THE PHENIX DETECTOR

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PHENIX

PHENIX – A Physics Experiment at RHIC

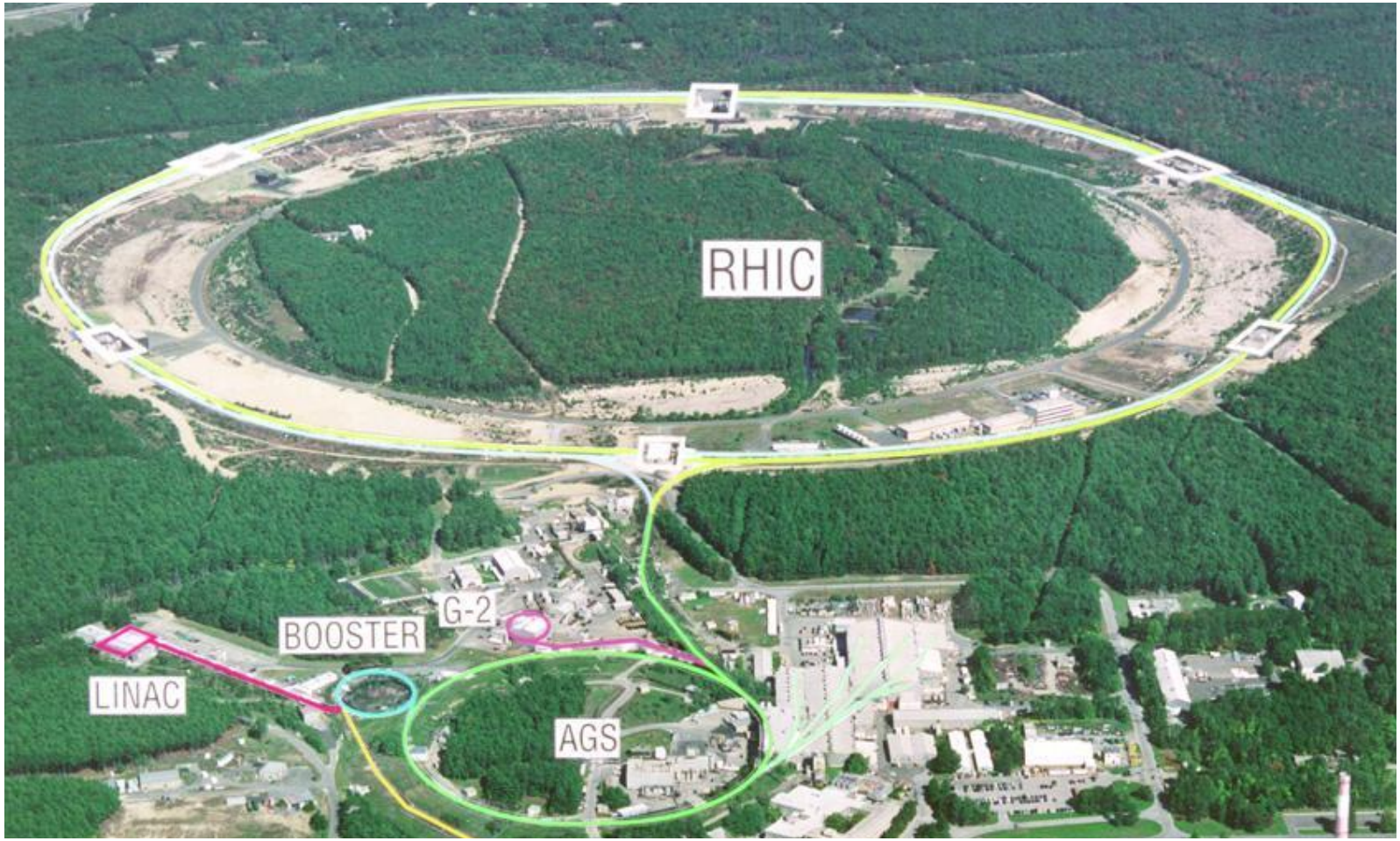
- PHENIX is at RHIC: Relativistic Heavy Ion Collider

PHENIX – A Physics Experiment at RHIC

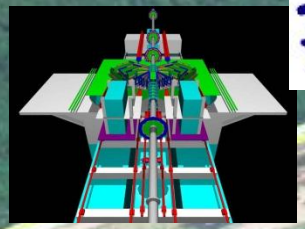
- RHIC is a Collider

PHENIX – A Physics Experiment at RHIC

- RHIC is an Ion-Ion Collider

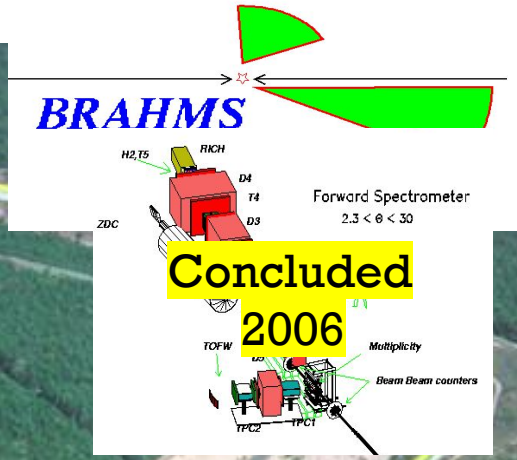


PHENIX – A Physics Experiment at RHIC



PHOBOS

Concluded 2005



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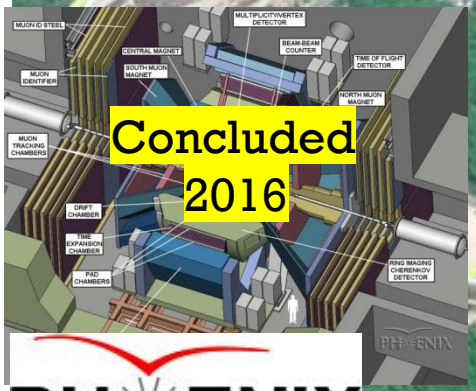
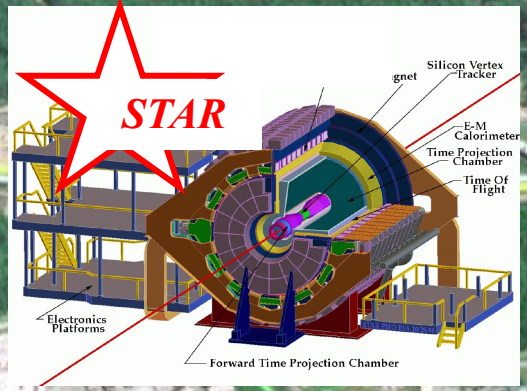


Concluded 2016

PHENIX

STAR



RHIC

BOOSTER

G-2

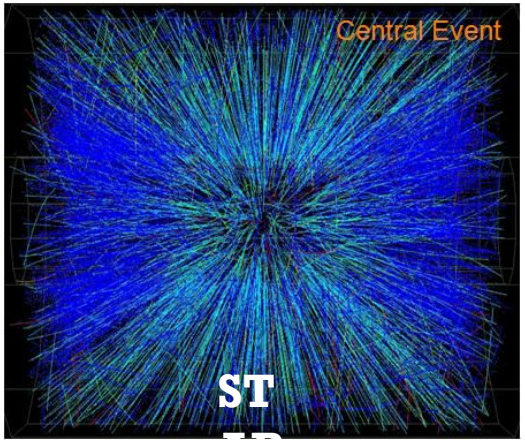
LINAC

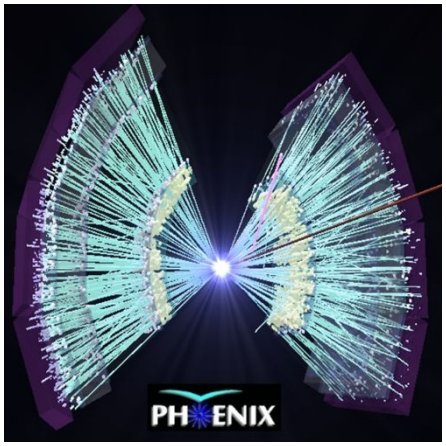
AGS

PHENIX – A Physics Experiment at RHIC

- 3.83 km circumference
- Two *independent* rings
  - 120 bunches/ring
  - 106 ns bunch crossing time
- Collides Any with Any

  So far:
  - Au+Au, p+p, d+Au, Cu+Cu, UU, Cu+Au, ^{3}He+Au, p+Au
- Top Center-of-Mass Energy
  - 510 GeV for p-p
  - 200 GeV/nucleon for Au-Au





