continuous sampling
Pile-up due to high count rate
Space charge build-up



Particle identification

Goal : $e^{\pm}$, $\mu^{\pm}$, $\pi^{\pm}$, $K^{\pm}$, $\bar{p}$, p

>3 σ π/K separation 0.5 – 4.5 GeV/c

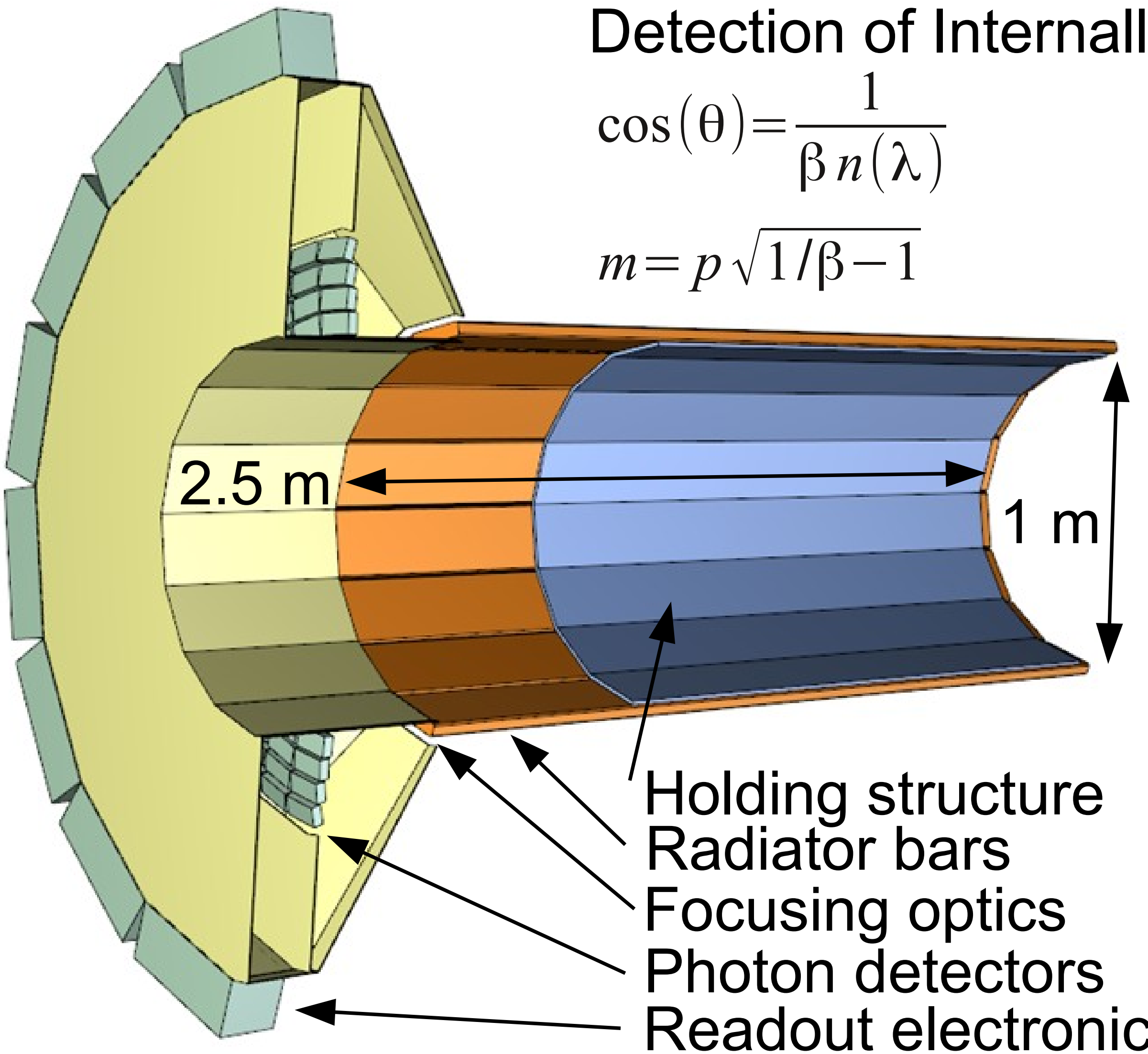


Particle identification
Barrel DIRC

Detection of Internally Reflected Cherenkov

$$\cos(\theta) = \frac{1}{\beta n(\lambda)}$$

$$m = p\sqrt{1/\beta - 1}$$



Low/uniform material budget
Primary process

96 fused silica bars (n=1.47)
17 x 33 x 2500 mm^3
MCP-Photon detection
7-10k Channels
0.5-1 T magnetic field
Dispersion correction

π/K separation
0.5 – 4.0 GeV/c
$\Theta = 22^{o} - 140^{o}$

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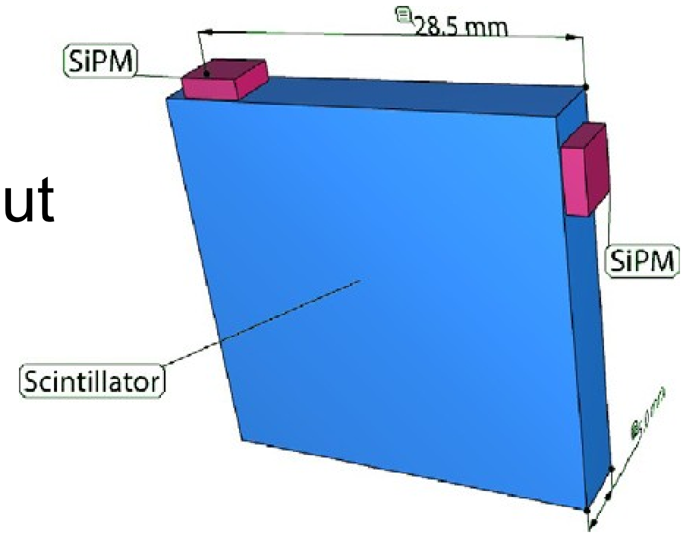
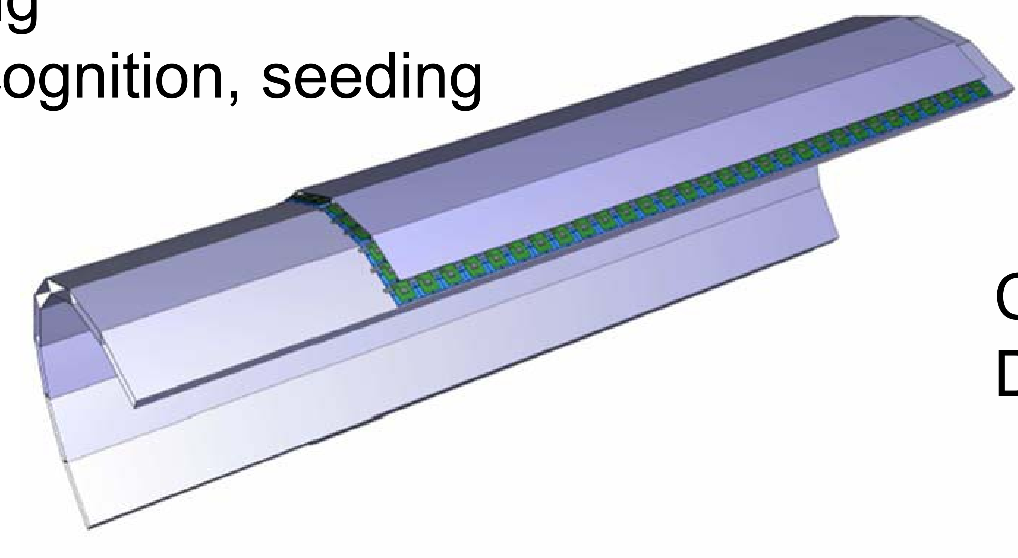
Particle identification Scintillating Tiles

