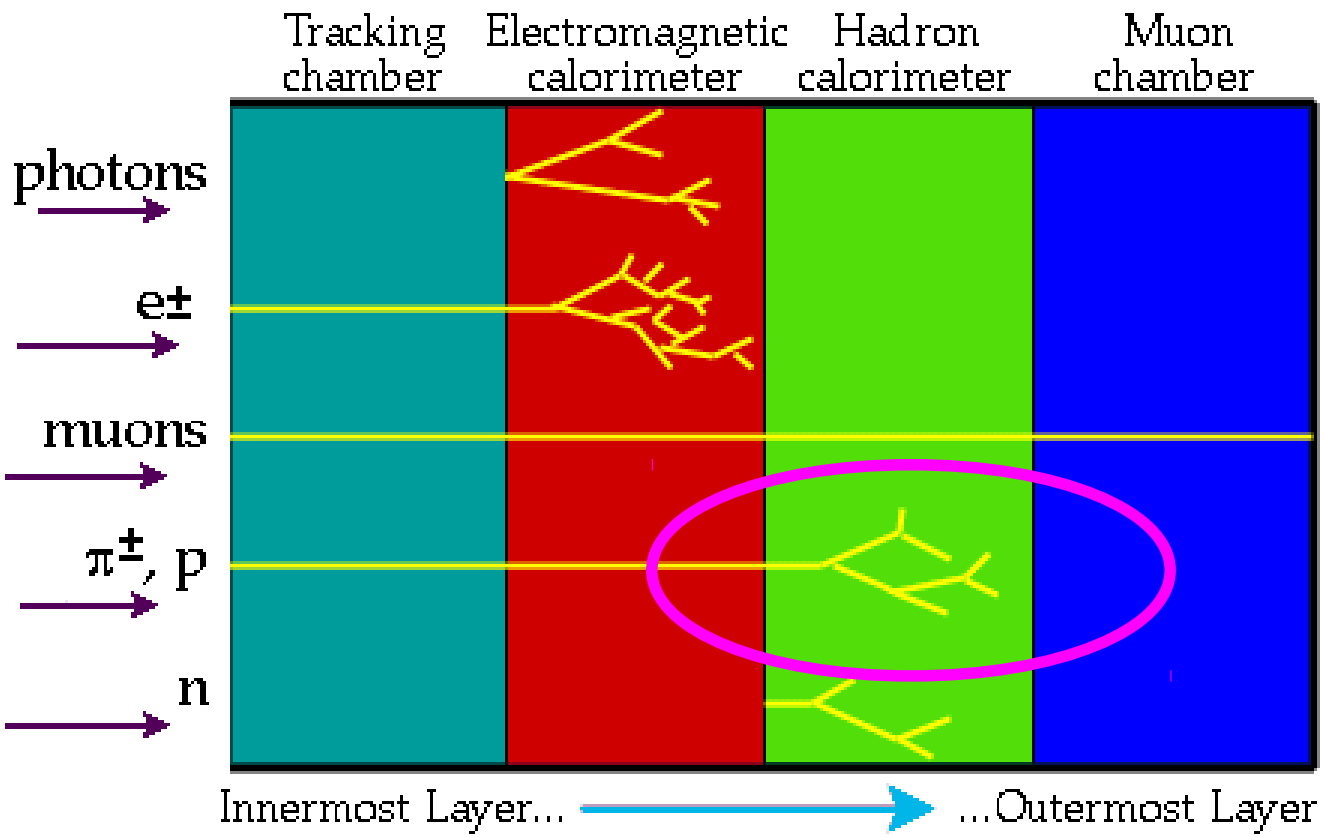
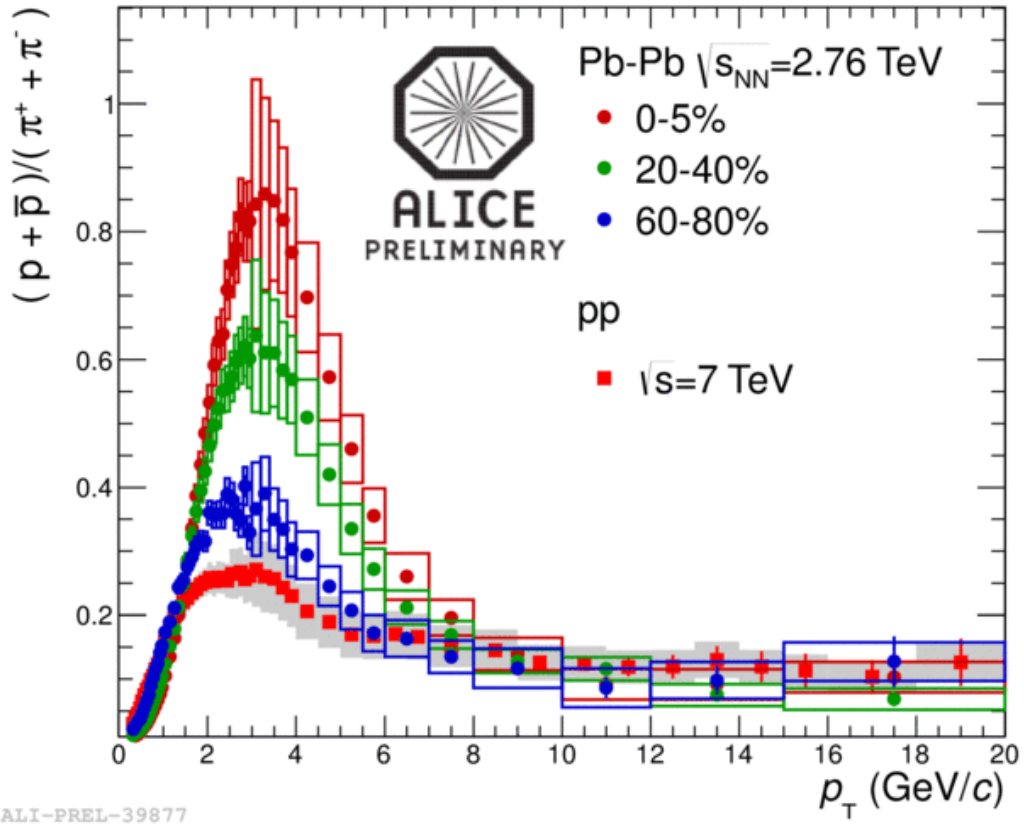
Particle Physics Detectors part 2

- Particle Identification detectors (Mainly charged hadronic separation π, K, p)
  - The BRAHMS experiment at RHIC
- A detailed example
  - The ALICE TPC

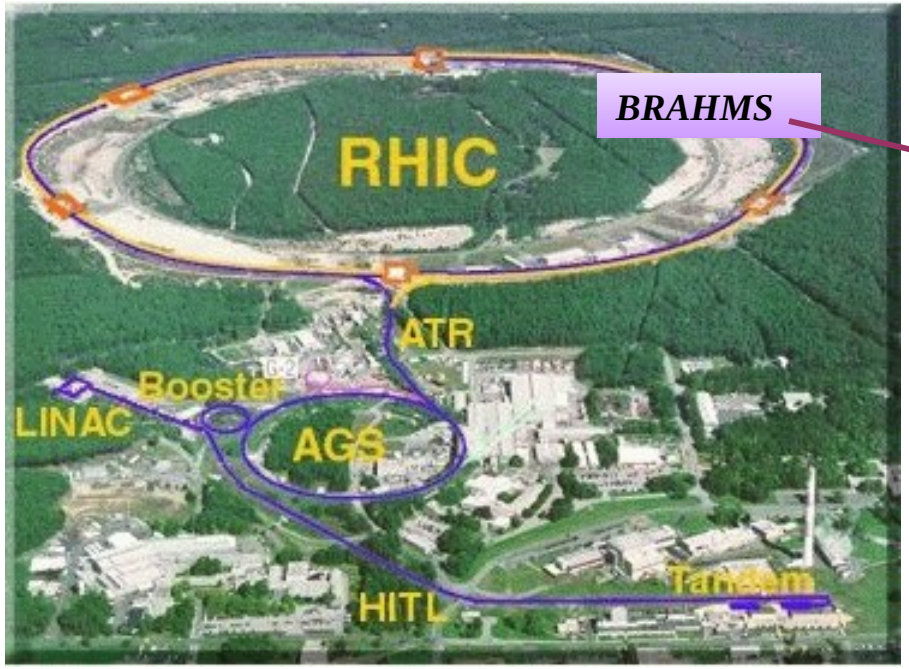

Tracking chamber
Electromagnetic calorimeter
Hadron calorimeter
Muon chamber
photons
e±
muons
π±, p
n
Innermost Layer...
...Outermost Layer