PHENIX – A Physics Experiment at RHIC

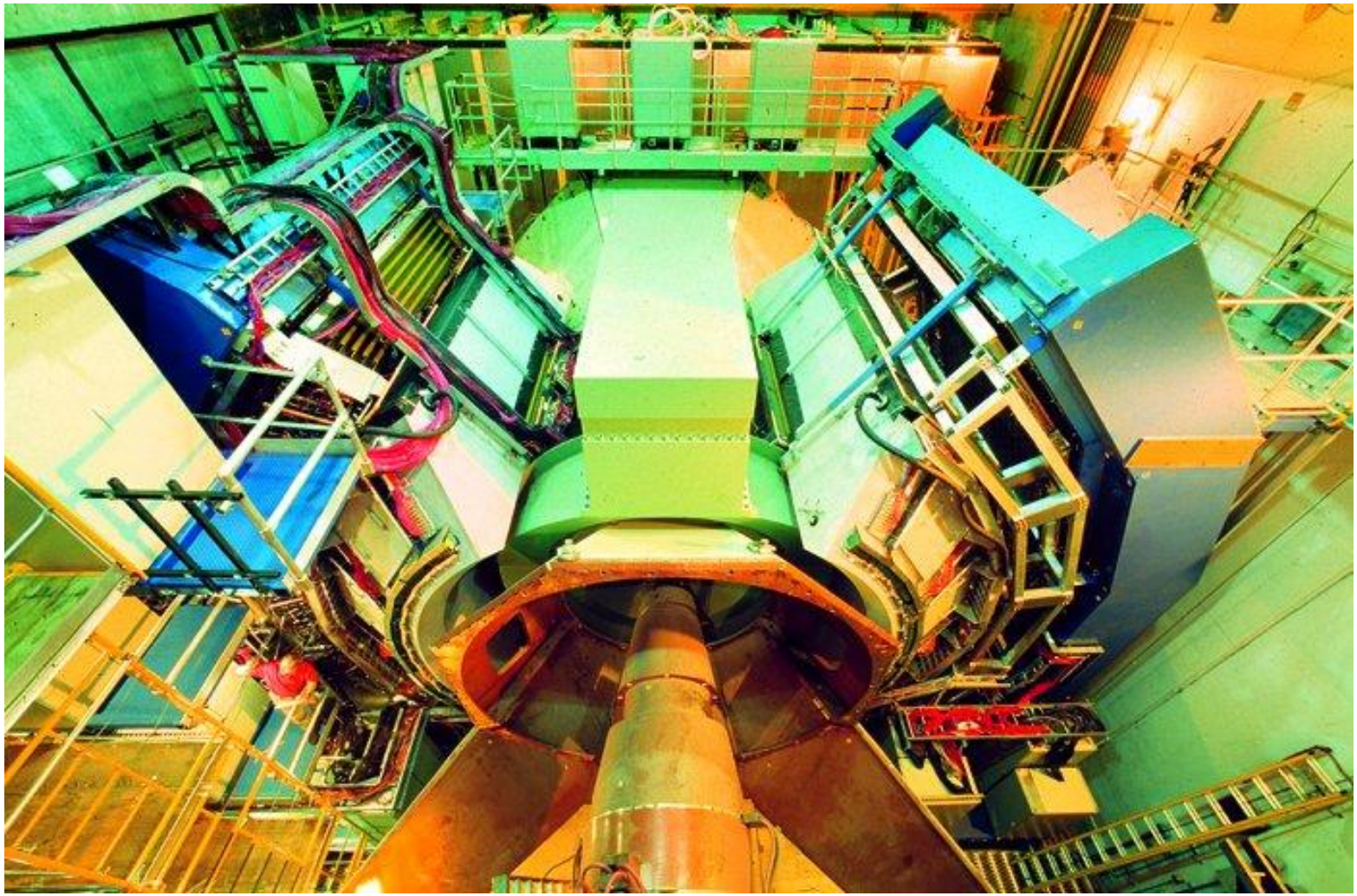
7

Pioneering **H**igh **E**nergy **N**uclear **I**nteraction e**X**periment

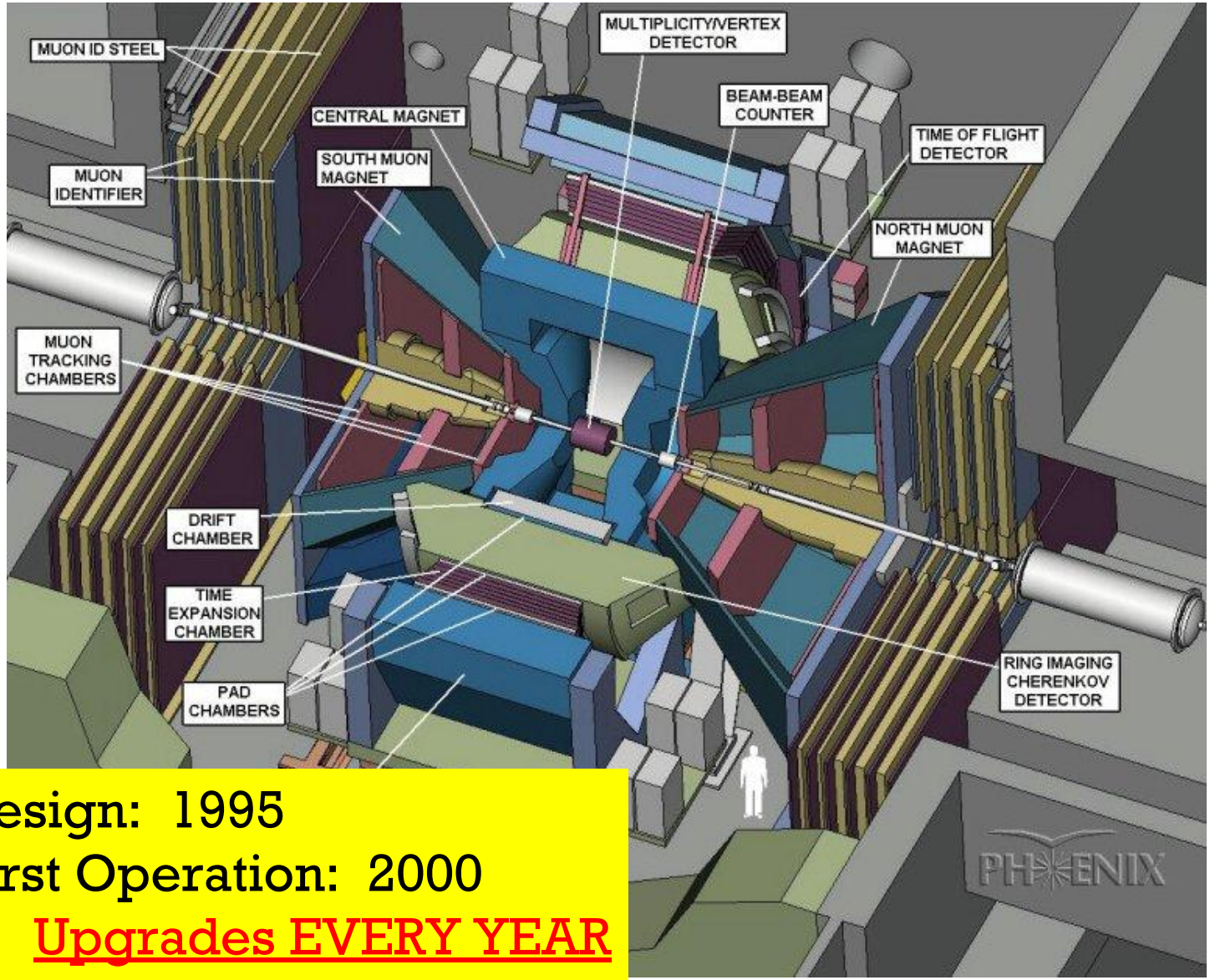
PHENIX – A Physics Experiment at RHIC

8

Pioneering **H**igh **E**nergy **N**uclear **I**nteraction e**X**periment



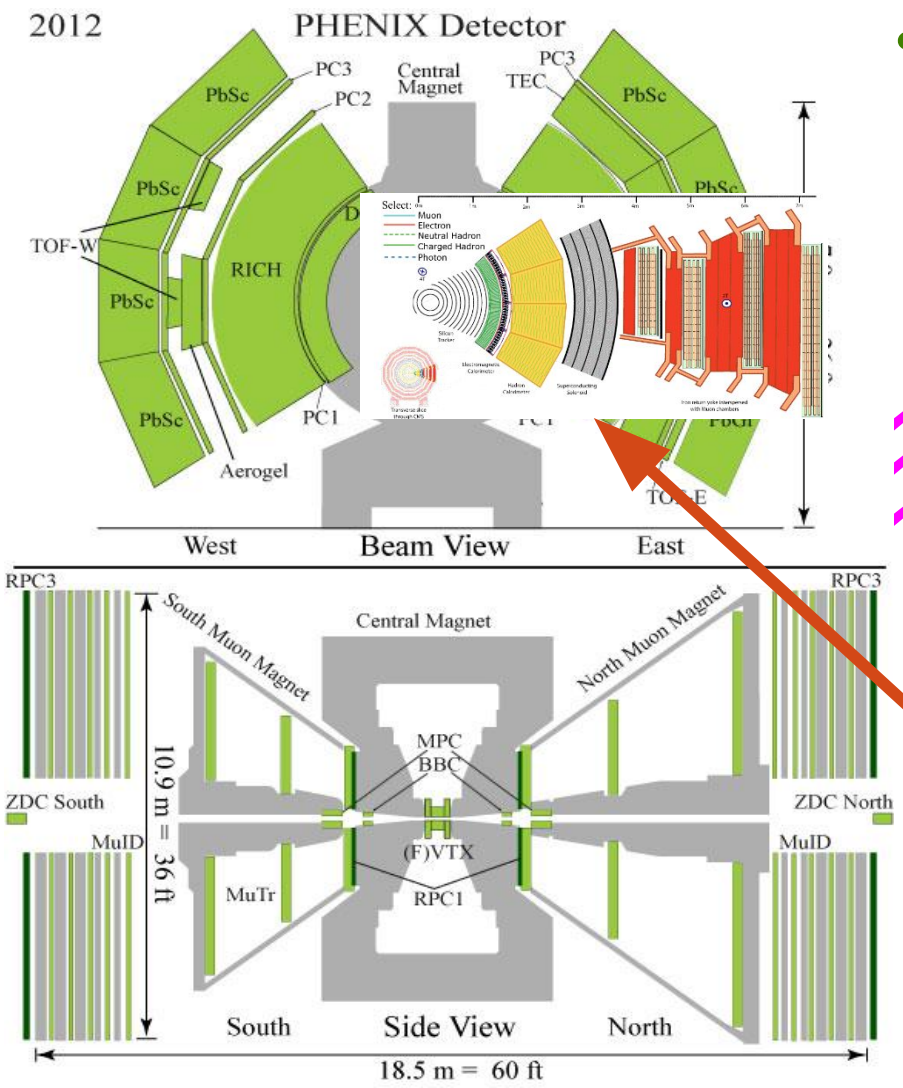
PHENIX – A Physics Experiment at RHIC



Design: 1995
First Operation: 2000
Upgrades EVERY YEAR

PHENIX – A Physics Experiment at RHIC

M. J. Tannenbaum



- **PHENIX is a special purpose detector designed and built to measure *rare processes* involving *leptons and photons* at the *highest luminosities.***
  - *possibility of zero magnetic field on axis*
  - *minimum of material in aperture 0.4% X_o*
  - *EMCAL RICH $e^{\pm}$ ID and lvl-1 trigger*
- *γ π^0 separation up to $p_T \sim 25$ GeV/c*
- *EMCAL and precision TOF for $h^{\pm}$ PID*
- *+ some special purpose detectors*

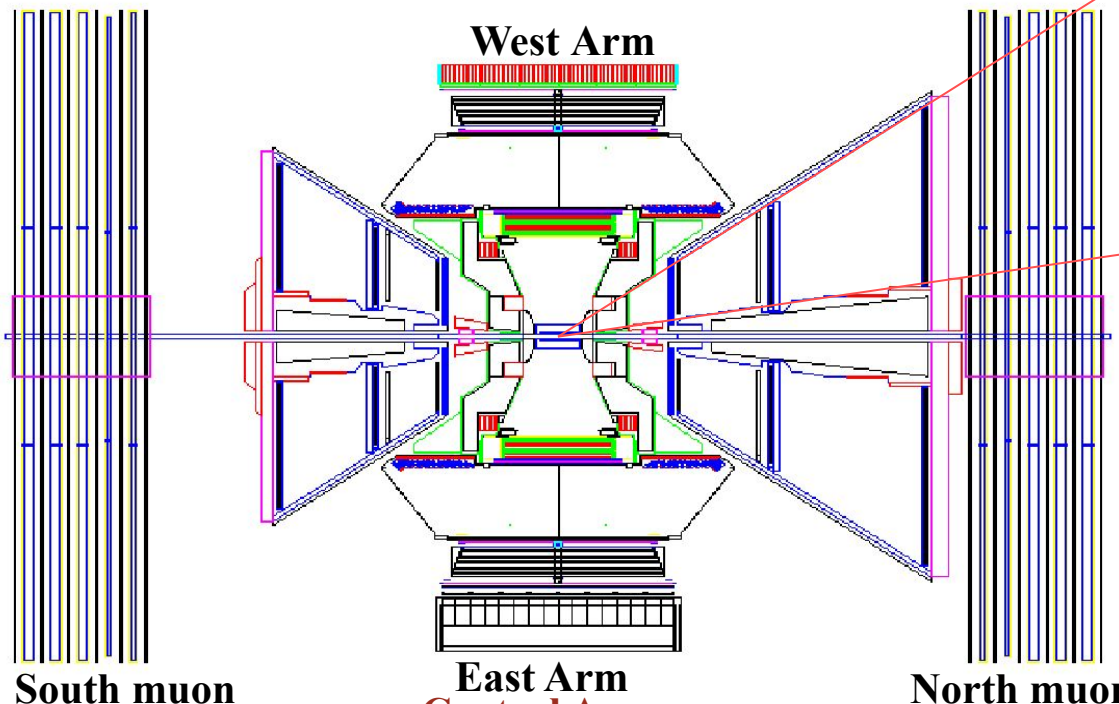
Comparison to scale with a wedge of CMS

PHENIX – A Physics Experiment at RHIC

- An experiment with something for everybody
- A complex apparatus to measure
  - Hadrons
  - Muons
  - Electrons
  - Photons

Executive summary:

- *High* resolution
- *High* granularity



Global
MVD/BB/ZDC

Muon Arms
Coverage (N&S)
-1.2< |y| <2.3
$-\pi < \varphi < \pi$
$\Delta M(J/\psi) = 105$MeV
$\Delta M(\gamma) = 180$MeV

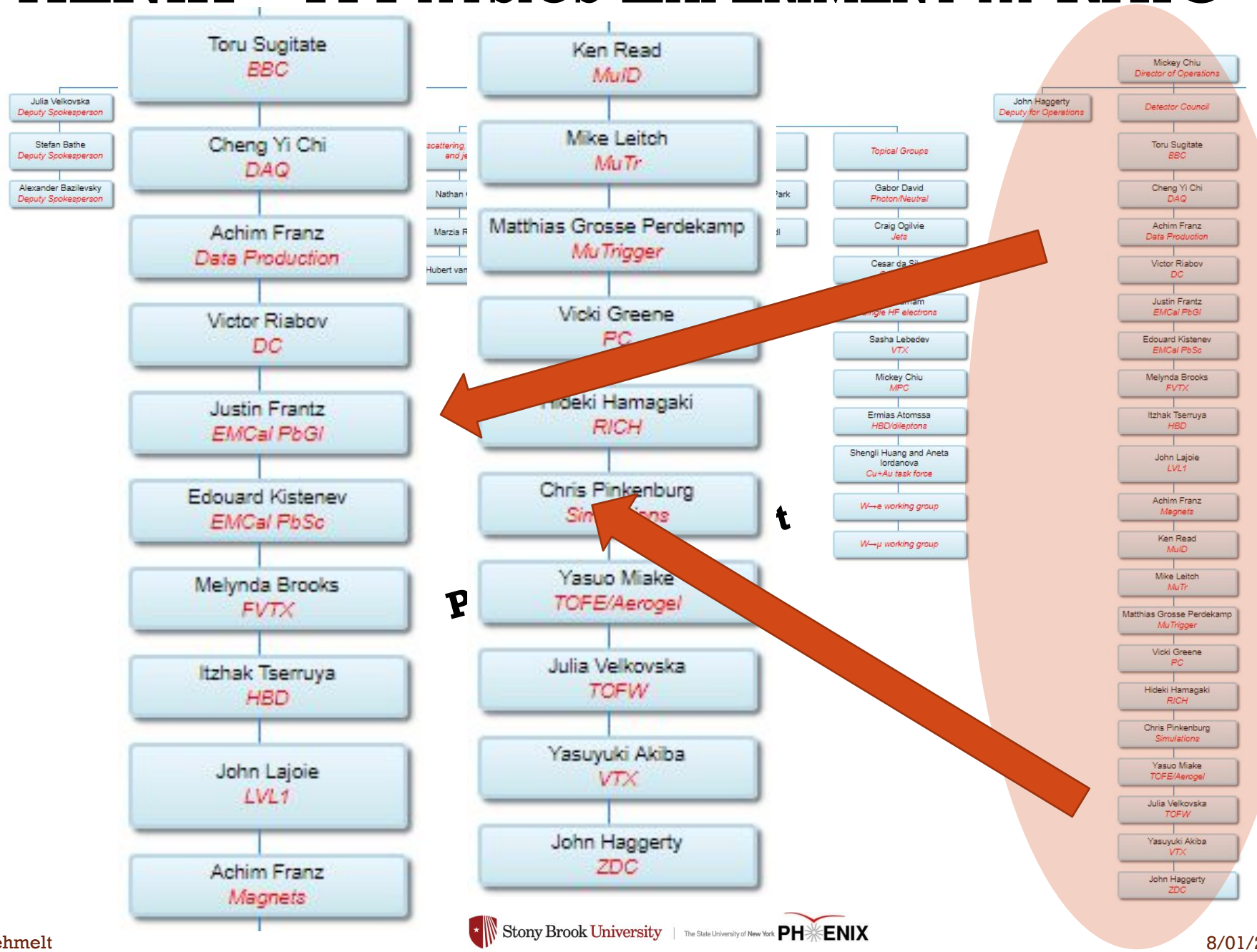
3 station CSC
5 layer MuID ($10X_0$)
p(μ)>3GeV/c

Central Arms
Coverage (E&W)
-0.35< y < 0.35
$30^o < |\varphi| < 120^o$
$\Delta M(J/\psi) = 20$MeV
$\Delta M(\gamma) = 160$MeV

PHENIX – A Physics Experiment at RHIC

- Main subdivision of the PHENIX detector
  - **Magnets**
  - **Event Characterization Detectors (Global Detectors)**
  - **Central Arm Detectors**
  - **Muon Arm Detectors**

PHENIX – A Physics Experiment at RHIC



PHENIX – A Physics Experiment at RHIC

PHENIX is an onion (as many detectors are)

Every shell serves a purpose

- First level: momentum measurement tracking
  - Second level: particle identification PID
    - Third level: energy measurement
      - Miscellaneous

PHENIX is subdivided in ***Central*** & ***Forward***

PHENIX – MAGNETS

- First level: momentum measurement tracking

Though magnets are not detectors:

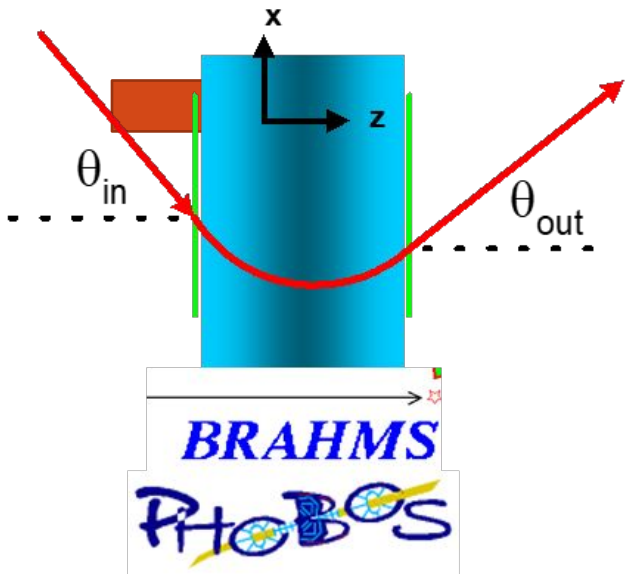
→ **Nothing works without magnets**

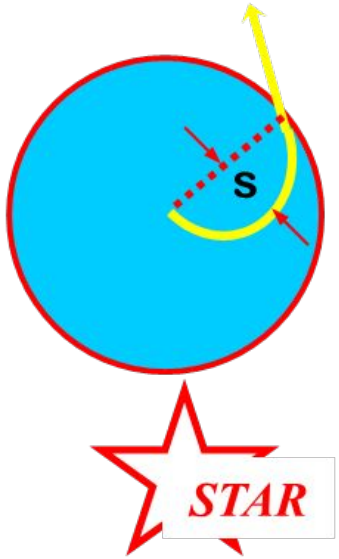
- Three magnet systems in PHENIX
  1. Central Magnet (CM) for Central Arm
  2. Forward Magnet North (Muon Arm North)
  3. Forward Magnet South (Muon Arm South)