Time resolution <100 ps
Granular structure (3 cm x 3 cm pads)
Double Si-based photon detector/readout



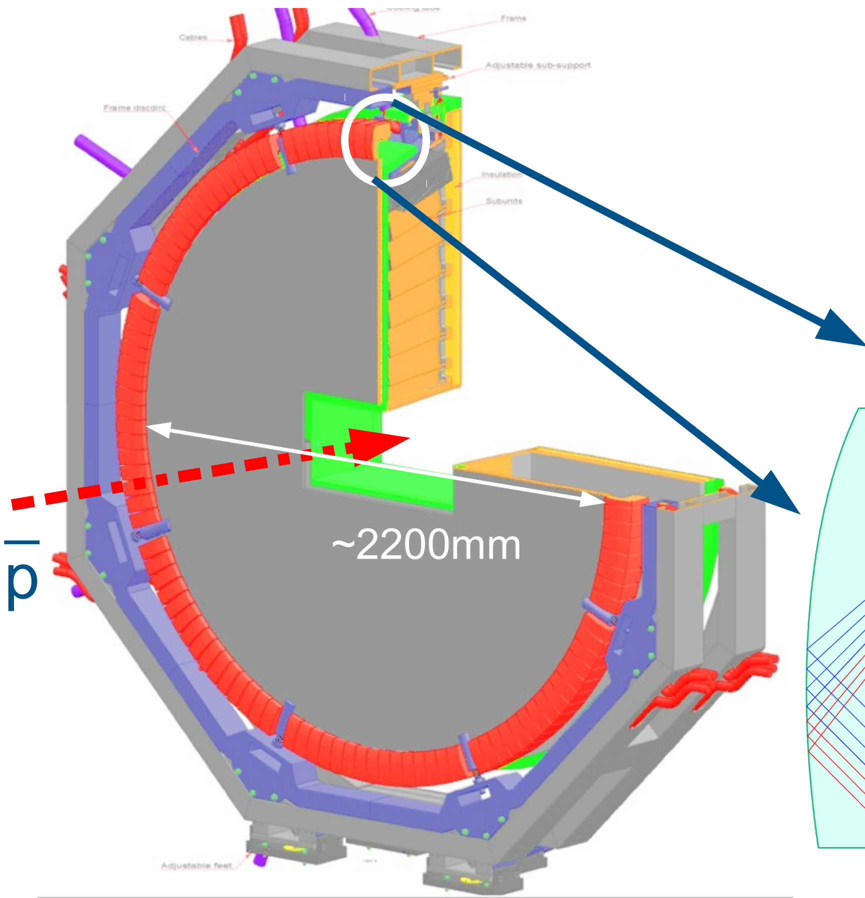
π/K separation
  0.4 – 0.7 GeV/c
  Θ = 22° - 90°
Event timing
Pattern recognition, seeding

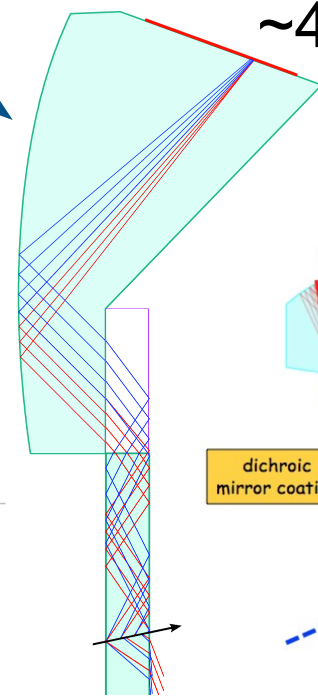


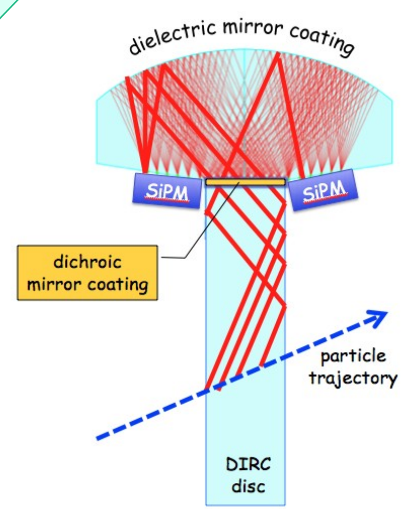
Concept and
Design phase

Particle identification
Disc DIRC

Thin fused silica disc (15 mm)
Chromatic correction/selection
Parallel-to-point optics
1T magnetic field
MCP-/Si-Photon detection
~4000 channels