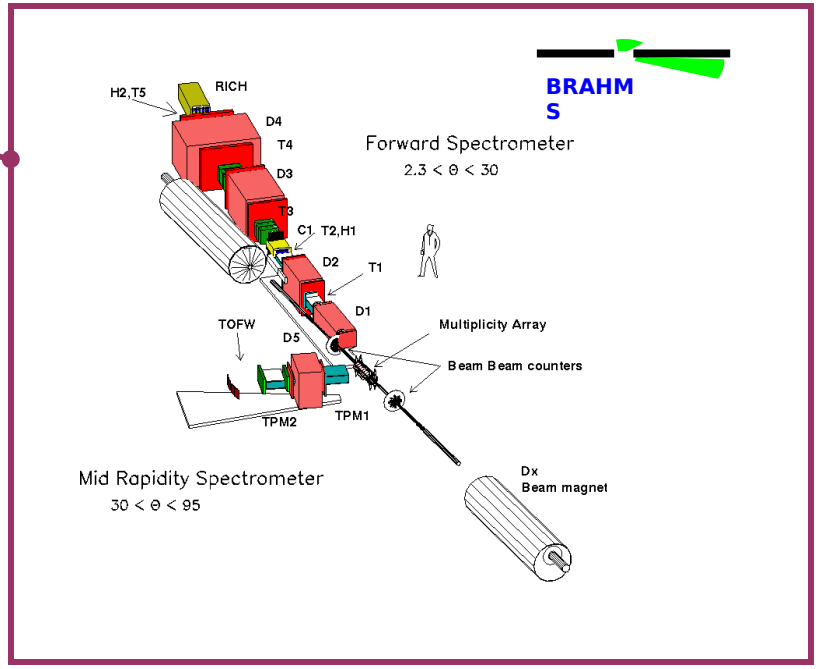
Why particle identification: Additional information



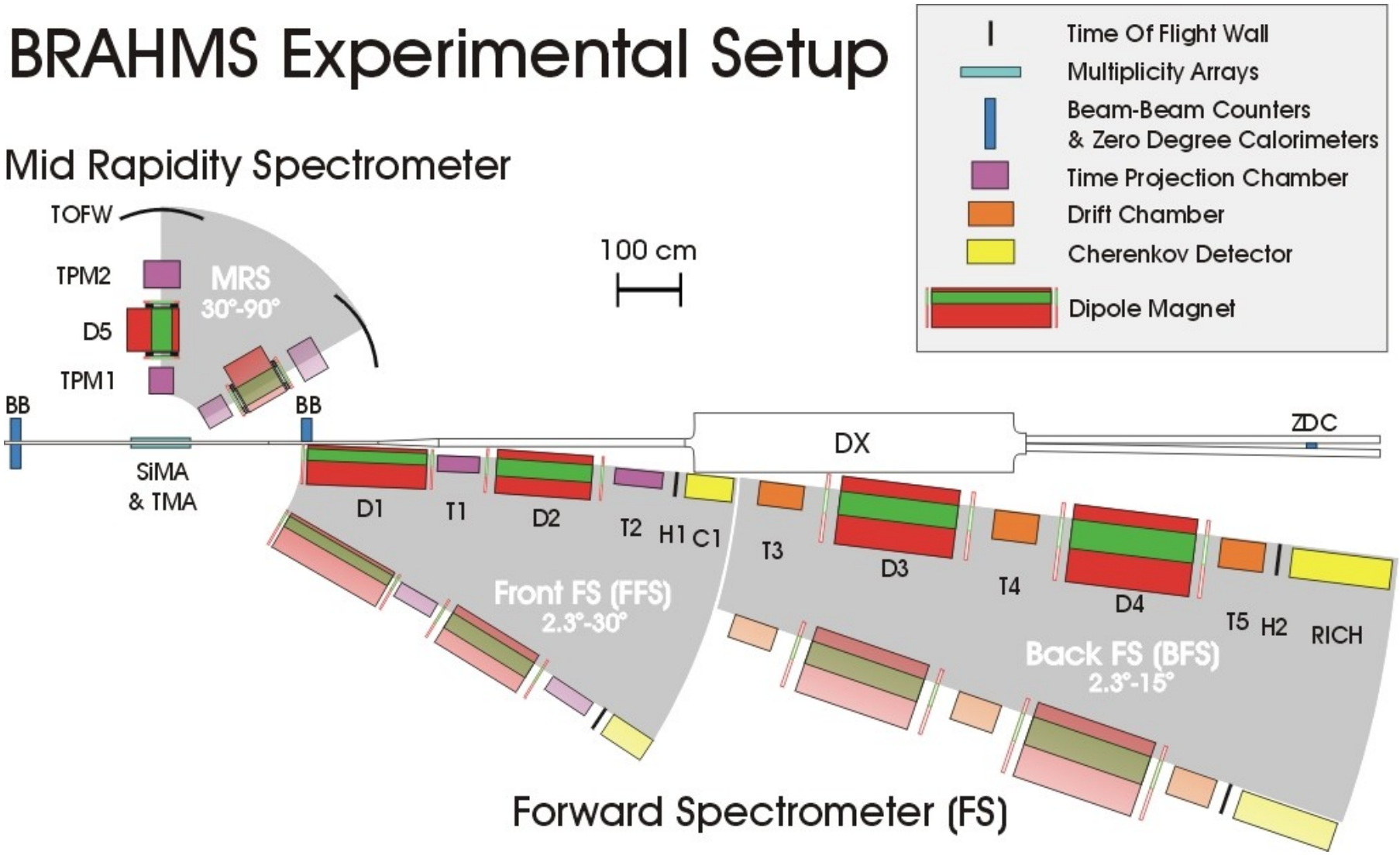
Example: proton/pion ratio vs transverse momentum p_T