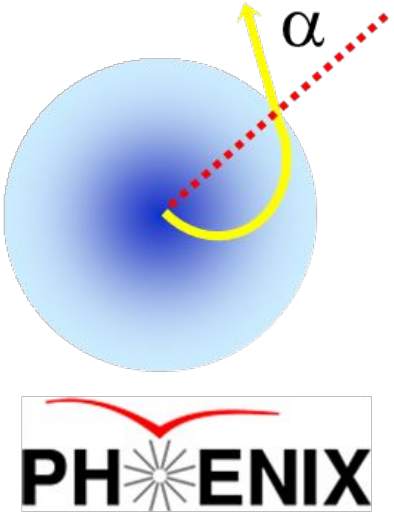
PHENIX – MAGNETS

$$\frac{d\vec{p}}{dt} = \frac{e}{c}\vec{v} \times \vec{B} \qquad |\vec{p}_{\perp}| = \frac{e}{c} B \cdot R, \qquad \frac{e}{c} = \frac{0.3\ GeV/c}{Tesla - meter}$$

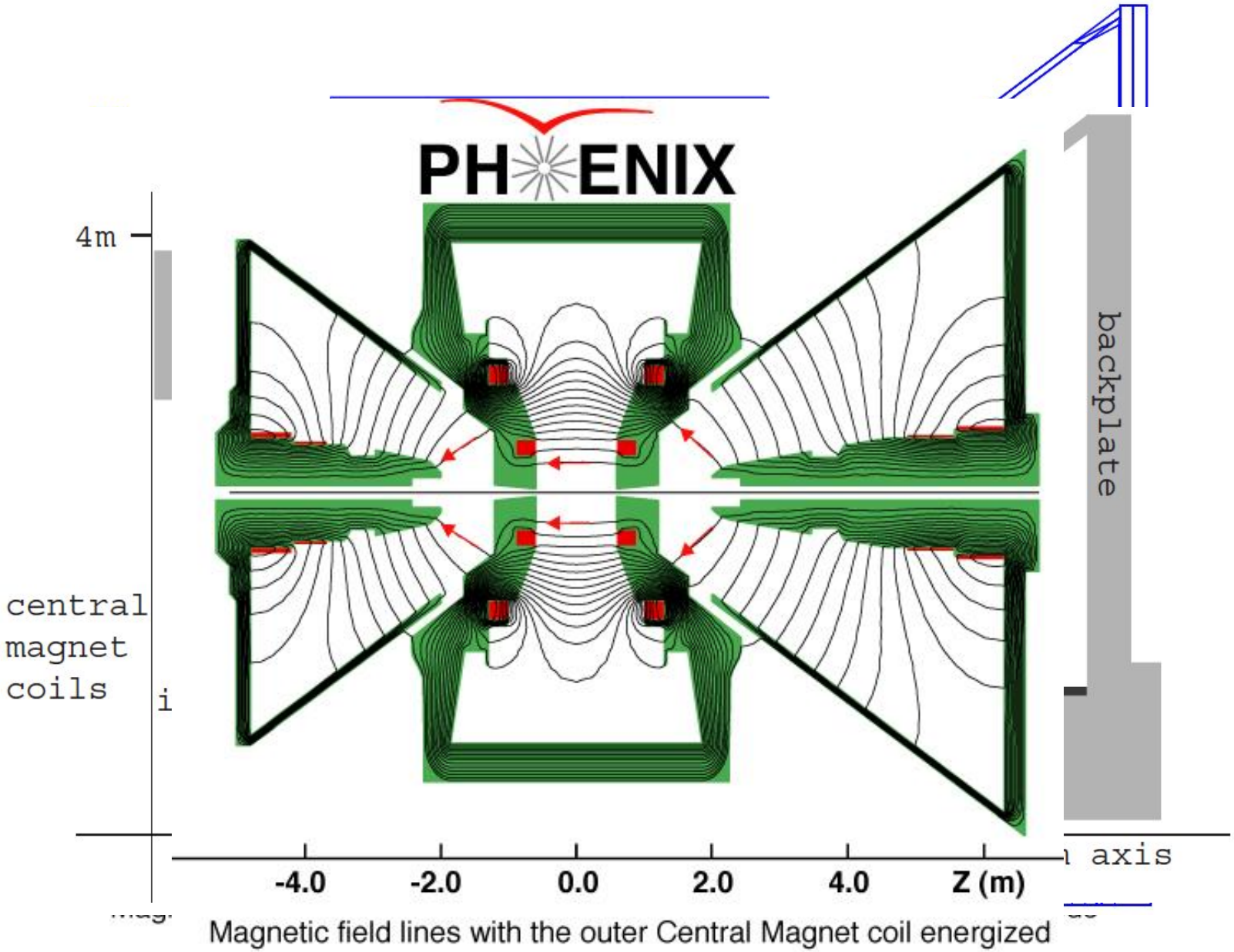
1 meter of 1 Tesla field deflects p = 1 GeV/c by ~17°





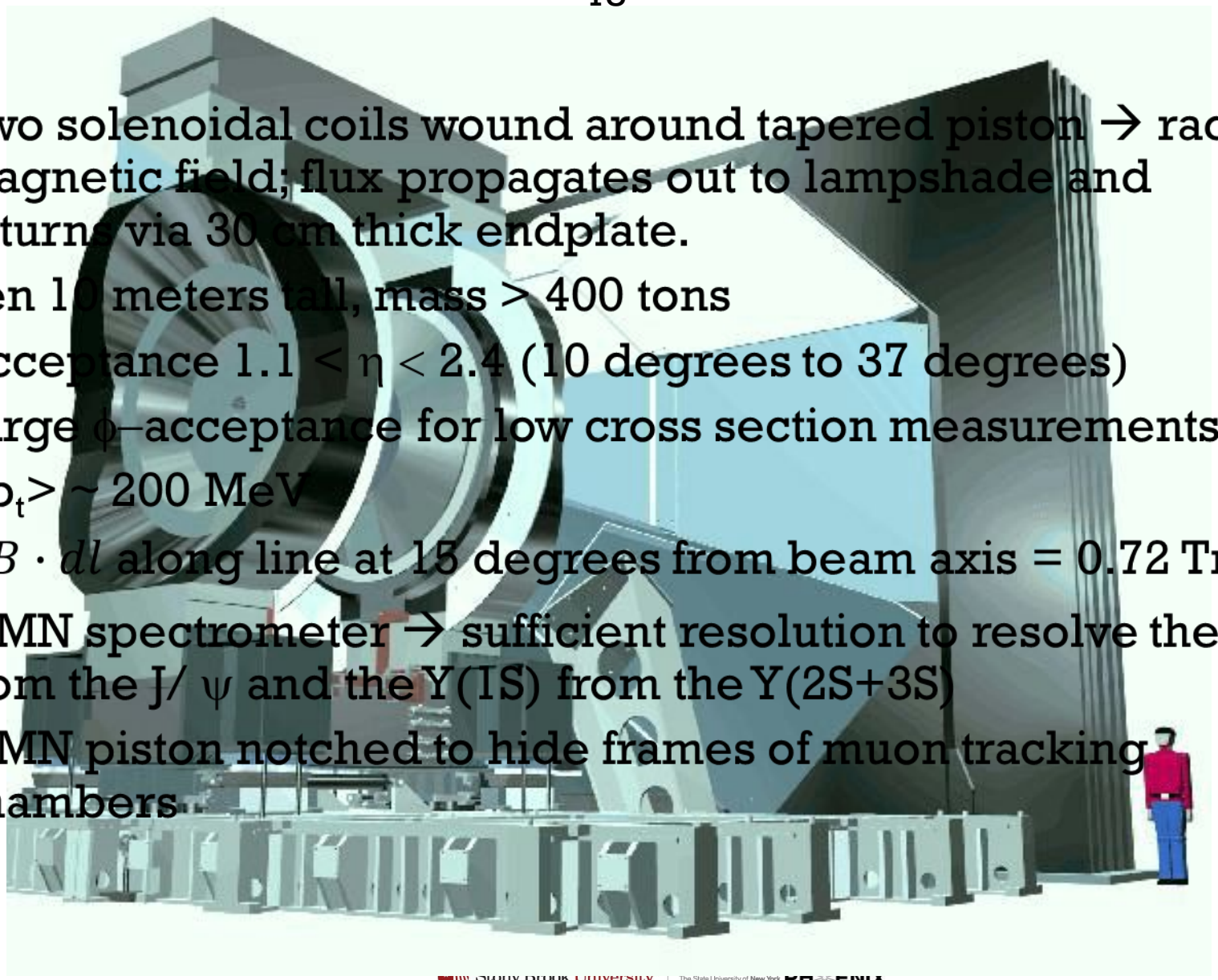


PHENIX – MAGNETS



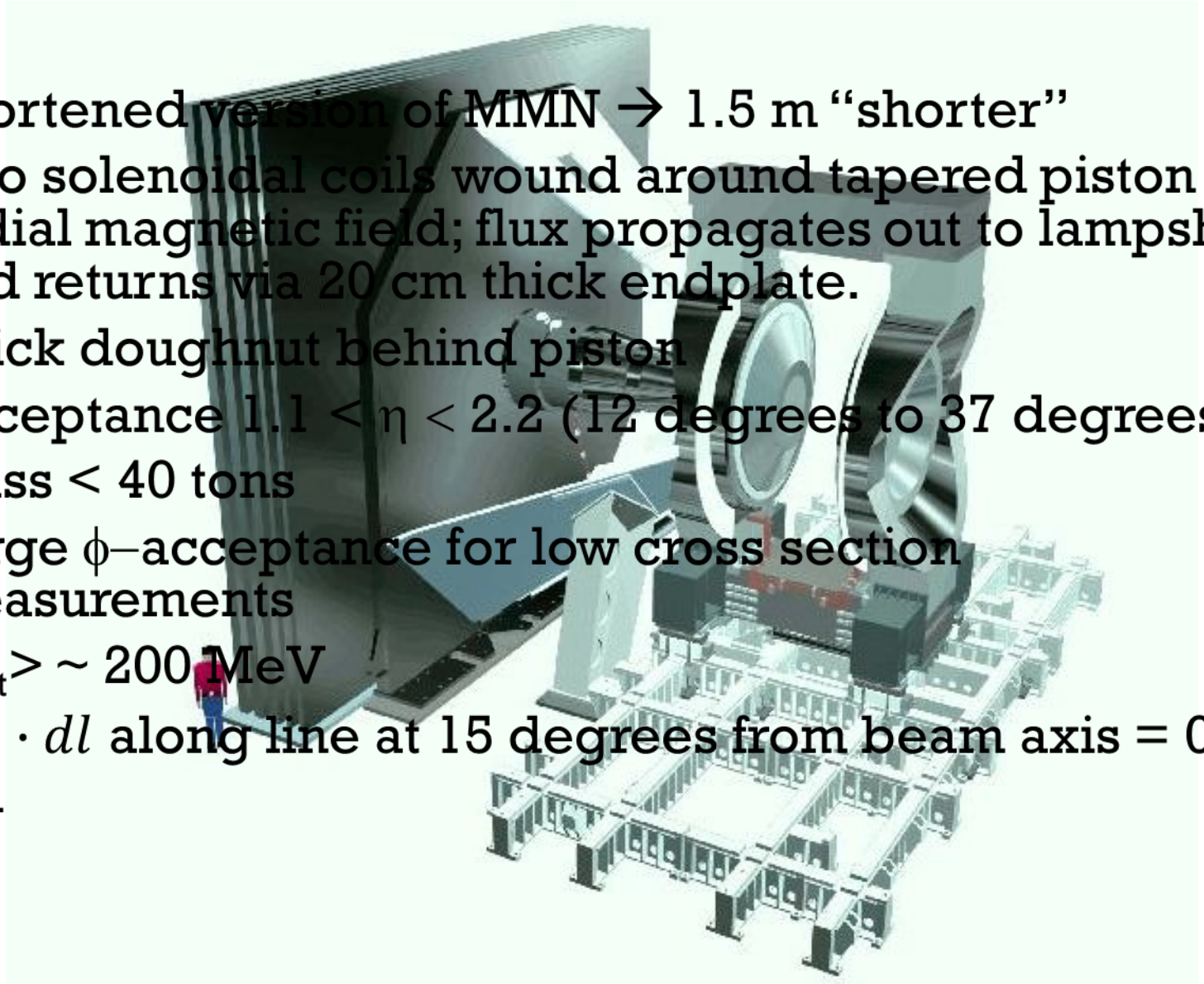
Magnetic field lines with the outer Central Magnet coil energized

PHENIX – FORWARD MAGNET NORTH MMN



- Two solenoidal coils wound around tapered piston → radial magnetic field; flux propagates out to lampshade and returns via 30 cm thick endplate.
- Ten 10 meters tall, mass > 400 tons
- Acceptance $1.1 < \eta < 2.4$ (10 degrees to 37 degrees)
- Large ϕ–acceptance for low cross section measurements
- $\langle p_t \rangle \sim 200$ MeV
- $\int B \cdot dl$ along line at 15 degrees from beam axis = 0.72 Tm
- MMN spectrometer → sufficient resolution to resolve the ψ' from the J/ ψ and the Υ(1S) from the Υ(2S+3S)
- MMN piston notched to hide frames of muon tracking chambers