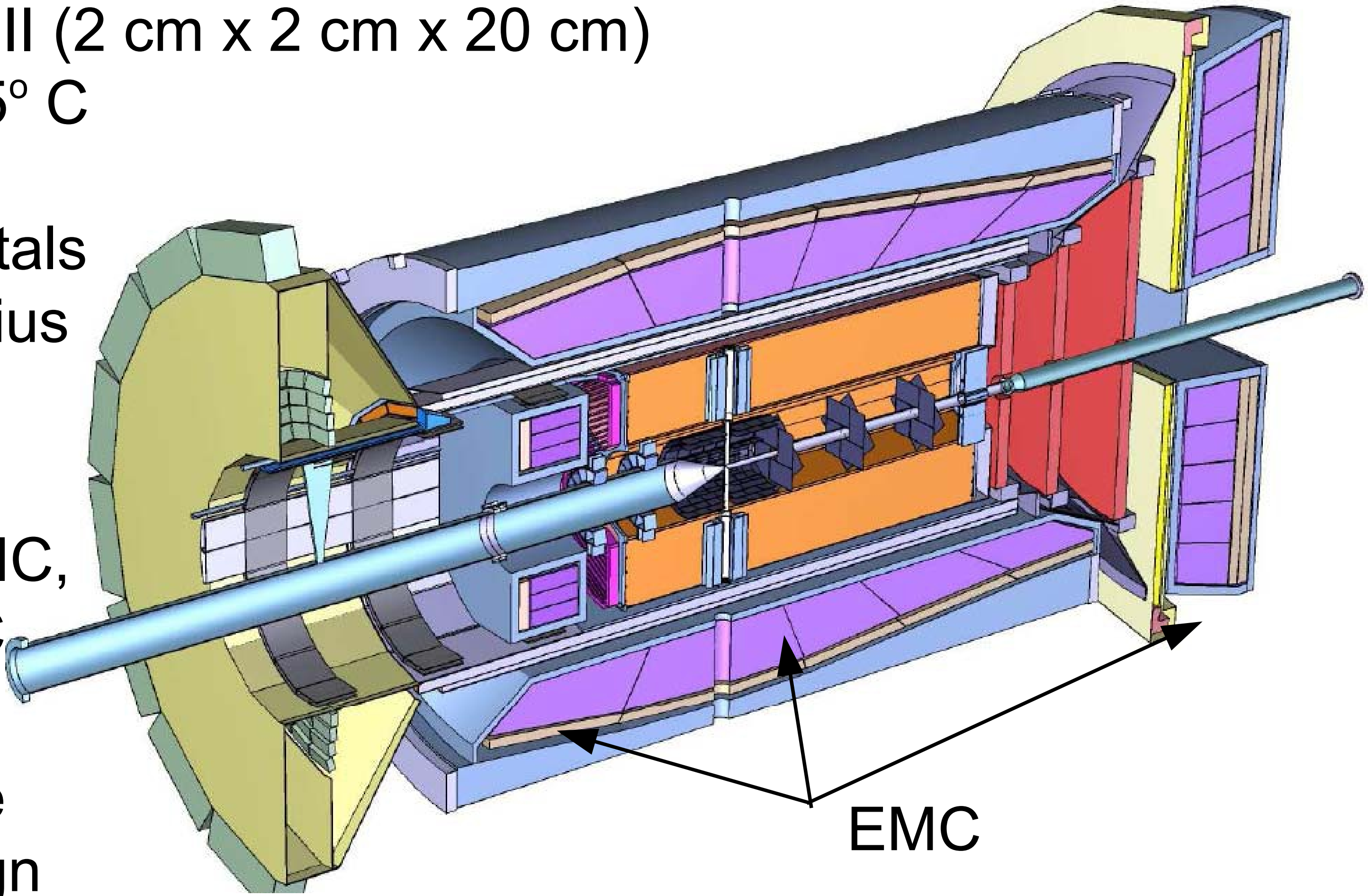
$$\cos(\theta) = \frac{1}{\beta n(\lambda)}$$

$$m = p\sqrt{1/\beta - 1}$$

π/K separation
0.5 – 4.5 GeV/c
$\Theta = 5^\circ / 10^\circ - 22^\circ$

Electro-Magnetic Calorimeter

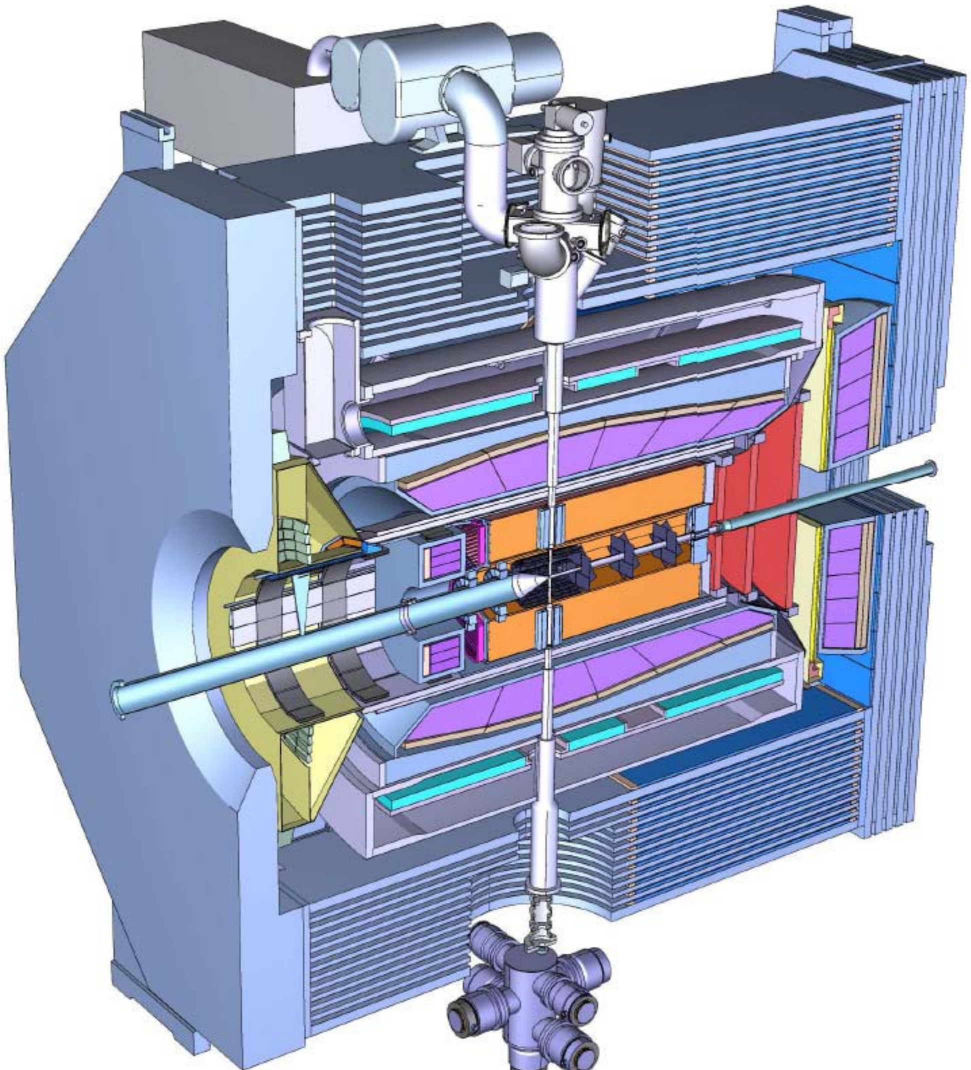
Improved PWO II (2 cm x 2 cm x 20 cm)
Operation at -25° C
ΔT ~0.1 K
~16k PWO crystals
57 cm inner radius
22 X_o thickness
Readout
- VPT+Apfel ASIC,
- LAAPD+SADC



Goal :
- 4π acceptance
- Compact design
- γ-detection few MeV to 10GeV
- $\sigma(E)/E \sim 1.5\%/\sqrt{E} + 0.3\ \%$