BRAHMS at The Relativistic Heavy Ion Collider

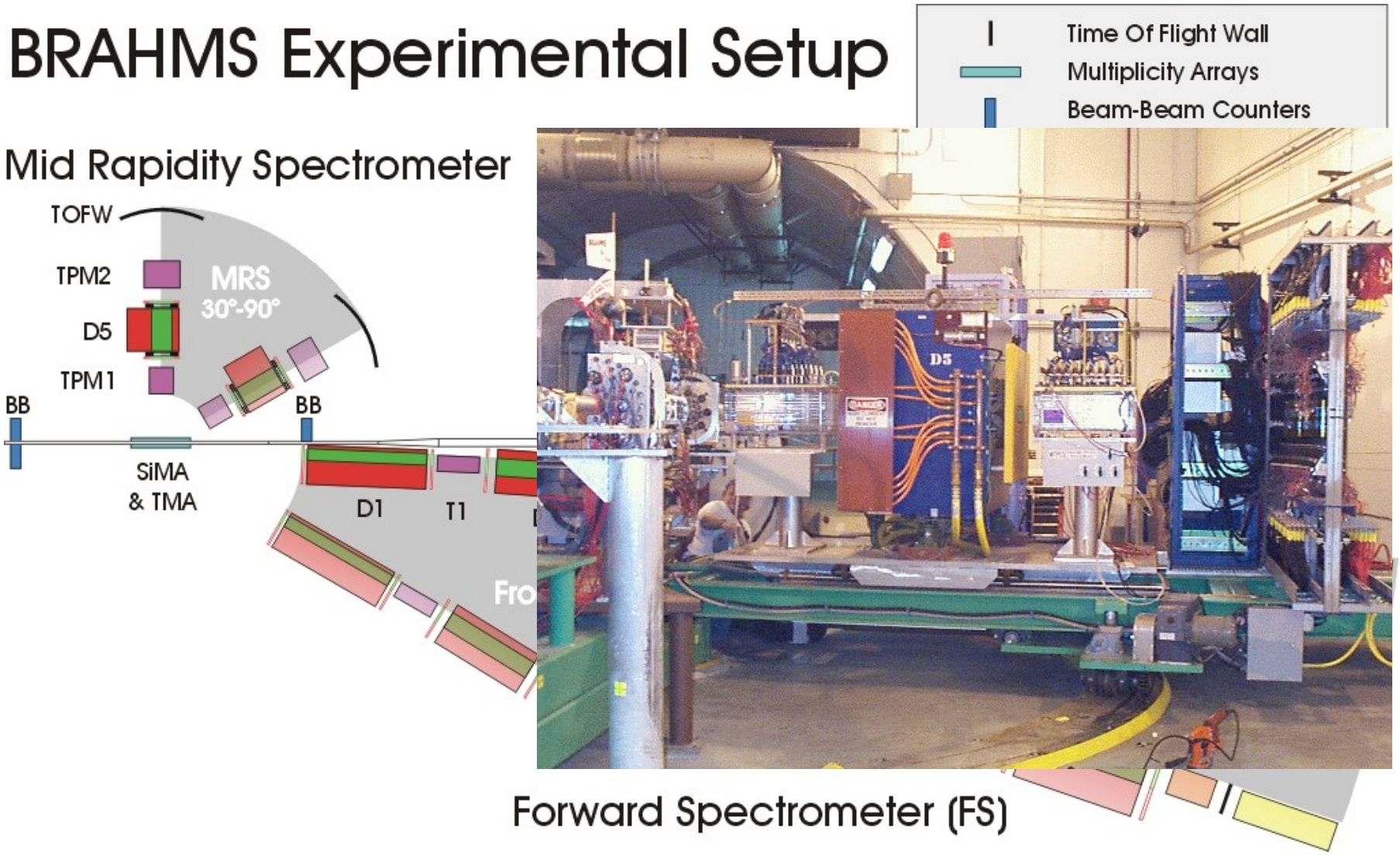




The BRAHMS detector



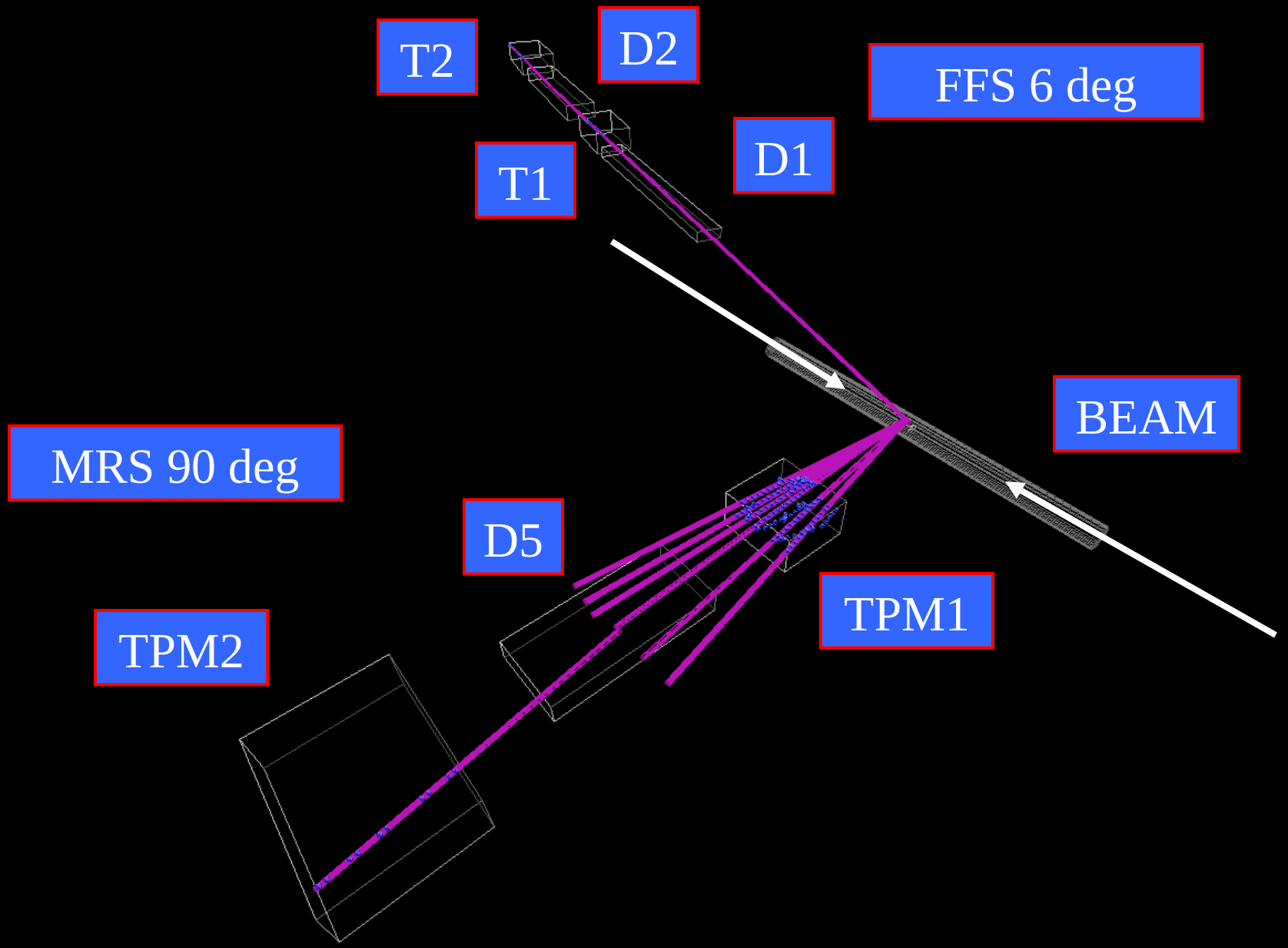
The BRAHMS detector



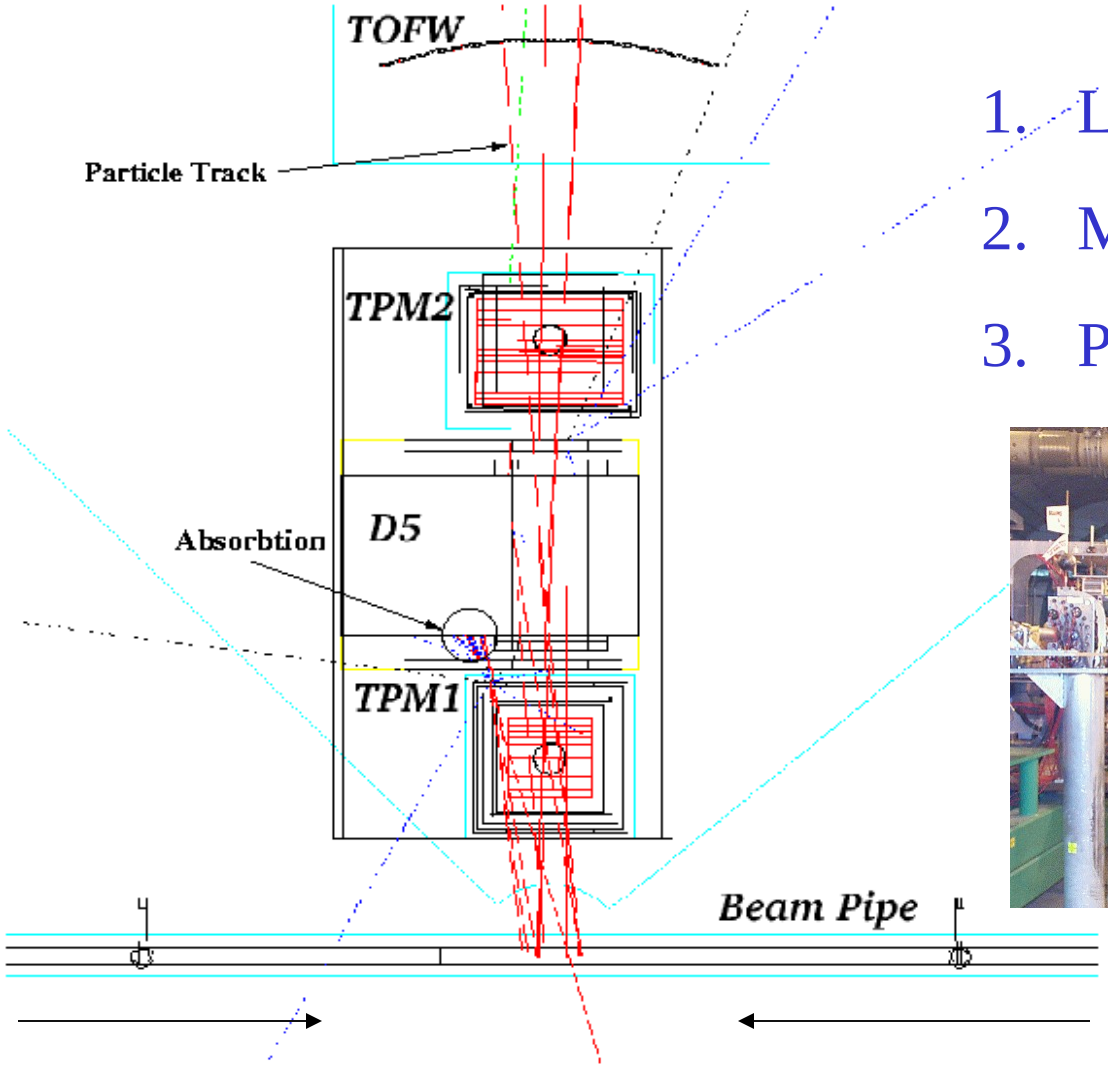
detector

Time Of Flight Wall
Multiplicity Arrays
Beam-Beam Counters
& Zero Degree Calorimeters
Time Projection Chamber
Drift Chamber
Cherenkov Detector
Dipole Magnet
BB
SiMA
& TMA
D1
T1