PHENIX – FORWARD MAGNET SOUTH MMS

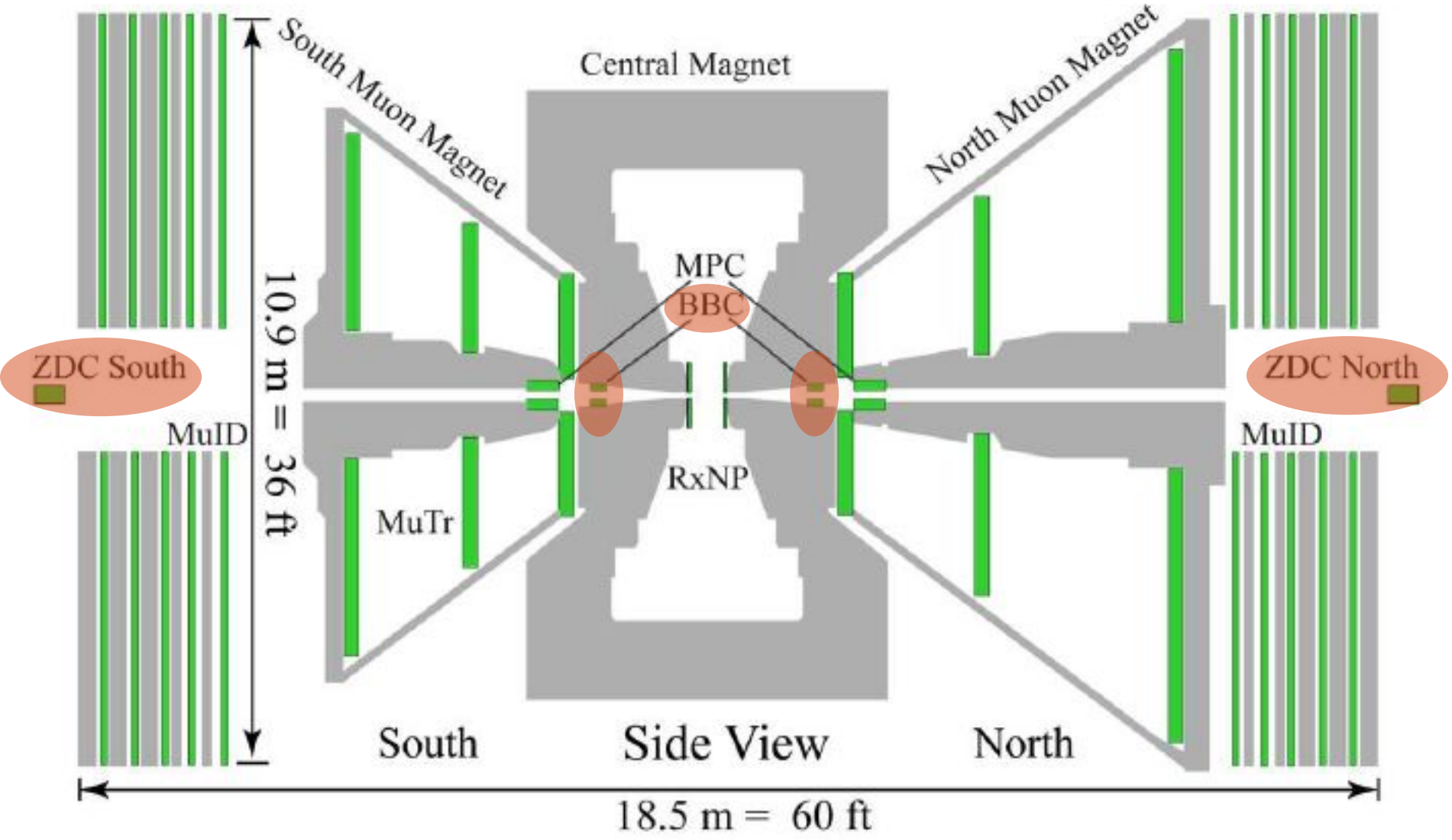


- Shortened version of MMN → 1.5 m "shorter"
- Two solenoidal coils wound around tapered piston → radial magnetic field; flux propagates out to lampshade and returns via 20 cm thick endplate.
- Thick doughnut behind piston
- Acceptance $1.1 < \eta < 2.2$ (12 degrees to 37 degrees)
- Mass < 40 tons
- Large ϕ–acceptance for low cross section measurements
- $\langle p_t \rangle \sim 200$ MeV
- $\int B \cdot dl$ along line at 15 degrees from beam axis = 0.75 Tm

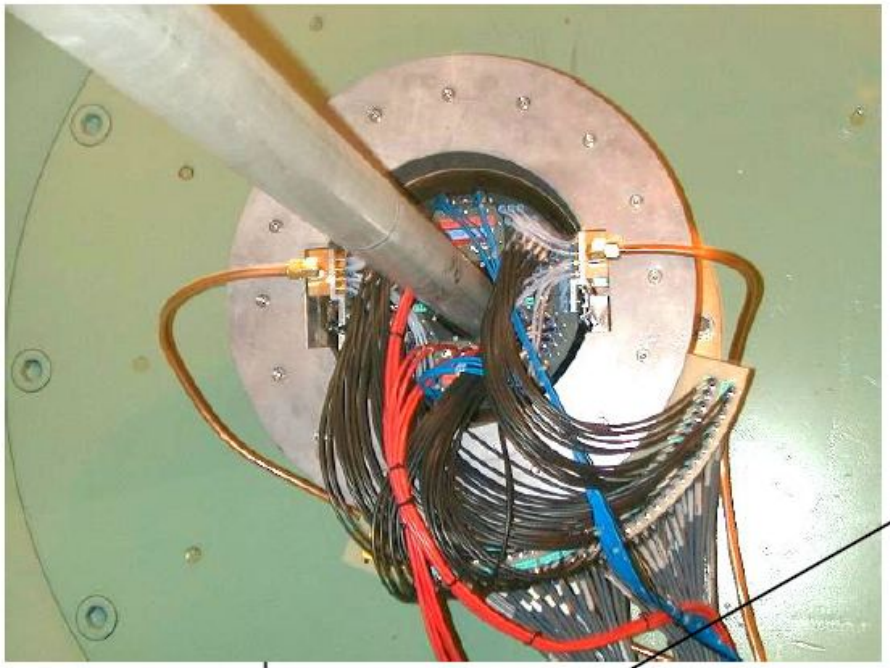
PHENIX – CENTRAL MAGNET CM

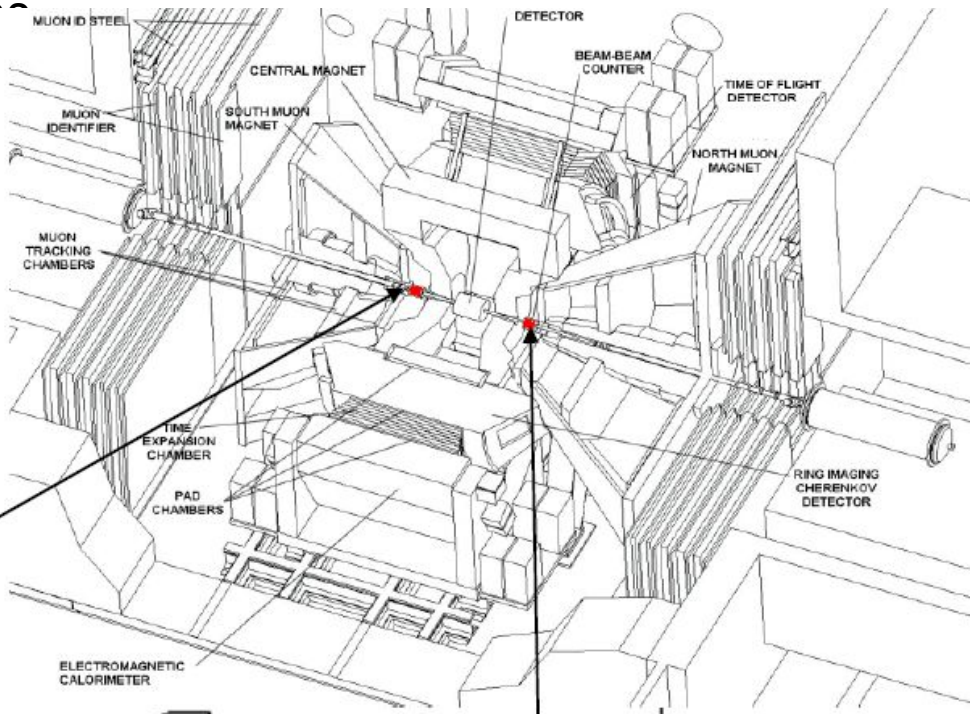
- Axial field magnet energized by two pairs of concentric coils, can be run separately, together, or in opposition configuration
- 9 meters tall, mass ~ 500 tons
- $|\eta| < 0.35$
- $\int B \cdot dl = 0.78$ Tm at $\eta = 0$
- Single particle resolution < 1% for 200 MeV/c < p_t < 1 GeV/c
- Magnetic field low in active volume of RICH → minimize distortion of particle tracks → $\int B \cdot dl = 10^{-2}$ Tm for 2.4 m < r < 4.0 m
- $B_{total} <= 2 \times 10^{-2}$ T near RICH phototubes
- $B_{total} <= 10^{-3}$ T near EM Cal phototubes
- Pole faces serve as primary absorber of hadrons for the Muon arm spectrometers
- Neutron and gamma ray absorbers attached to CM

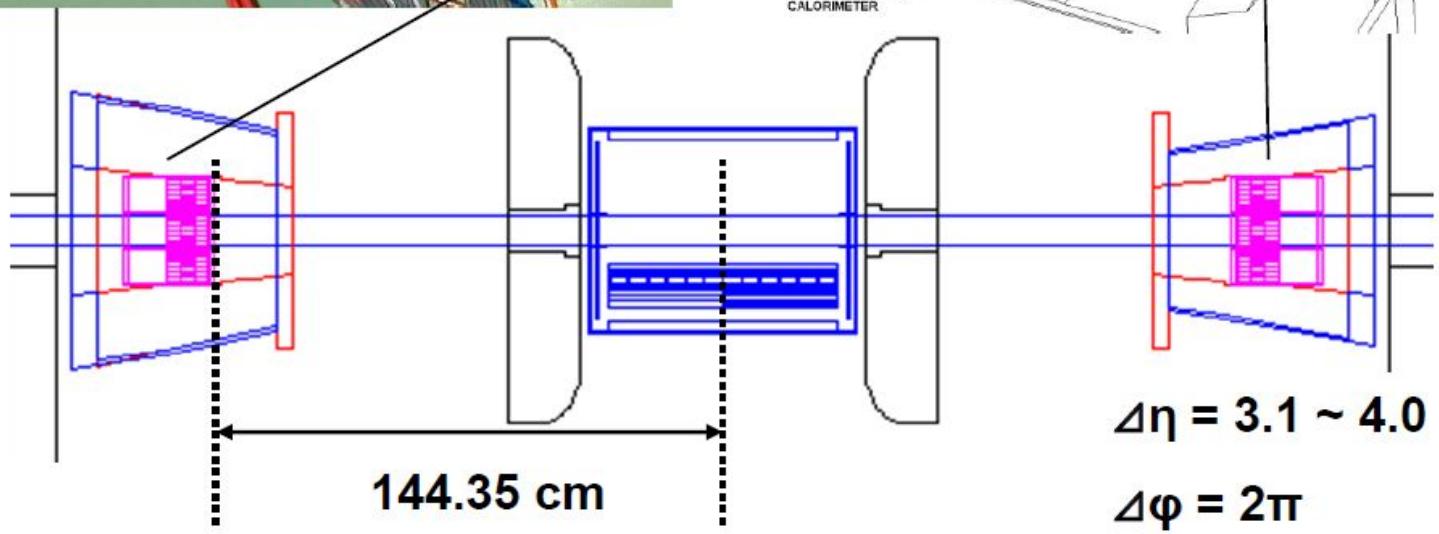
PHENIX – GLOBAL DETECTORS



PHENIX – BEAM-BEAM COUNTER BBC

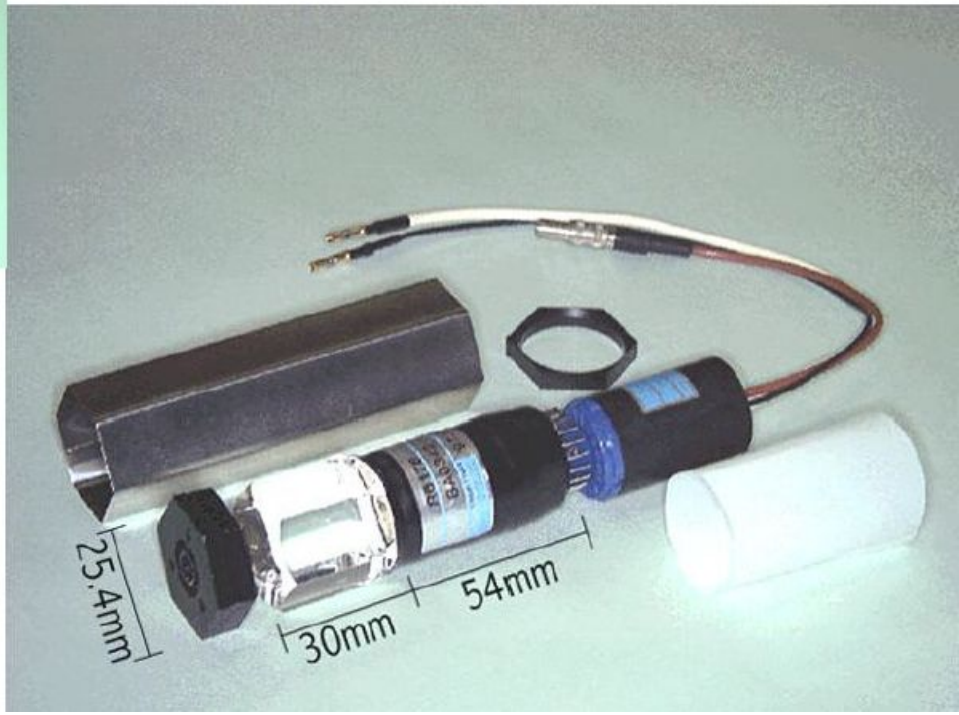






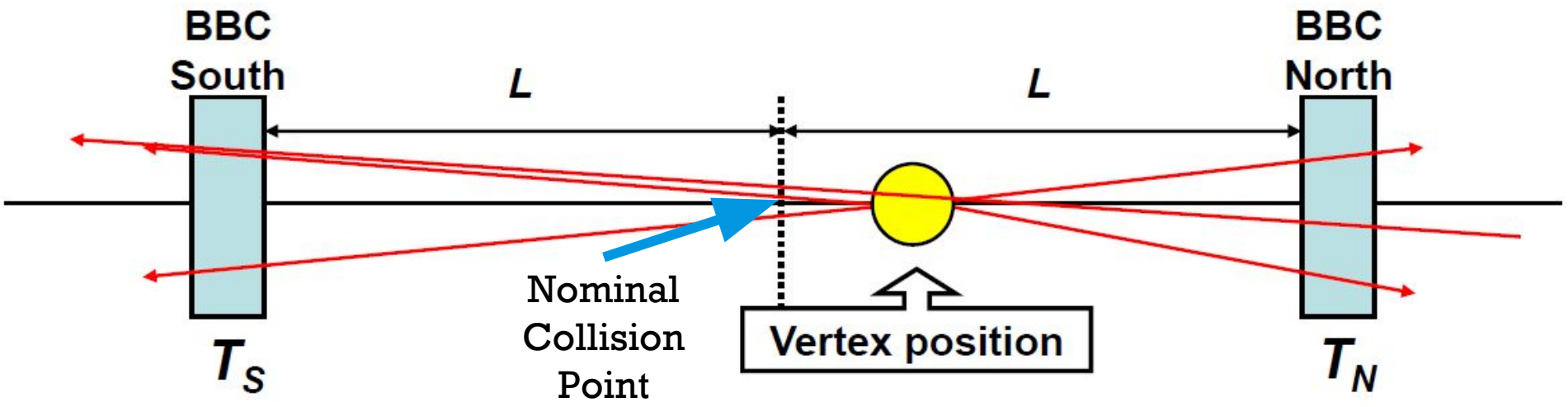
PHENIX – BBC

BBC has 64 elements for North and South arm.