TDR : arXiv:0810.1216v1

Target Spectrometer



Solenid

Super conducting

2 T field

1.8 m coil diameter

2.6 m coil length

Θ - angle coverage

Inner detectors

10^{o} – 140^{o} horizontal

5^{o} – 140^{o} vertical

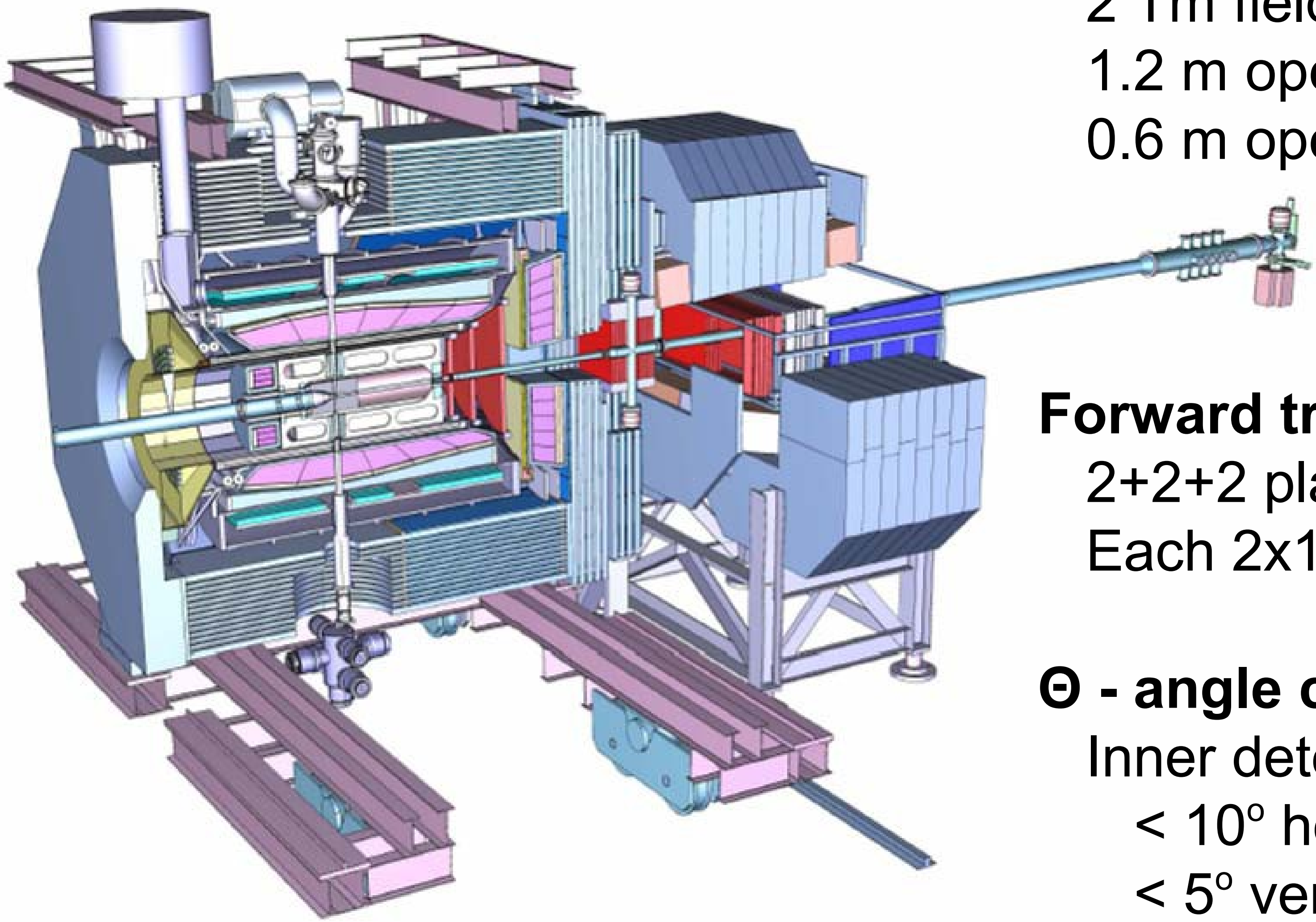
EMC almost 4π

Instrumented Yoke

Micro Drift Tubes

μ-detection < 15 GeV

Dipole magnet

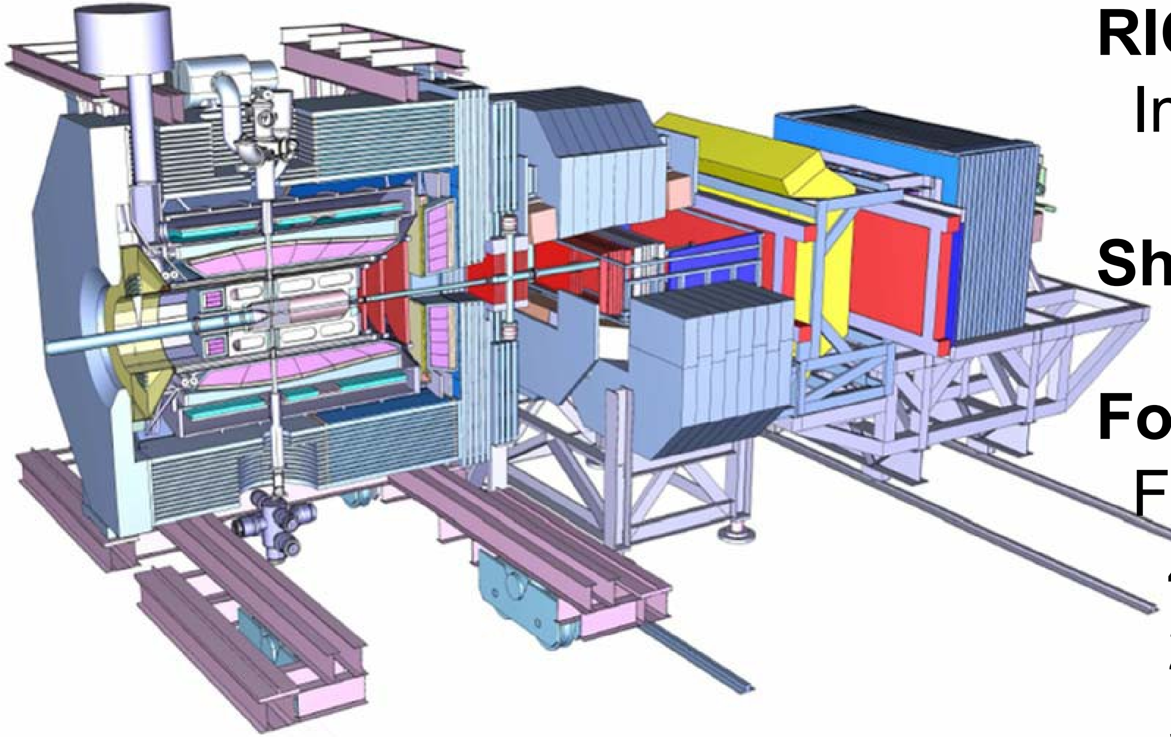


Dipole
- 2 Tm field integral
- 1.2 m opening width
- 0.6 m opening height

Forward tracker
- 2+2+2 planar tracker
- Each 2x16 straw tubes

Θ - angle coverage
- Inner detectors
  - < 10º horizontal
  - < 5º vertical

Forward Spectrometer



RICH
Improved HERMES RICH

Shashlyk Calorimeter

Forward TOF wall
Fast scintillator like BC408
- 46 slabs 140x10x2.5 cm^3
- 20 slabs 140x 5x2.5 cm^3
- 50 ps time resolution
- 3σ for 2.8 – 4.7 GeV/c