D2
T2
H1
C1
DX
ZDC
T3
D3
T4
D4
T5
H2
RICH
Front FS (FFS)
2.3°-30°
Back FS (BFS)
2.3°-15°
Forward Spectrometer (FS)

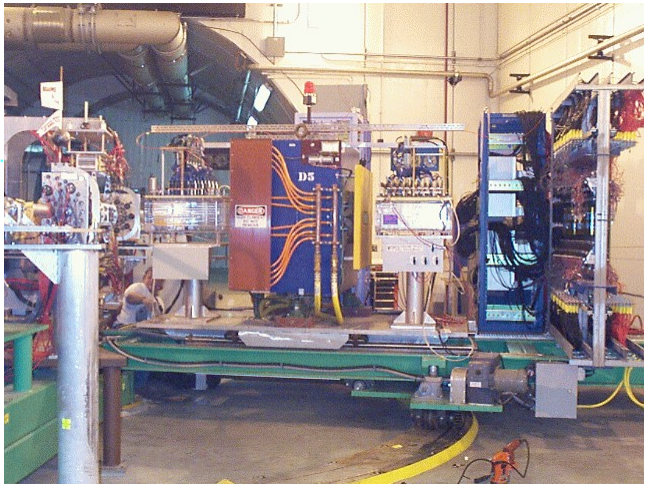
A BRAHMS event



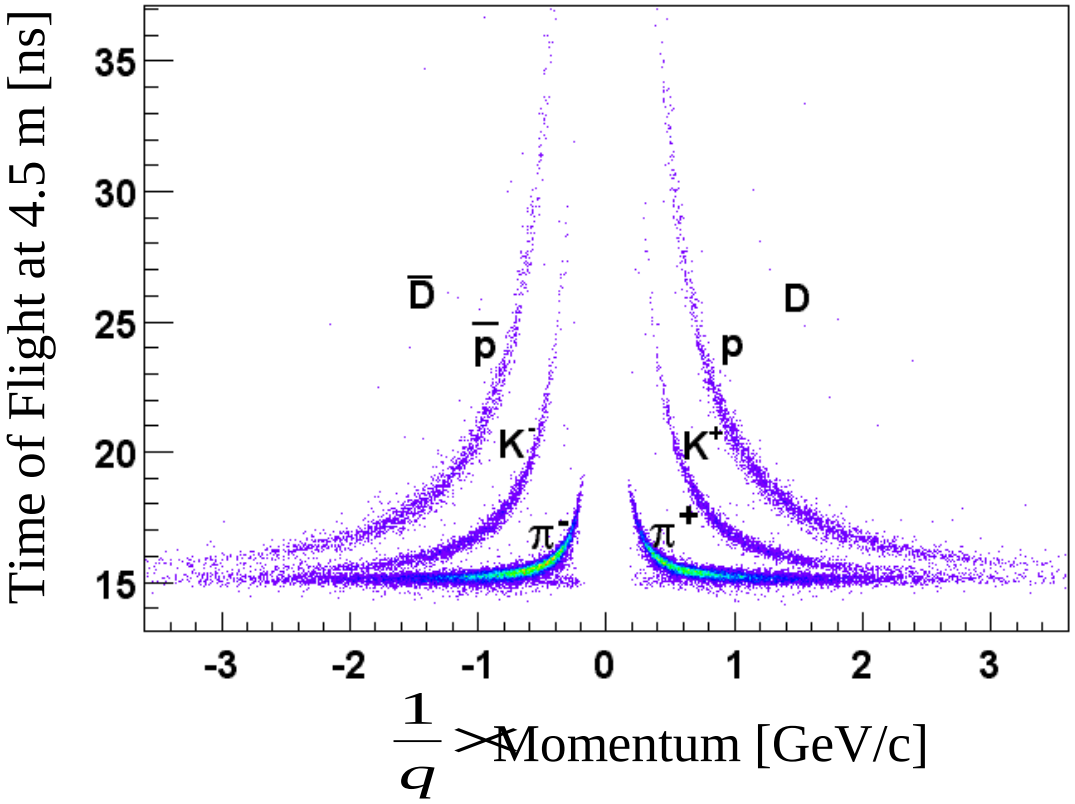
Event reconstruction - Tracks

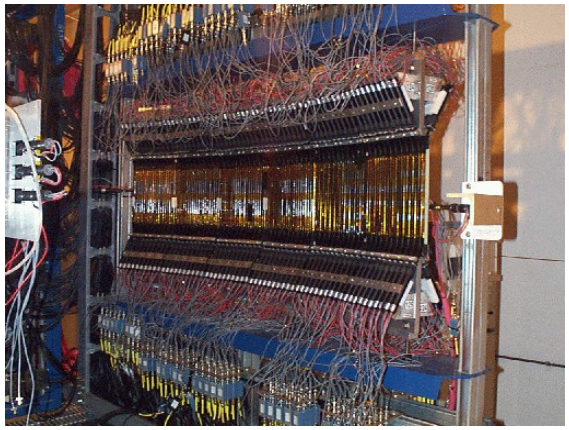


1. Local tracking
2. Matching (momentum)
3. Particle identification



PID with the Time-of-flight Wall TOFW (MRS)