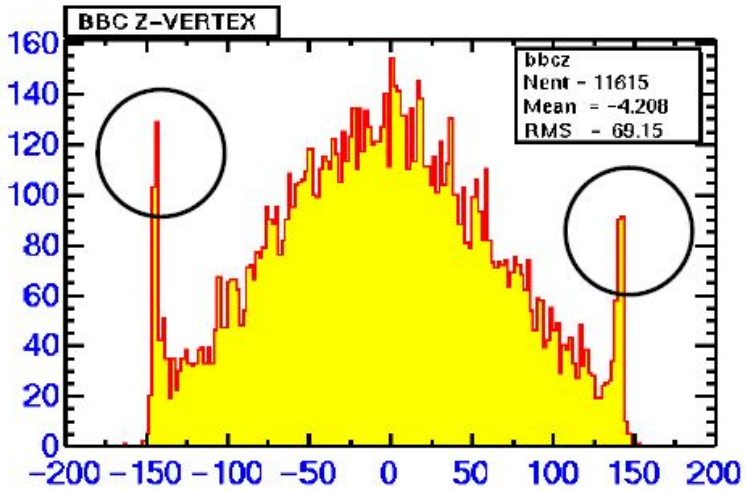
Each element consists of quartz Cherenkov radiator and meshed dynode PMT.

PHENIX – BBC



$$\textbf{Z-Vertex} = \frac{T_S - T_N}{2} \times c$$

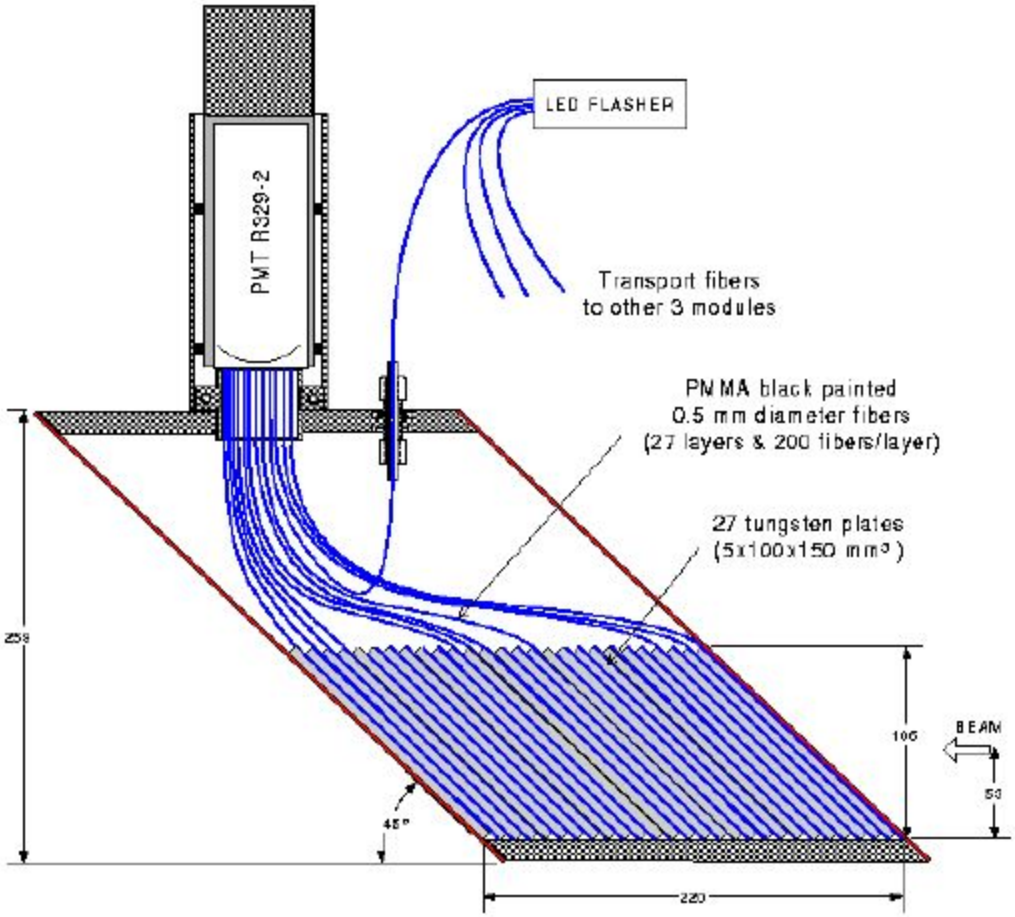
$$\textbf{Time zero} = \frac{T_S + T_N - 2L/c}{2}$$



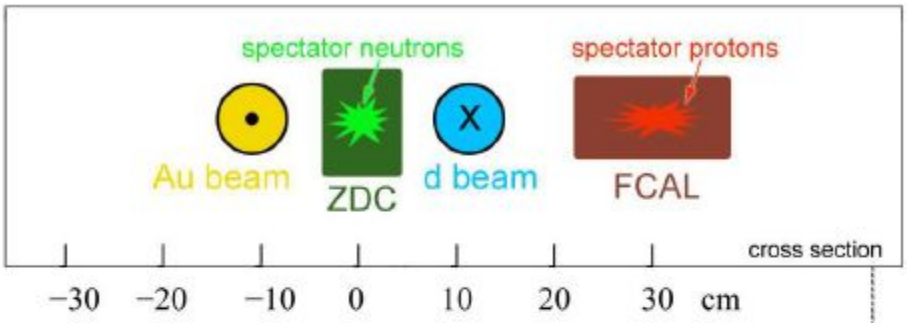
$T_{N/S}$: average hit time, c : light velocity, L : 144.35 cm

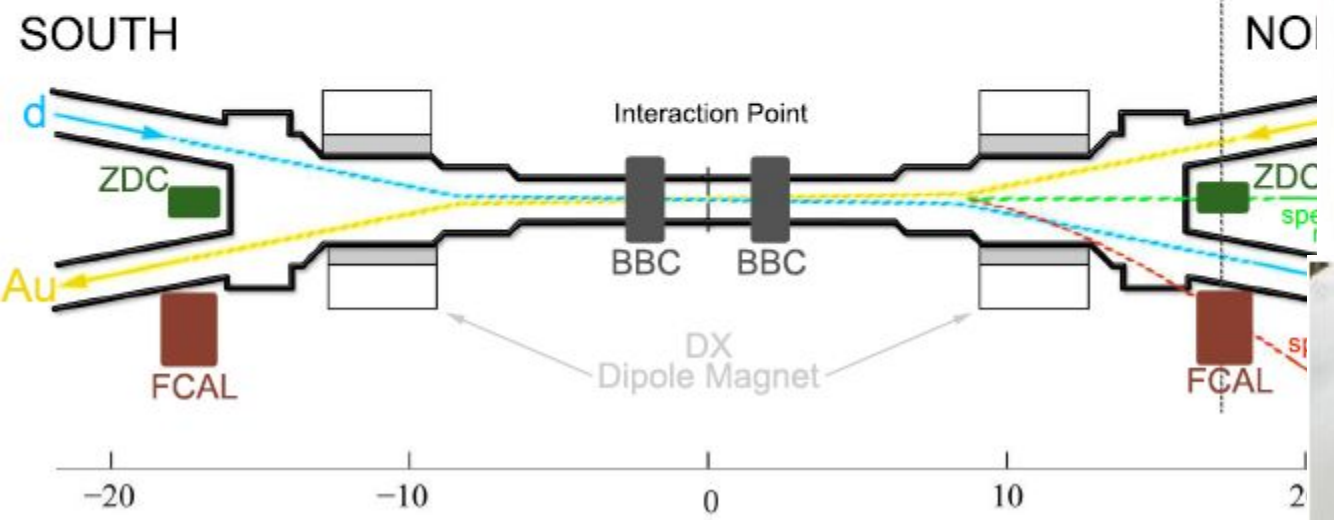
PHENIX – ZERO DEGREE CALORIMETER ZDC

- Small transverse area hadronic calorimeters
- Measure <u>neutral</u> energy within a 2 mrad cone about the beam direction
  - Charged particles are swept away by DX magnets
- Three Cherenkov sampling Tungsten plate modules per ZDC read out by one PMT
- Common to all RHIC experiments



PHENIX – ZDC


spectator neutrons
spectator protons
Au beam
ZDC
d beam
FCAL
cross section
−30 −20 −10 0 10 20 30 cm


SOUTH
NO
d
Interaction Point
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BBC
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FCAL
DX
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FCAL
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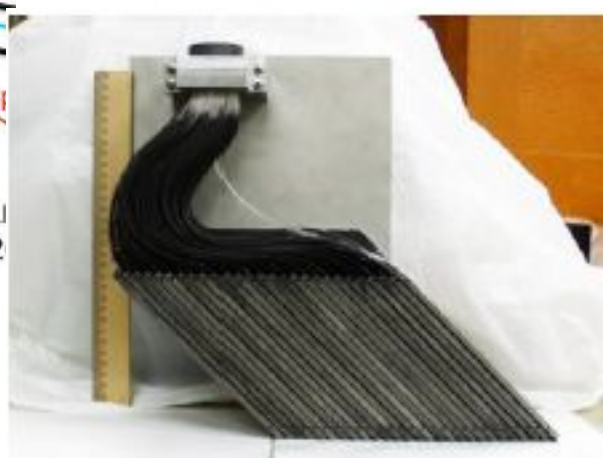
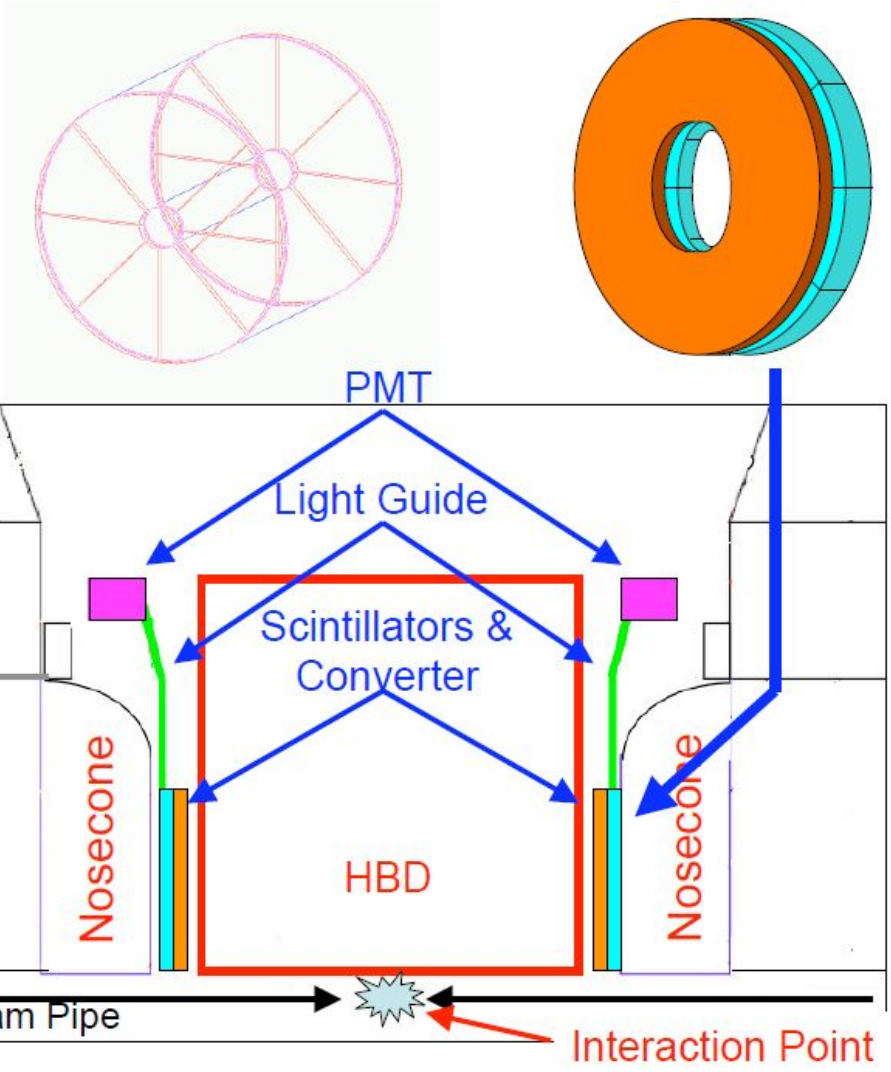