or Resistive Plate Chamber

Muon Range System
37 layers Mini Drift Tubes, ~4k MDT, ~30k wires, ~75k stripes

Shashlyk calorimeter

Module

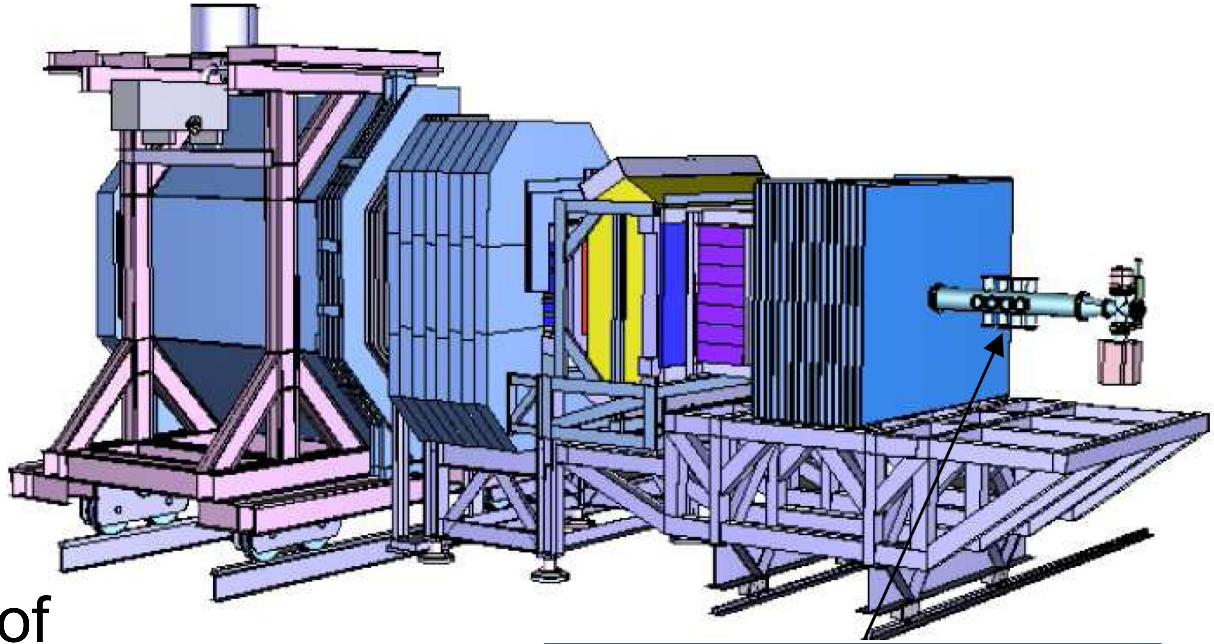
380 Layers of 0.3 mm lead and 1.5 mm scintillator
680 mm total length
55 mm x 55 mm tranverse size
36 BCF-91A WLS fibers (Ø1mm) for light collection
Photon detection via PMT
59 mm Moliere Radius
20 X_0 Total radiation length
LED for gain monitoring

Calorimeter

7 m from IP
Active Area : 3 m x 1.5 m
374 supermodules with each 4 modules
$\sigma(E)/E = 5.6/E + 2.4/\sqrt{E} + 1.3$ % ([E]=GeV)

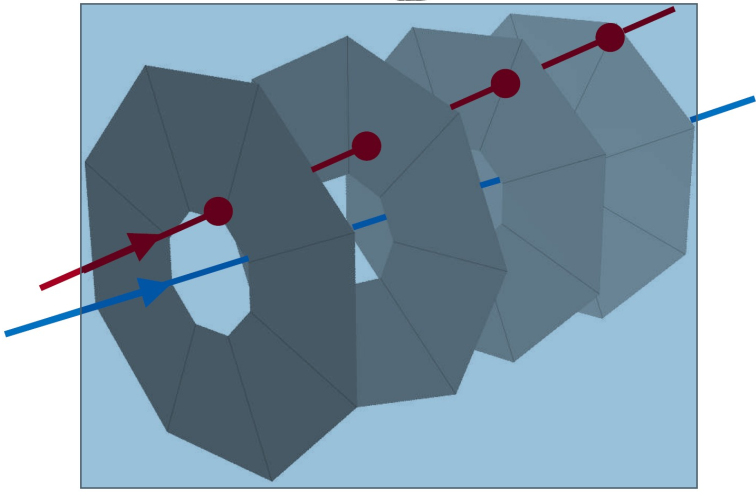
Luminosity monitor

Goal :
Count normalisation



Concept :
Low t elastic scattering

Design :
4 double sided planes of
8 silicon trapezoids at
11 m behind IP
10 cm plane distance each
22.5 deg plane rotation each
150/300 µm thick at 45 deg angle
3-8 mrad acceptance



DAQ (Synchronization Of Data Acquisition)