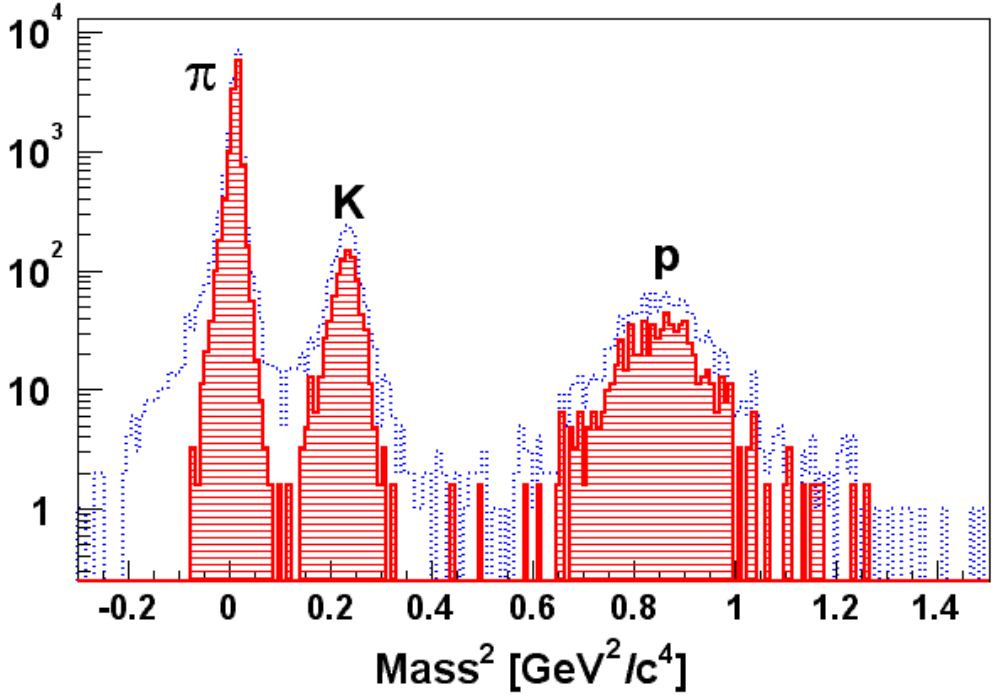




125 scintillator slats

Tof resolution : σ ≈ 100 ps

PID with m^2

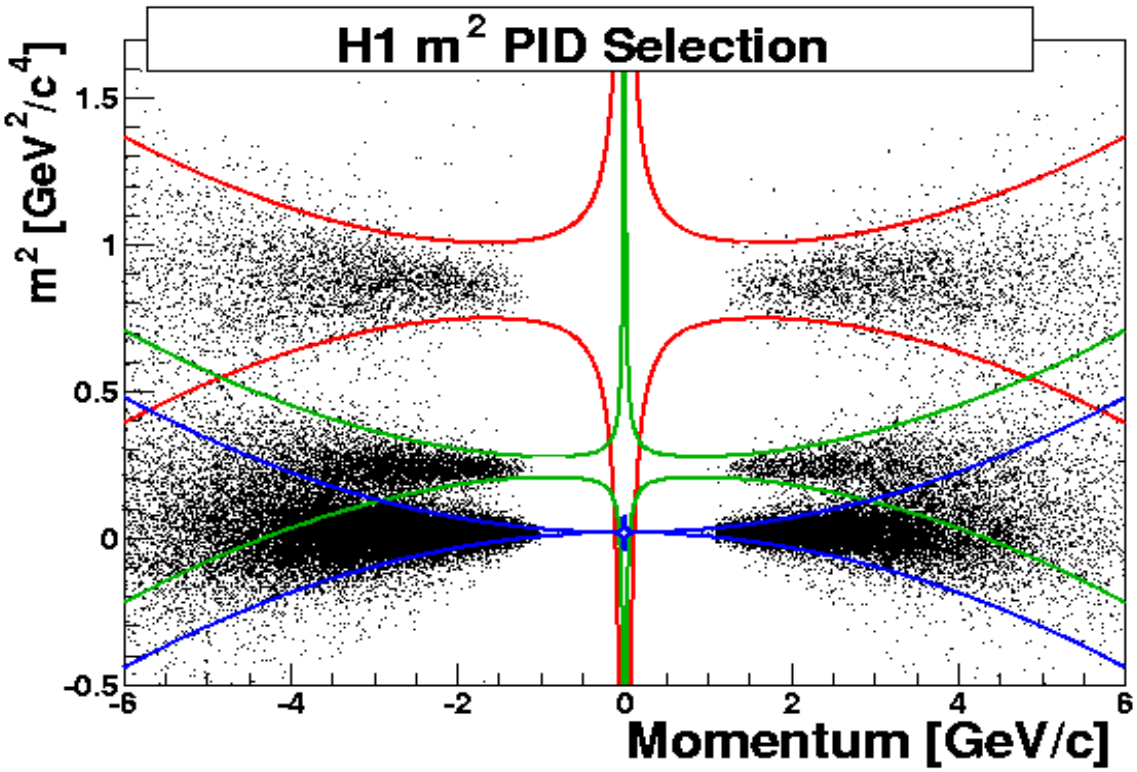


- How do you obtain m^2 from momentum p and $\beta = \frac{L}{TOF}$
- Answer:
  (why m^2)

$$m^2 = p^2\left(\frac{1}{\beta^2} - 1\right)$$

Proton PID using TOF

$$m^2 = p^2\left(\frac{1}{\beta^2} - 1\right)$$



2σcuts

p

K

π

m^2 momentum dependence parameterized by :

$$\frac{\sigma^2_{m^2}}{4} = m^4 p^2 \sigma^2_{p_{angle}} + m^4 \sigma^2_{p_{multi}} (1 + \frac{m^2}{p^2}) + p^2 (m^2 + p^2) \sigma^2_{TOF}$$

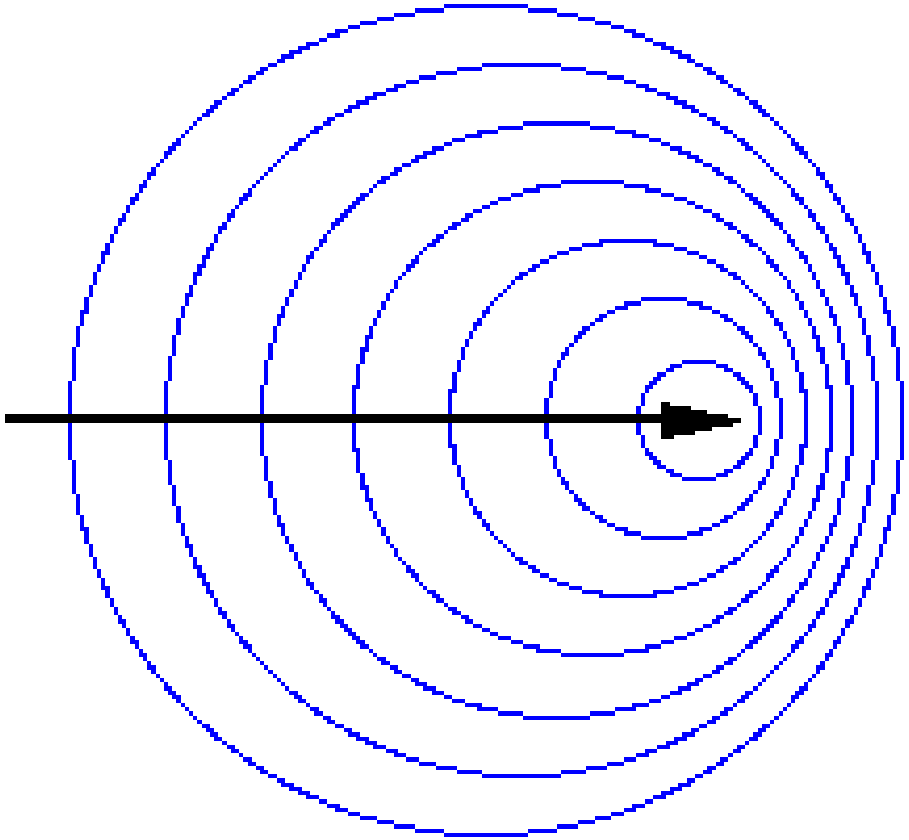
Cherenkov radiation

- Cherenkov radiation happens when the speed β of a charged particle is larger than the speed of light in the medium:

  $c_{medium} = c/n$, where n is the refractive index

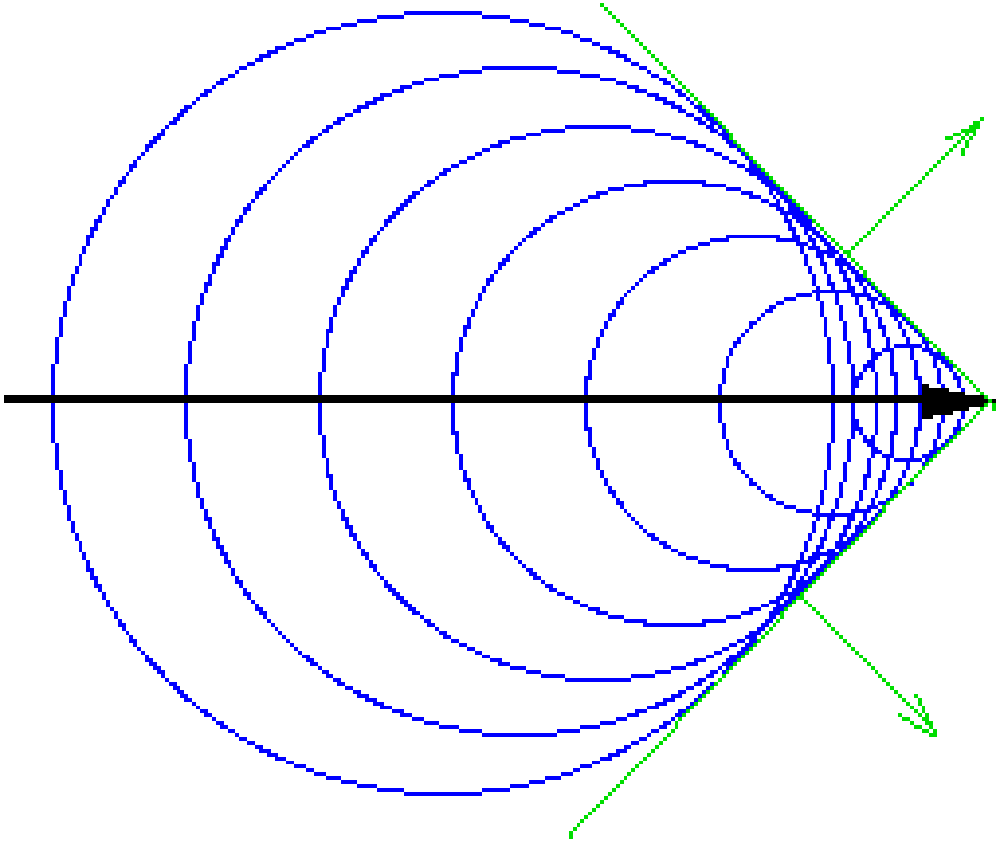
Velocity smaller than c_{medium}

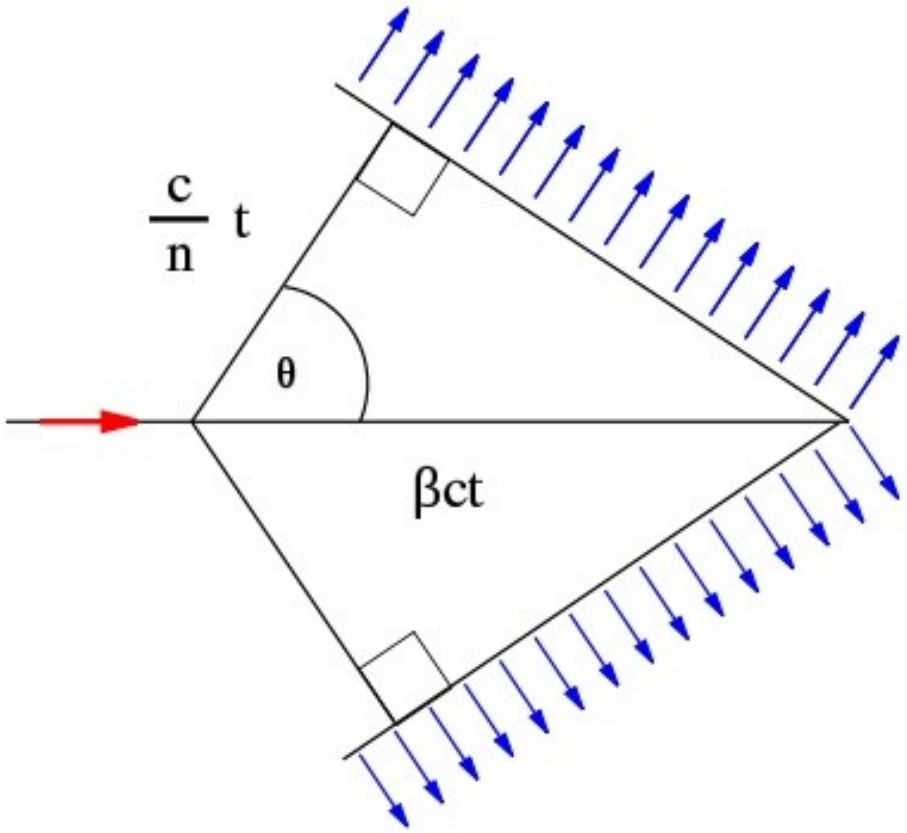
light “emitted” at earlier times is faster than charged particle



Velocity greater than c_{medium}

light “emitted” at earlier times is slower than charged particle





The Cherenkov angle statisfies:

$$\cos\theta = \frac{1}{n\beta}$$

What are the limits?

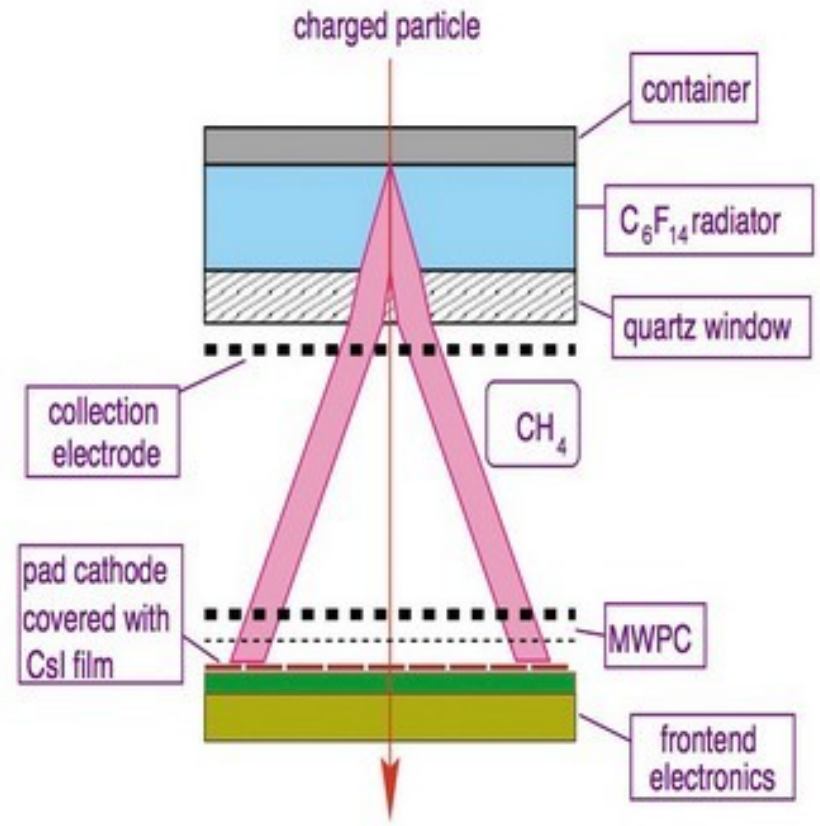
Example of refractive indexes

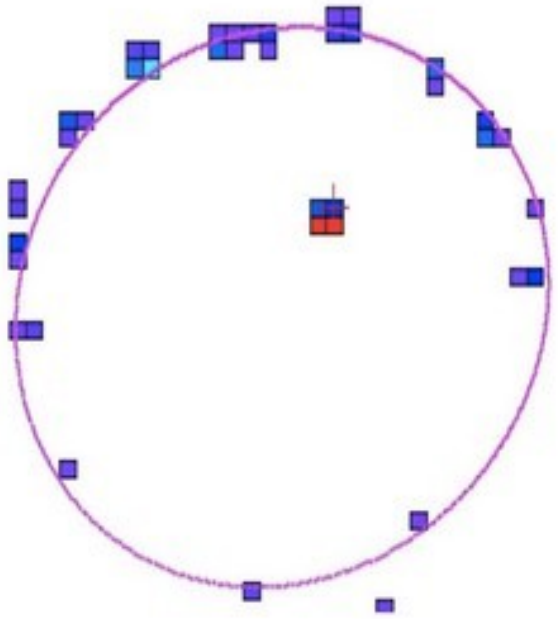
TABLE 4.4 The refractive index n and the threshold value of γ_{th} for some commonly used Čerenkov radiators, together with the number of photons/cm emitted in the visible region 300–700 nm by a particle with unit charge and $\beta \approx 1$.