PHENIX – REACTION PLANE DETECTOR RXNP

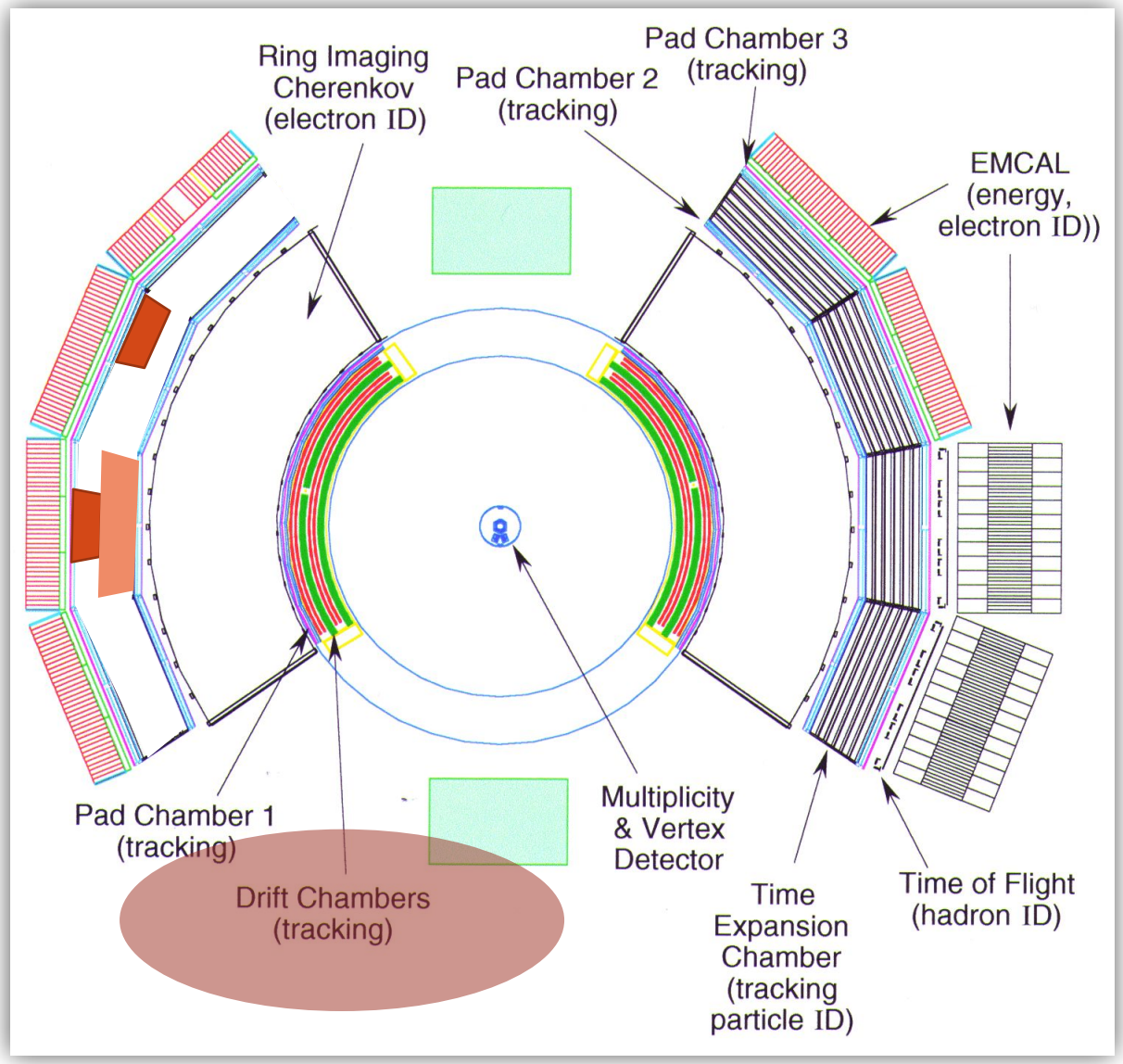
- Determines reaction plane
  - Plastic scintillators
  - Converter material in front of scintillator
  - Lightguides
  - Photo-multiplier tubes PMT



PHENIX – RXNP

- **Plastic scintillator (2 cm thickness)**
  - **Particle passes through and forces electrons into excited states**
  - **Excited electrons returns to ground state by emitting photons fluorescence**
- **Converter materials (2 cm thick Pb)**
  - **Triggers addt'l electrons to be passing through scintillator**
- **12 φ-segments**
- **2 η-segments**

PHENIX – CENTRAL DRIFT CHAMBER DC



PHENIX – DC

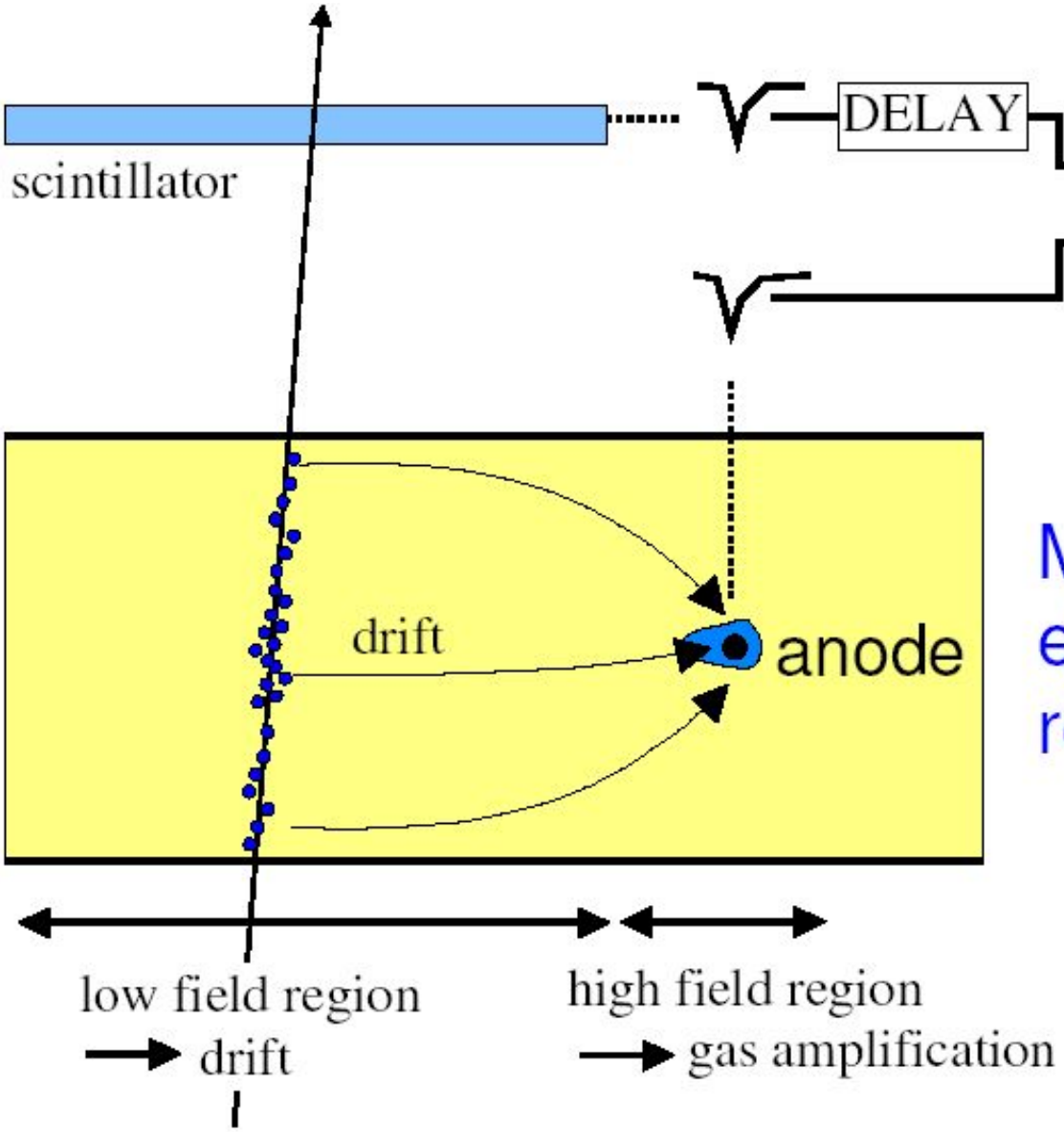
Drift Chamber

PHENIX – DC

- Gas ionization due to charged particle leads to electron clouds that drift along electric field lines
- Position measurement of track points
- Requirements:
  - Visible signal readout → gas amplification at wire
  - Measurement of drift time → constant drift velocity
  - Known position of readout

$$X = X(t) = V_{drift} \cdot t \rightarrow \text{refers back to creation of track point}$$

PHENIX – DC



Measure arrival time of electrons at sense wire relative to a time t_0.

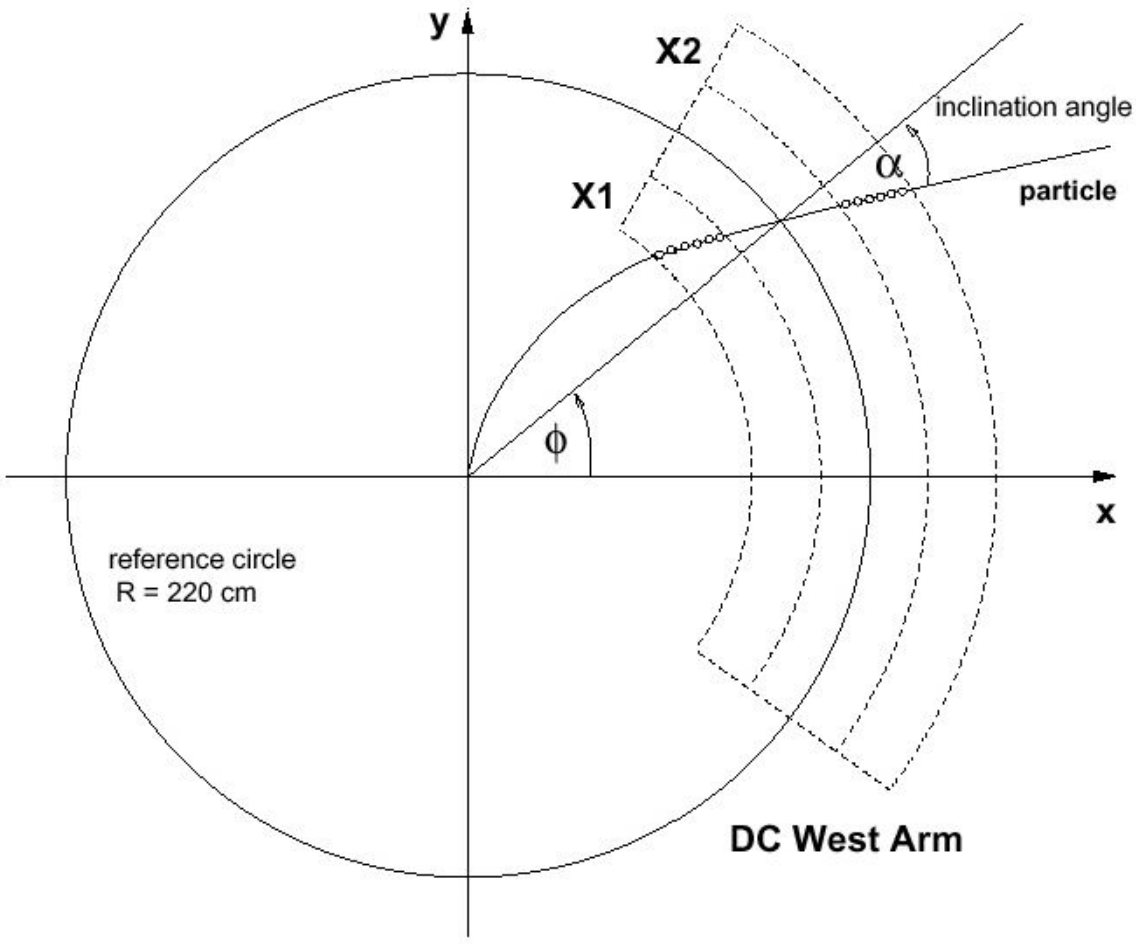
PHENIX – DC

- Provide high resolution p_t measurement
- Participate in pattern recognition due to high particle track densities

  - Spatial resolution requirements
    - R-φ position (single wire) better than 150 μm
    - Z position better than 2 mm
  - Other requirements
    - Two track separation better than 1.5 mm
    - High efficiency

PHENIX – DC

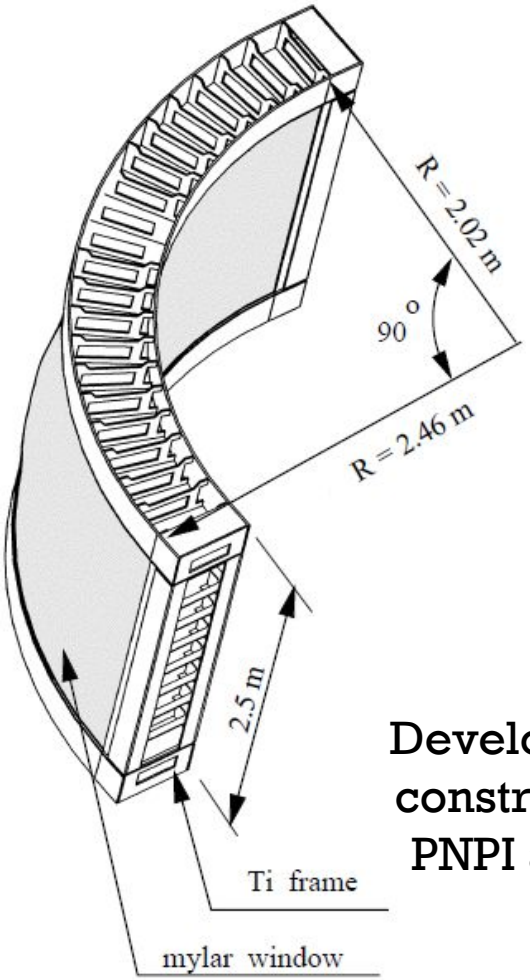
- Track determinati
  - No magnetic field ir DC (only small residual)
    - Straight track sectic in DC
    - Determine α and φ
    - Perform Hough transform: calculate (α−φ)-combinations from hits and bin them, search for maxima thereafter