Problem : Similar signal/background signature

→ no central trigger as all sub-detectors needed

Solution

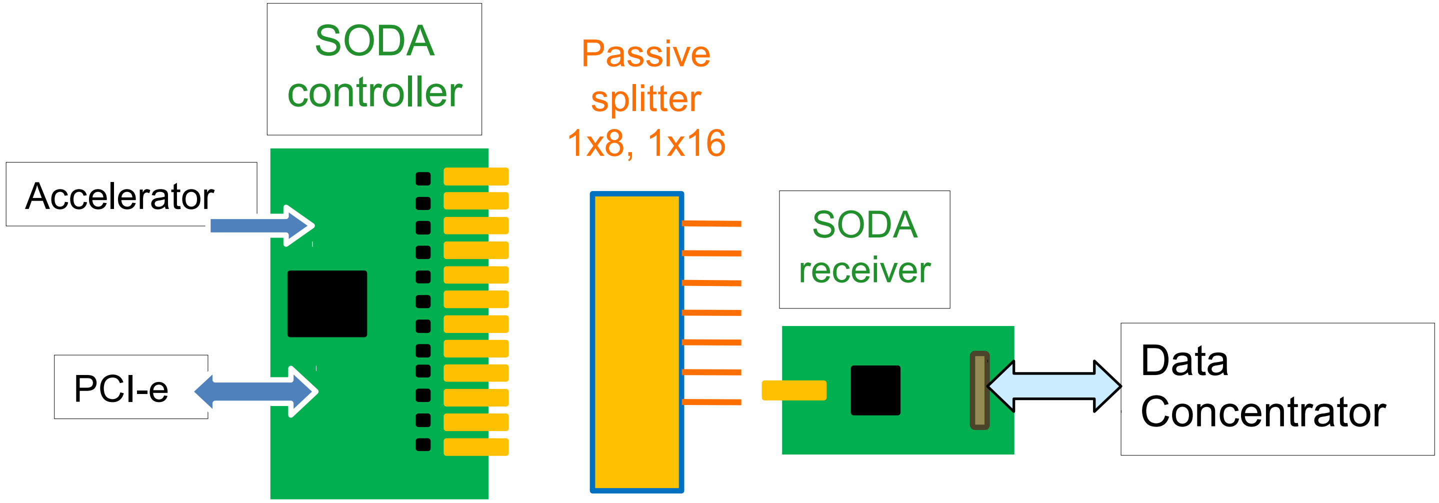
→ continuous/selftriggered readout

→ timestamping of data

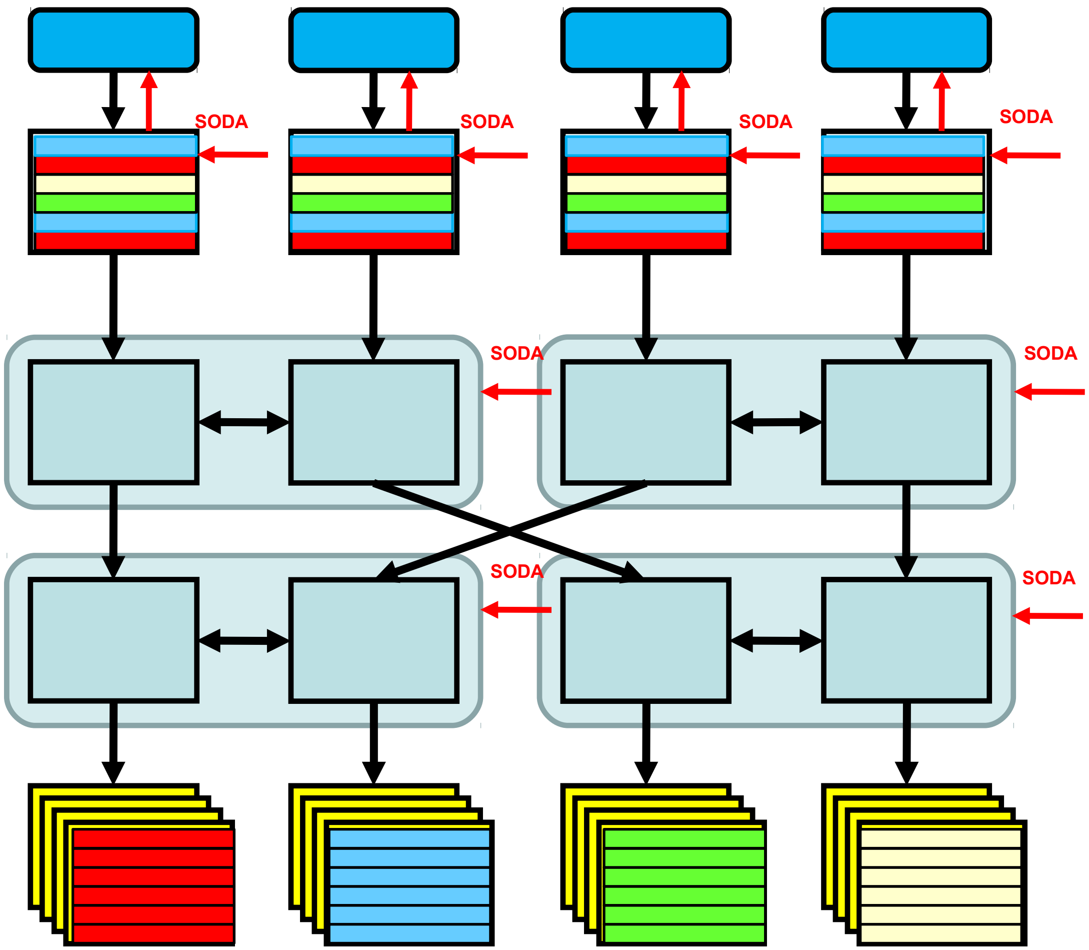
~ 15 ps to data concentrator

~ 20 ps to frontend electronics

→ information distribution system



DAQ (programmable physics machine)