Medium	$n-1$	γ_{th}	Photons/cm
Helium (STP)	3.5×10^{-5}	120	0.03
CO_2(STP)	4.1×10^{-4}	35	0.40
Silica aerogel	0.025 – 0.075	4.6 – 2.7	24 – 66
Water	0.33	1.52	213
Glass	0.46 – 0.75	1.37 – 1.22	261 – 331

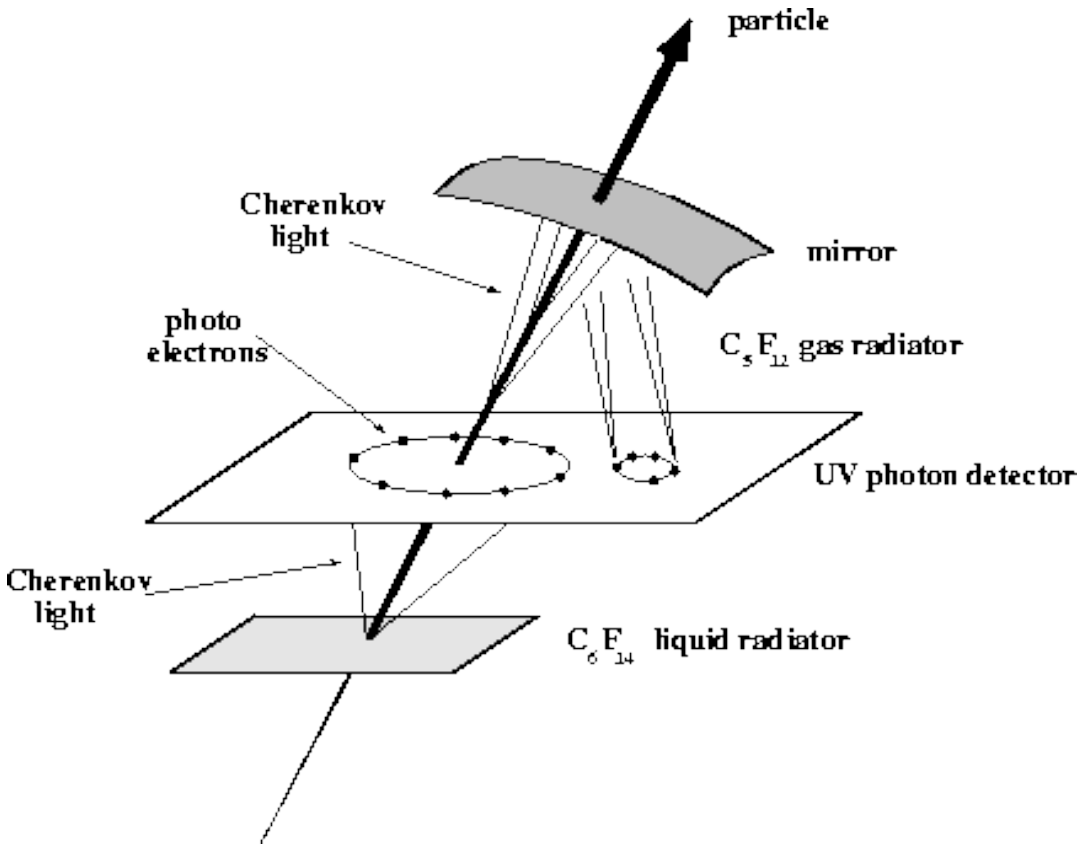
Threshold in γ

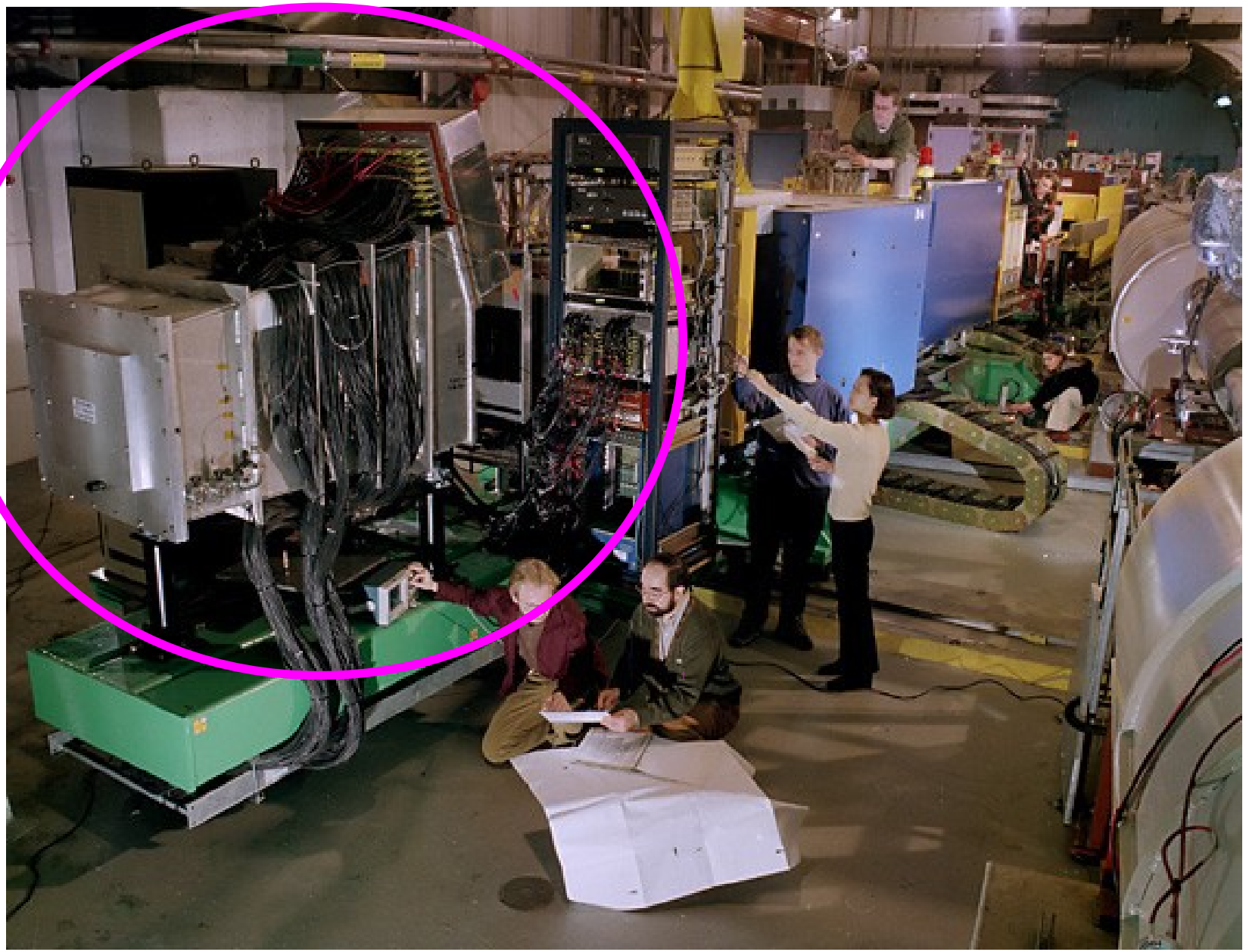
Practical use: RICH v1



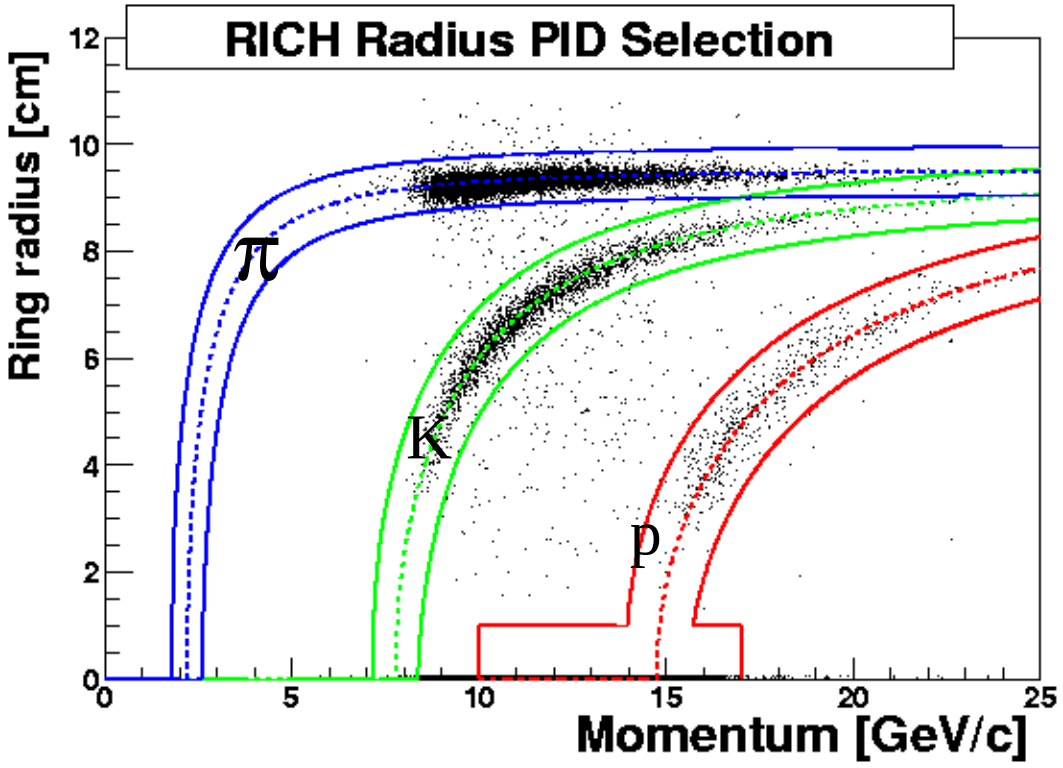


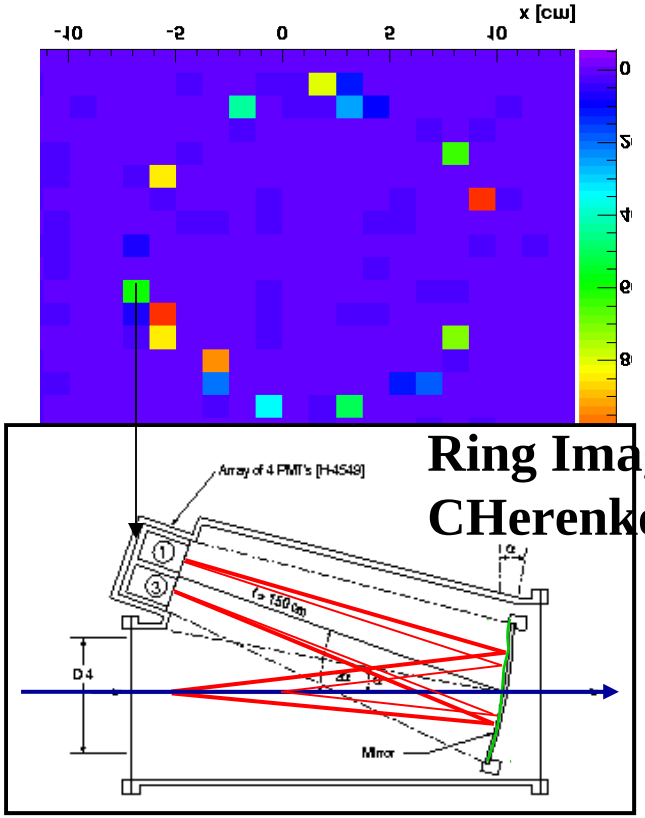
RICH with mirror





Proton PID in the FS





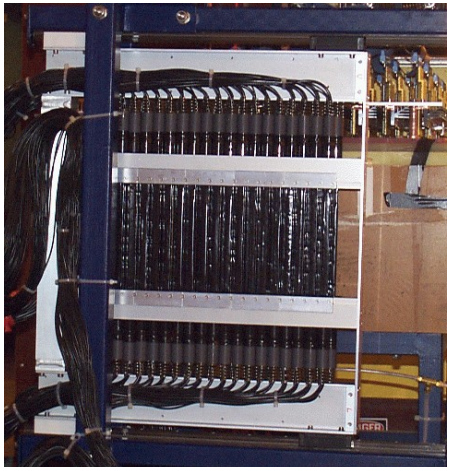
Ring Imaging CHerenkov