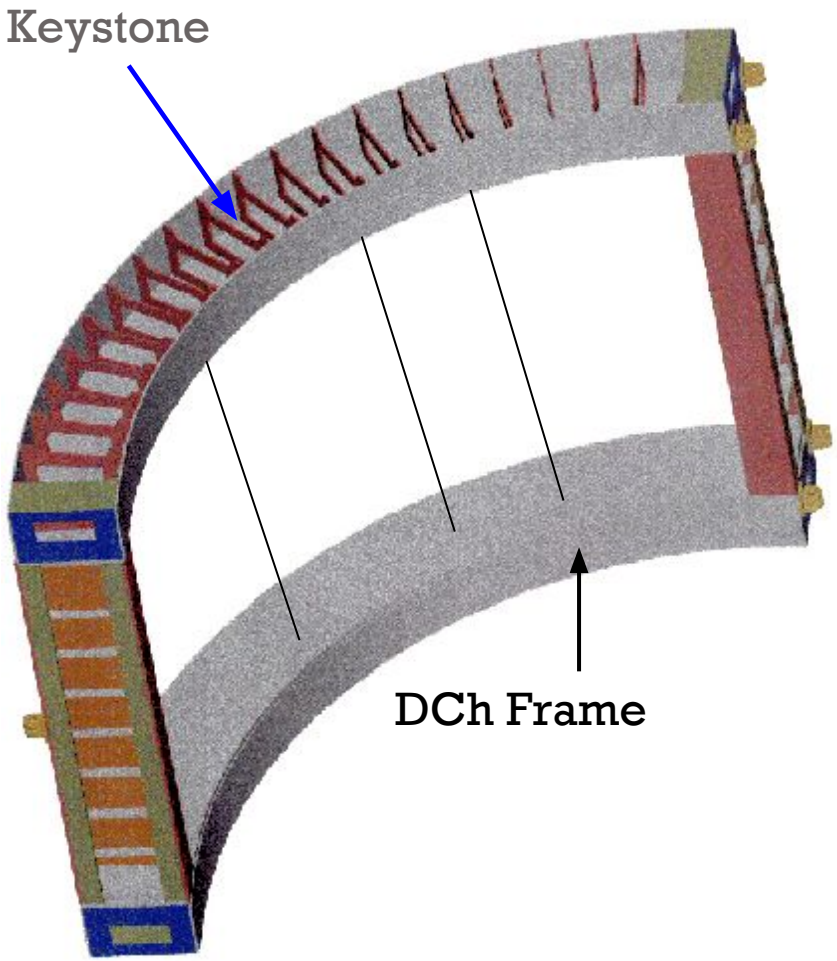
PHENIX – DC

- Some geometrical figures
  - Acceptance:
    - 90° in φ, each for West and East
    - 1800 mm along beam-axis, i.e. ±900 mm around IP
    - $|\eta| < 0.35$
    - West: $-34° < \varphi < 56°$; East: $125° < \varphi < 215°$, i.e. 11° tilted ↑
  - Dimensions
    - Inner radius: 2020 mm
    - Outer radius: 2460 mm
    - Length: 2500 mm
    - Volume ≈ 12 m^3 = 12,000 l per arm

PHENIX – DC

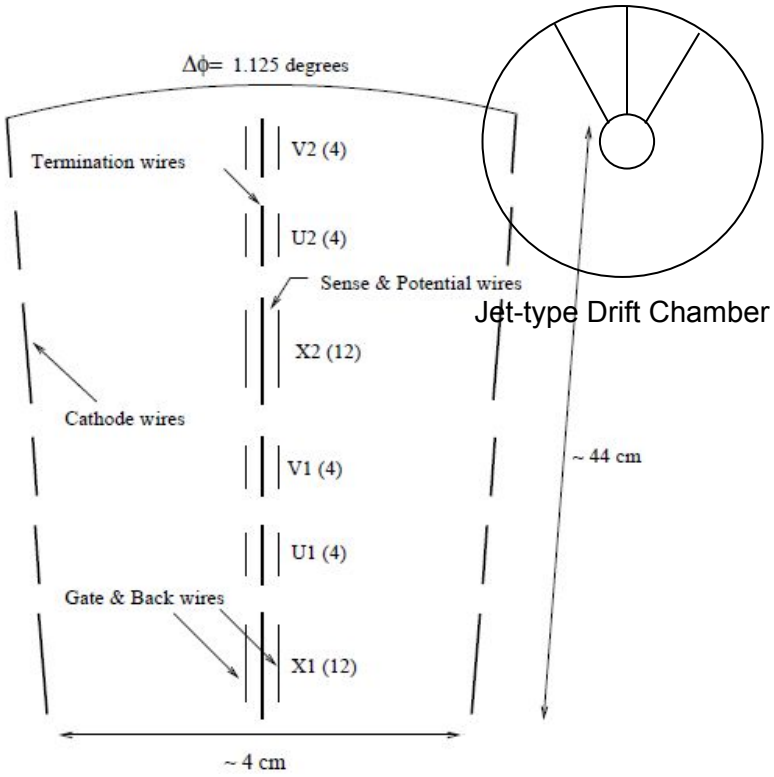


Developed and constructed by PNPI and SBU



PHENIX – DC

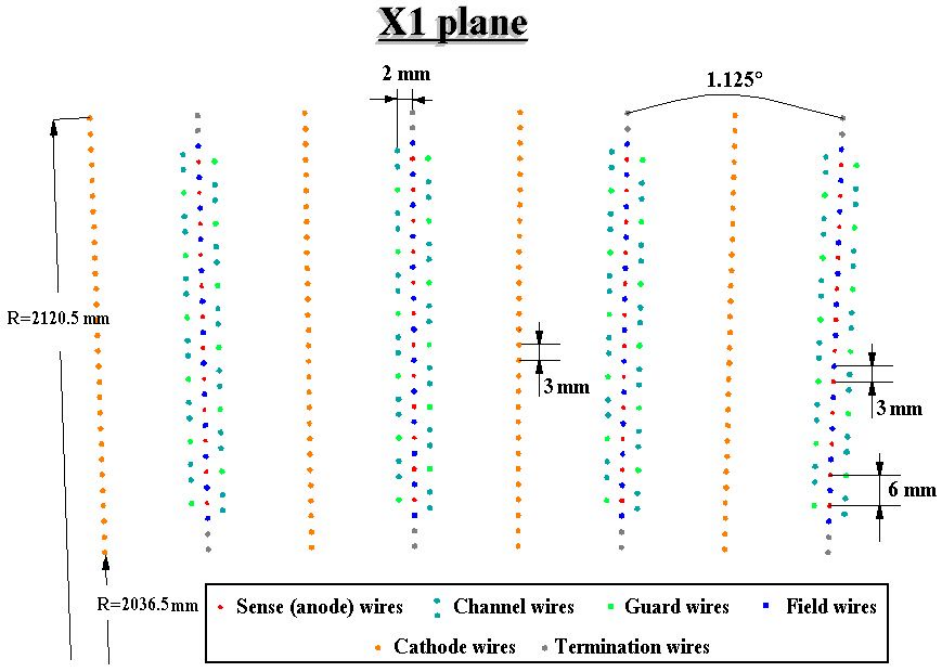
- Design of Drift Chamber (DCh)
  - Multi-wire drift chamber, jet-type with 6.4k anode wires and 12.8k readout channels
  - Six radial layers of wires
    - X1, U1, V1, X2, U2,V2

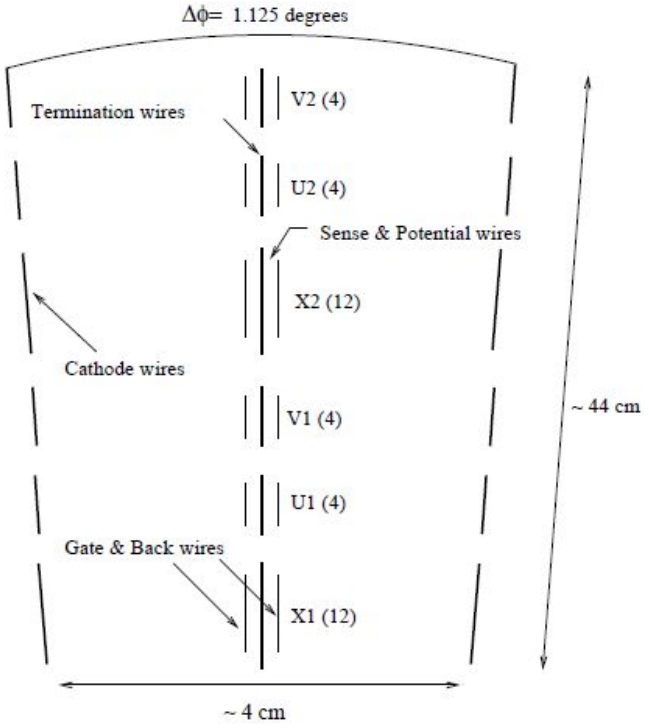


Jet-type Drift Chamber

PHENIX – DC

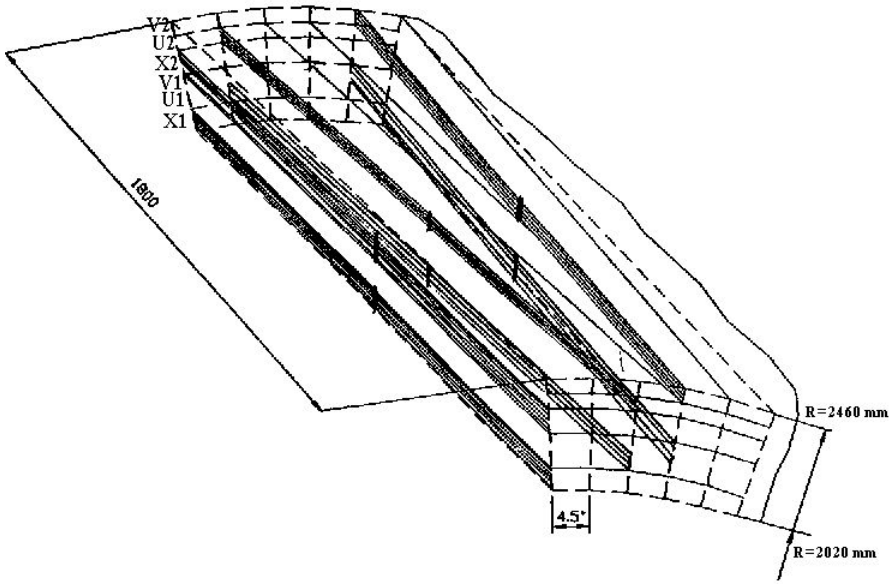
- X-layers: measure radial-azimuthal coordinate of track
  - Twelve anode wires per layer
- U-/V-layers: stereo layers, measure z-coordinate of track
  - Four anode wires per layer

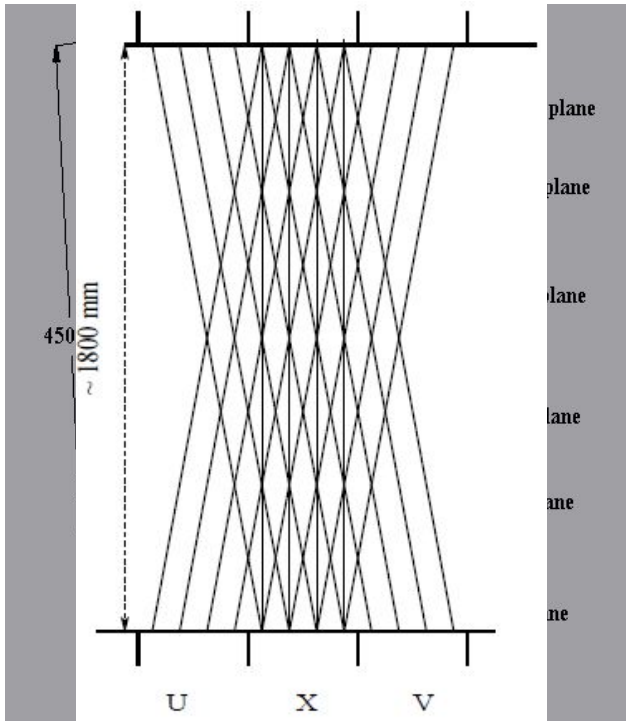




PHENIX – DC

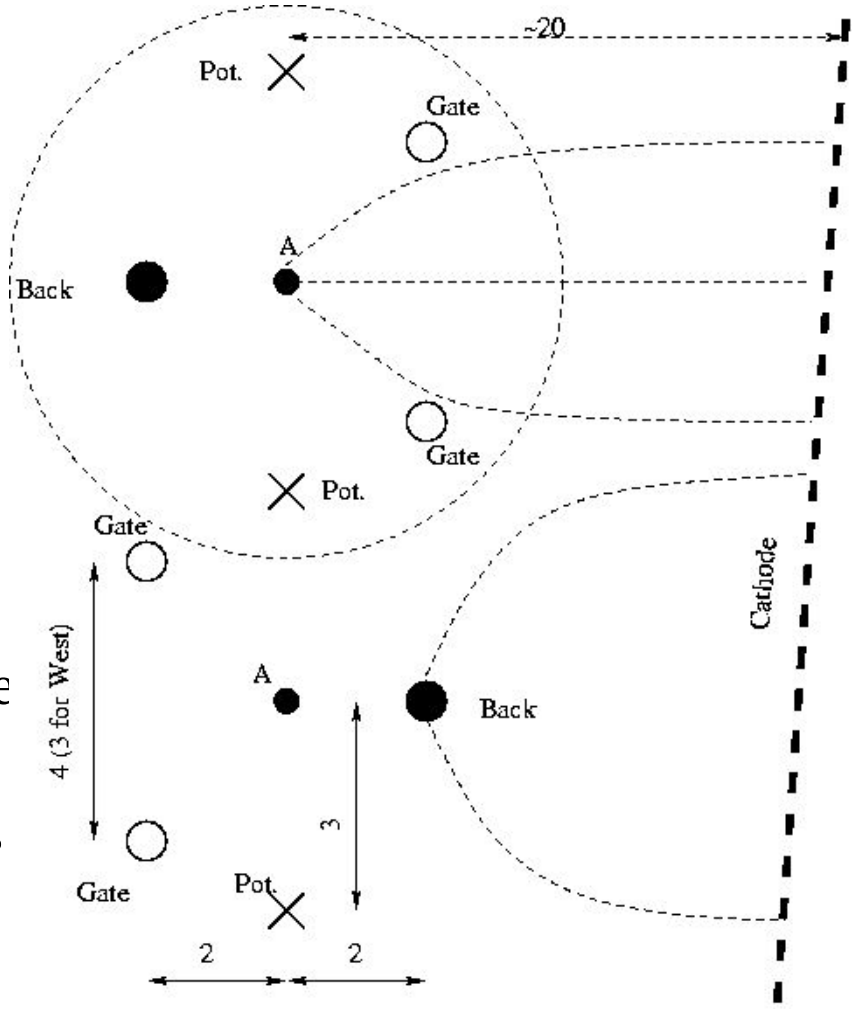
- 20 keystones per arm, 80 layers per arm
- Four *times* six layers per keystone, U/V layers start in one keystone and end in the neighboring (6° relative to X) → stereo measurement