Frontend electronics

Data concentrator

First stage
Burst Event Builder

Second stage
Burst Event Builder

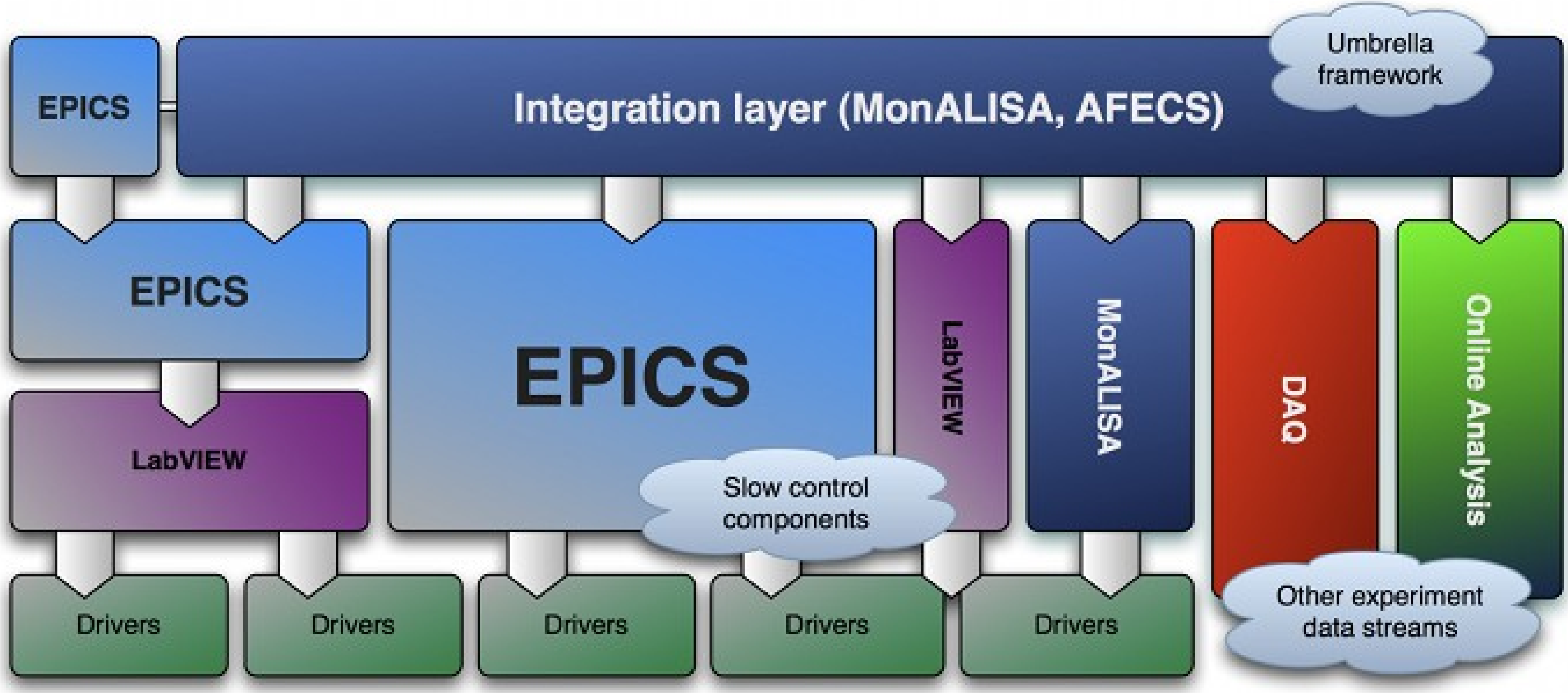
Compute node on
Computer farm

20 MHz interaction rate x 4-8KB event size = 200 GB/s raw data rate

Detector Control System

Local and Remote access

based on AFECS, EPICS and MonaLisa



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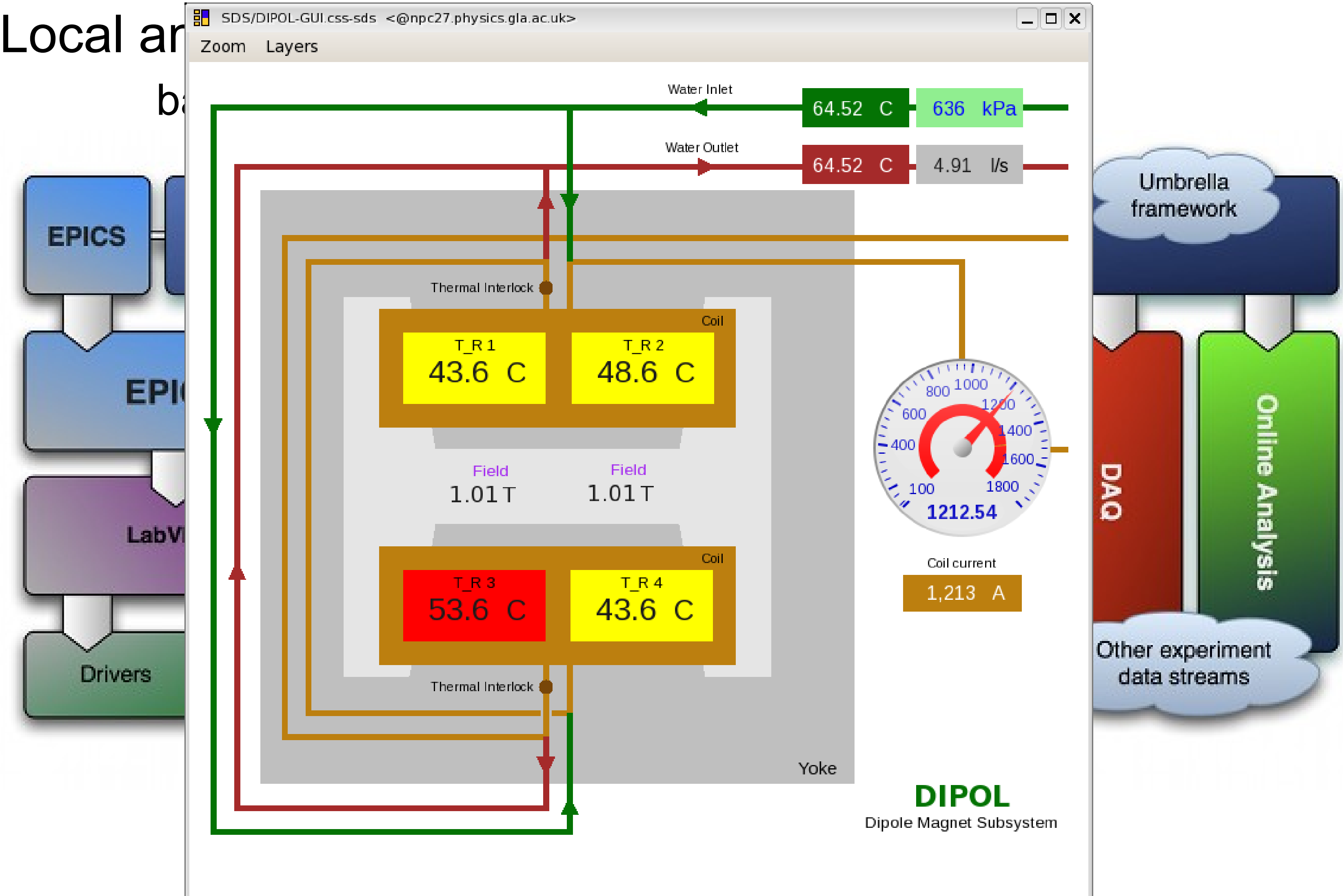
Detector Control System