The ring radius in the RICH depends on the velocity.

The RICH is used to identify protons directly and as a VETO counter for pions and kaons. Important to correct for contamination.

Advanced example: RICH as veto

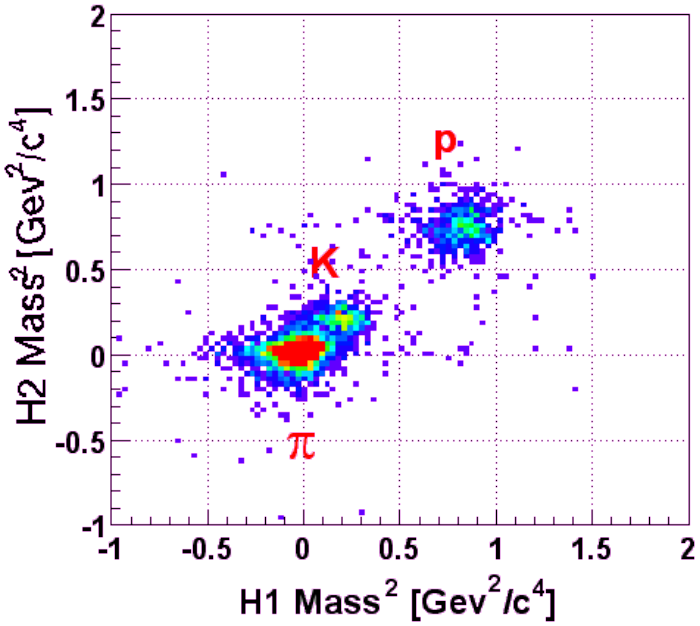
Time-of-flight wall H2



32 scintillator slats

18 meters from nominal vertex

TOF resolution: σ ≈ 85 ps



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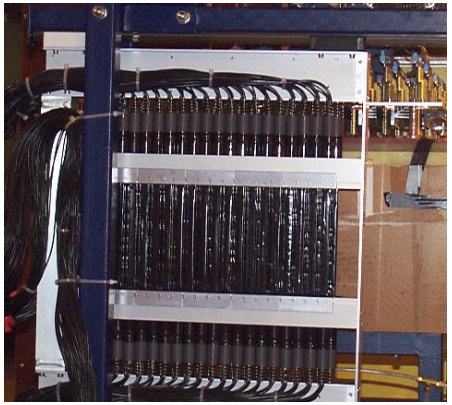

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