Local ar

b

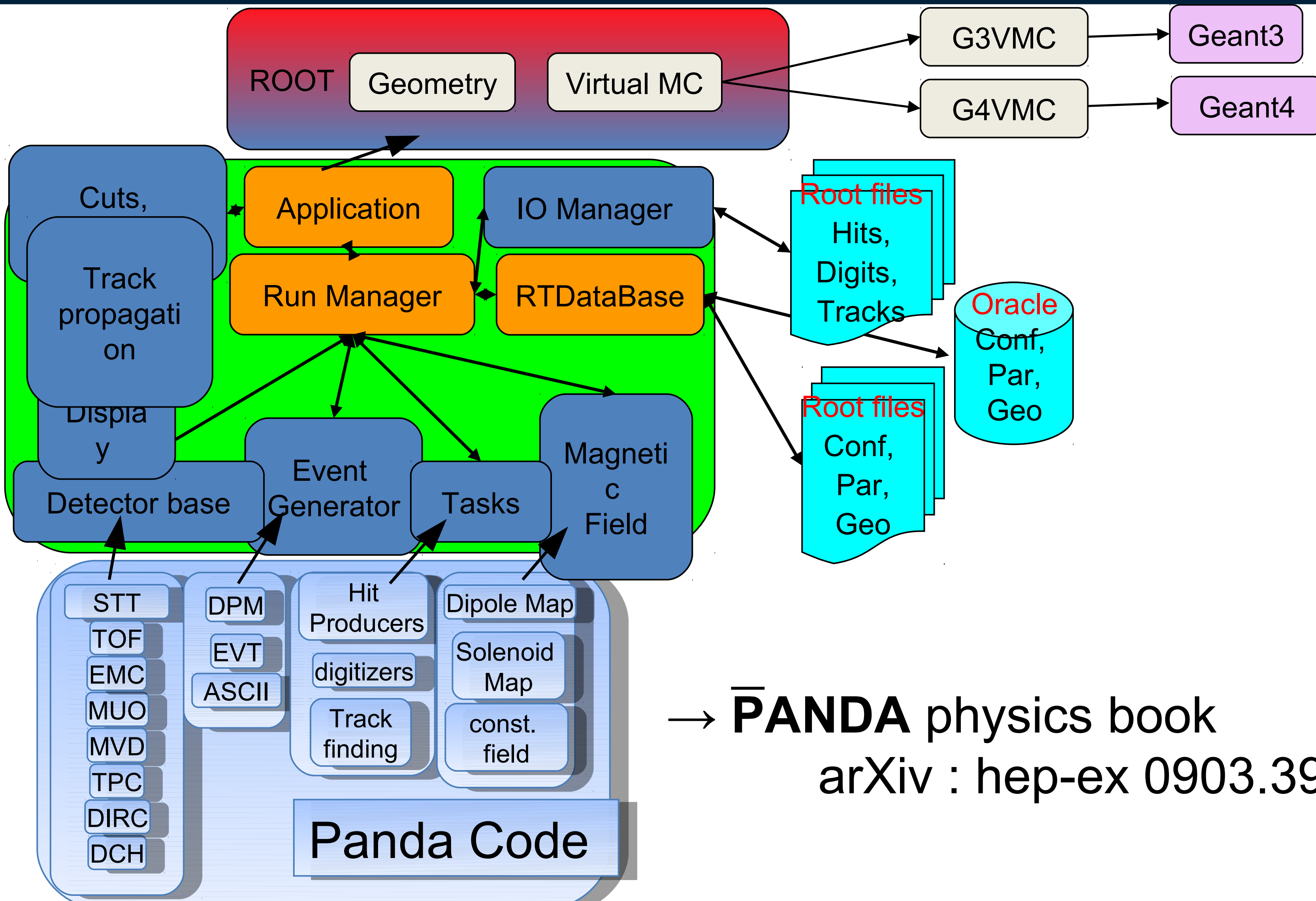


Grid system

Distributed computer farm

based on AliEn and MonaLisa

Simulation and Reconstruction



→ $\overline{\text{P}}$**ANDA** physics book
arXiv : hep-ex 0903.3905v1

$\overline{\text{P}}$ANDA detector performance

Integrated luminosity at $2*10^{32}$ cm^{-2} s^{-1} for 50% efficiency

~8 pb^{-1} / day

~3 fb^{-1} / year

Reconstructed events per year

~2 * 10^9 J/Ψ

~2 * 10^7 χ_2

~2 * 10^7 $D\overline{D}$

~2 * 10^8 $\Xi\overline{\Xi}$

Fine scan to measure masses with ΔM ≈ 50 keV and Γ ≈10 %

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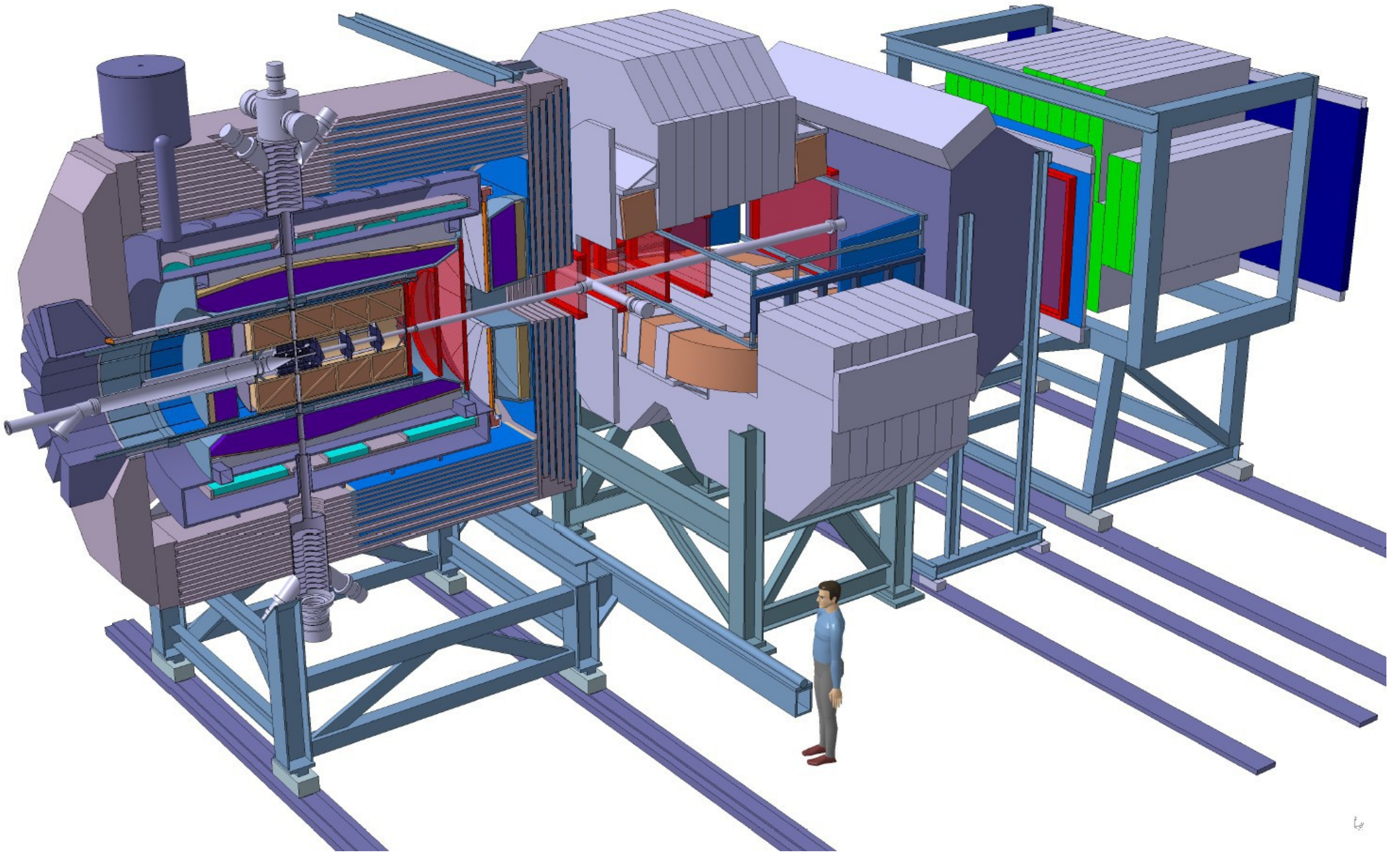
Summary

$\overline{\text{P}}$ANDA detector

General purpose detector
High rates
High precision
Various targets



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The $\bar{p}$anda collaboration

>=430 physicists from >=56 institutes in >=17 countries

Basel, Beijing, Bochum, Bombay, Bonn, Brescia, Bucharest, Catania, Chicago, Cracow, Darmstadt, Dresden, Dubna, Edinburgh, Erlangen, Evanston, Ferrara, Frankfurt, Frascati, Gatchina, Genova, Giessen, Glasgow, Groningen, Helsinki, Juelich, Katowice, Lanzhou, Lund, Mainz, Milano, Minsk, Moscow, Muenchen, Muenster, Mumbai, Novosibirsk, Orsay, Otwock-Swierk, Pavia, Protvino, Silesia, Stockholm, St. Petersburg, Torino, Trieste, Tuebingen, Uppsala, Valencia, Warsaw, Wien