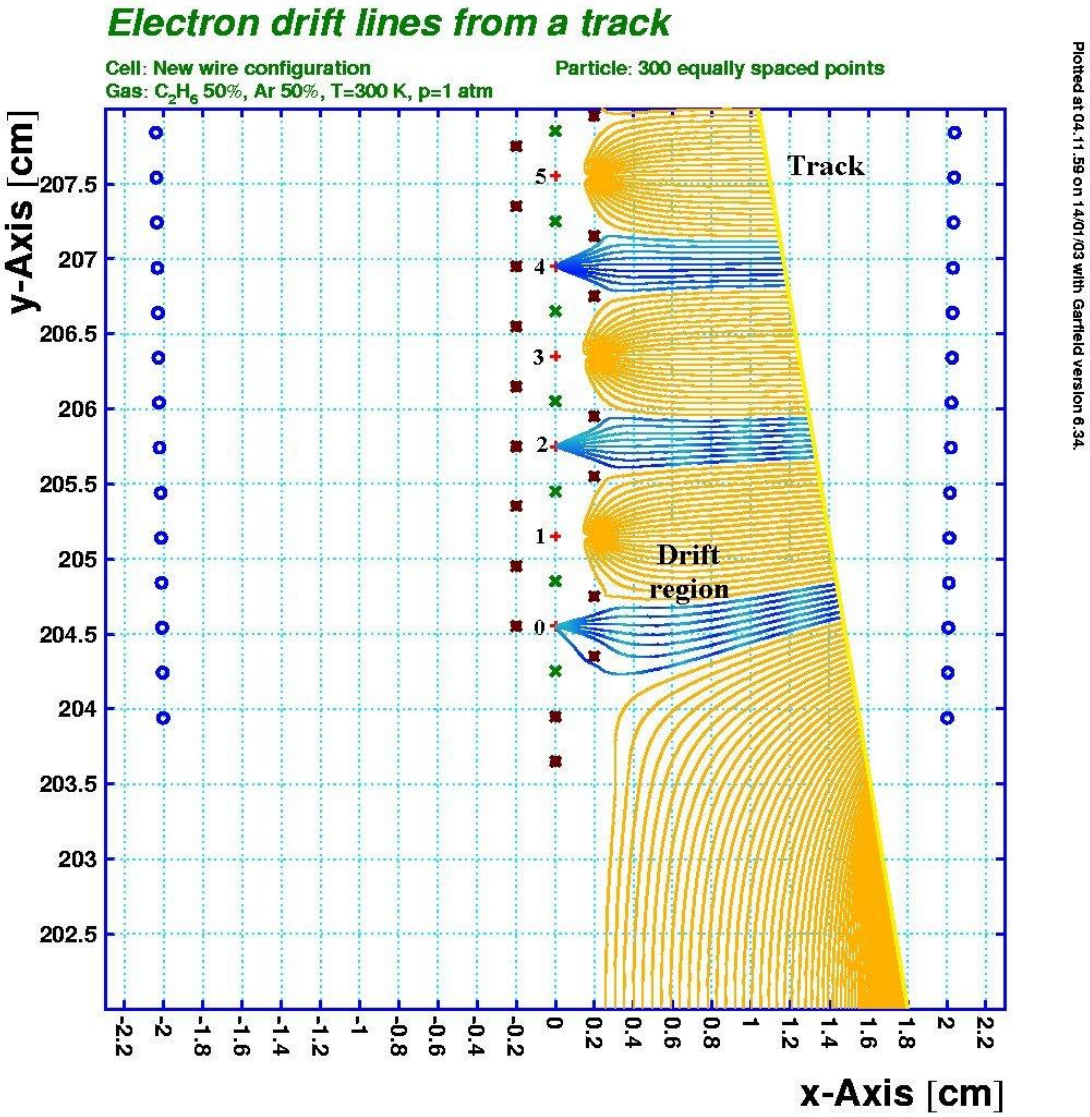


PHENIX – DC

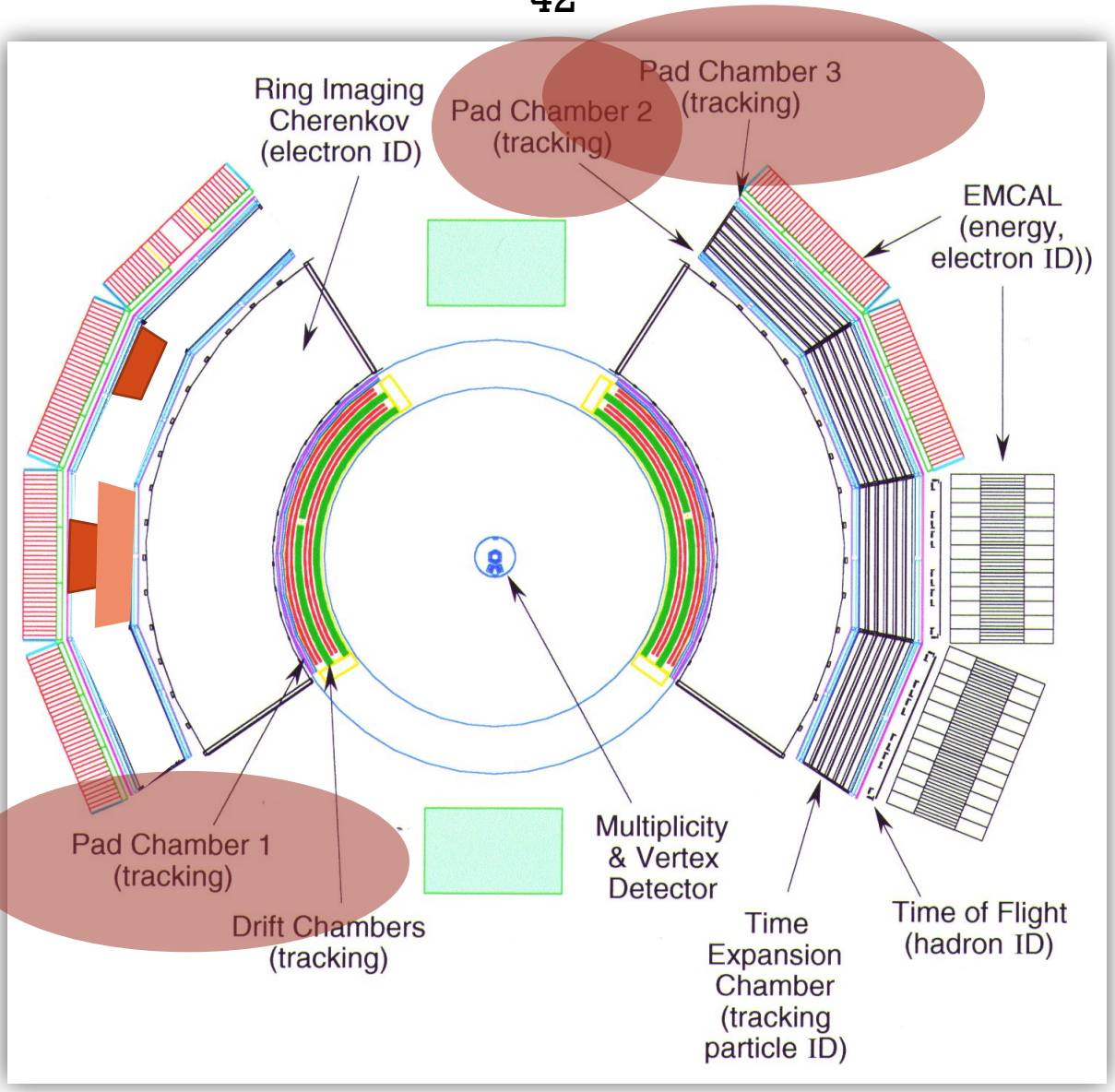
- Field forming wires
  - Potential wires, form strong electric fields and separate sensitive regions of individual anode wires; surrounded by:
  - Gate wires: limits track sample length to 3 mm and terminate unwanted drift lines
  - Back wires: terminates most of the drift lines from its side, thus eliminating left-right ambiguities and increasing signal rate



PHENIX – DC


Electron drift lines from a track
Cell: New wire configuration
Gas: C2H6 50%, Ar 50%, T=300 K, p=1 atm
Particle: 300 equally spaced points
Track
Drift region
0
1
2
3
4
5
y-Axis [cm]
x-Axis [cm]
Plotted at 04.11.59 on 14/01/03 with Garfield version 6.34.

PHENIX – PAD CHAMBER PC



PHENIX – PC

- PC1/PC2 (only West Arm)/PC3 □ three independent layers of Multi Wire Proportional Chamber MWPC
  - Each layer □ three planes sandwich structure
  - Two cathode planes, one wire plane
  - Cathode plane 1: solid
  - Cathode plane 2: pixelated
  - Three pixels define a cell □ interleaved
  - Interleaved pixels are chained in 9 x 9 blocks □ one electronics channel

Excursion: Proportional Counter to MWPC

- Space localization capability is limited

  $\Rightarrow$ determination of a particle, that has or has not traversed the counter's volume

- Stacking of many independent counters possible, but not very attractive of the mechanically point of view

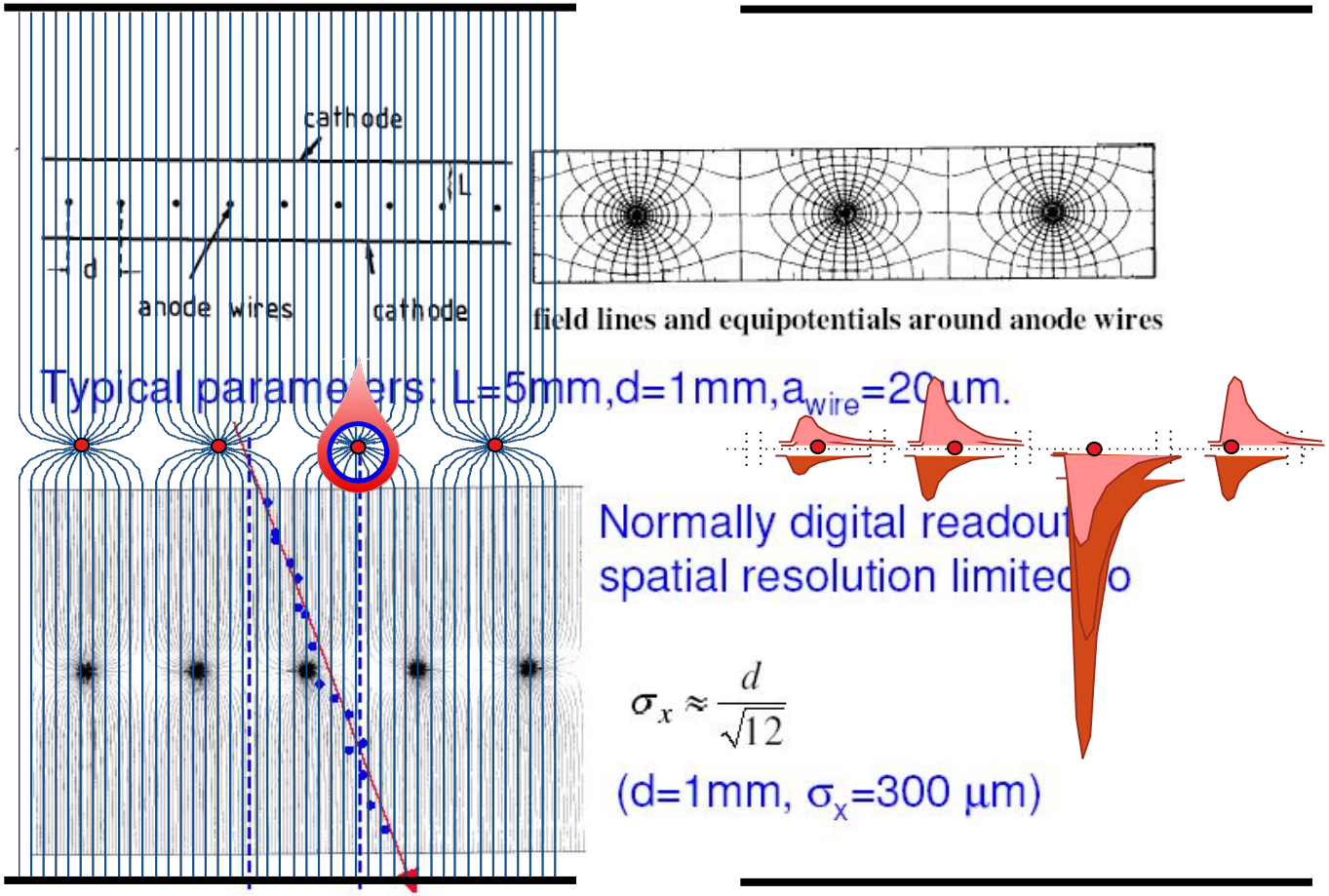
- Idea: multiwire structures $\Rightarrow$ but large capacitances between wires would cause signal to spread

PHENIX – PC

MWPC

Solution by G. Charpak (1968):

positive induced signal largely compensates negative signal



PHENIX – PC

The Nobel Prize in Physics 1992

The Royal Swedish Academy of Sciences awards the 1992 Nobel Prize in Physics to **Georges Charpak** for his invention and development of particle detectors, in particular the multiwire proportional chamber.

Georges Charpak
CERN, Geneva, Switzerland

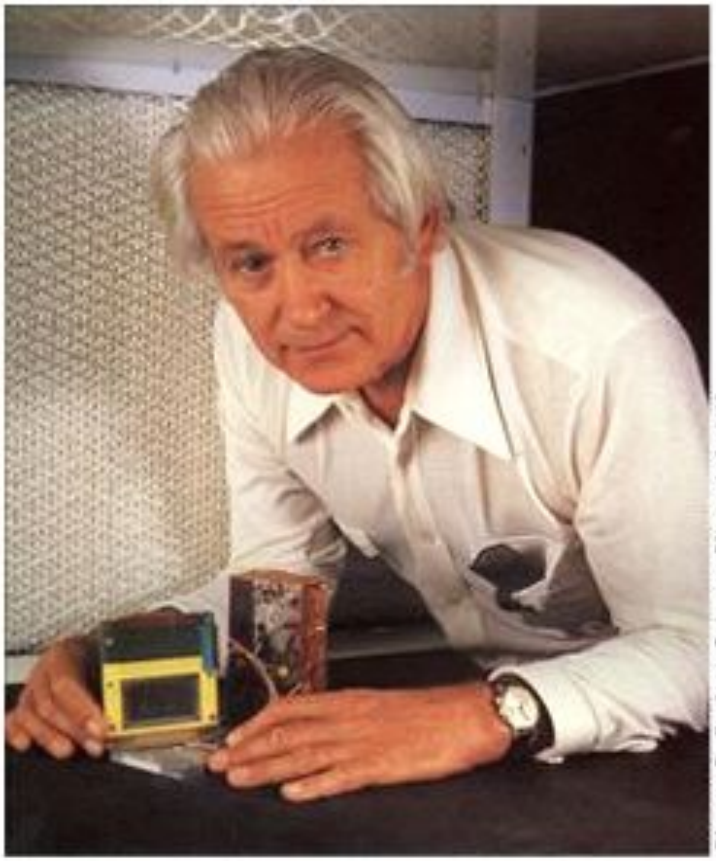
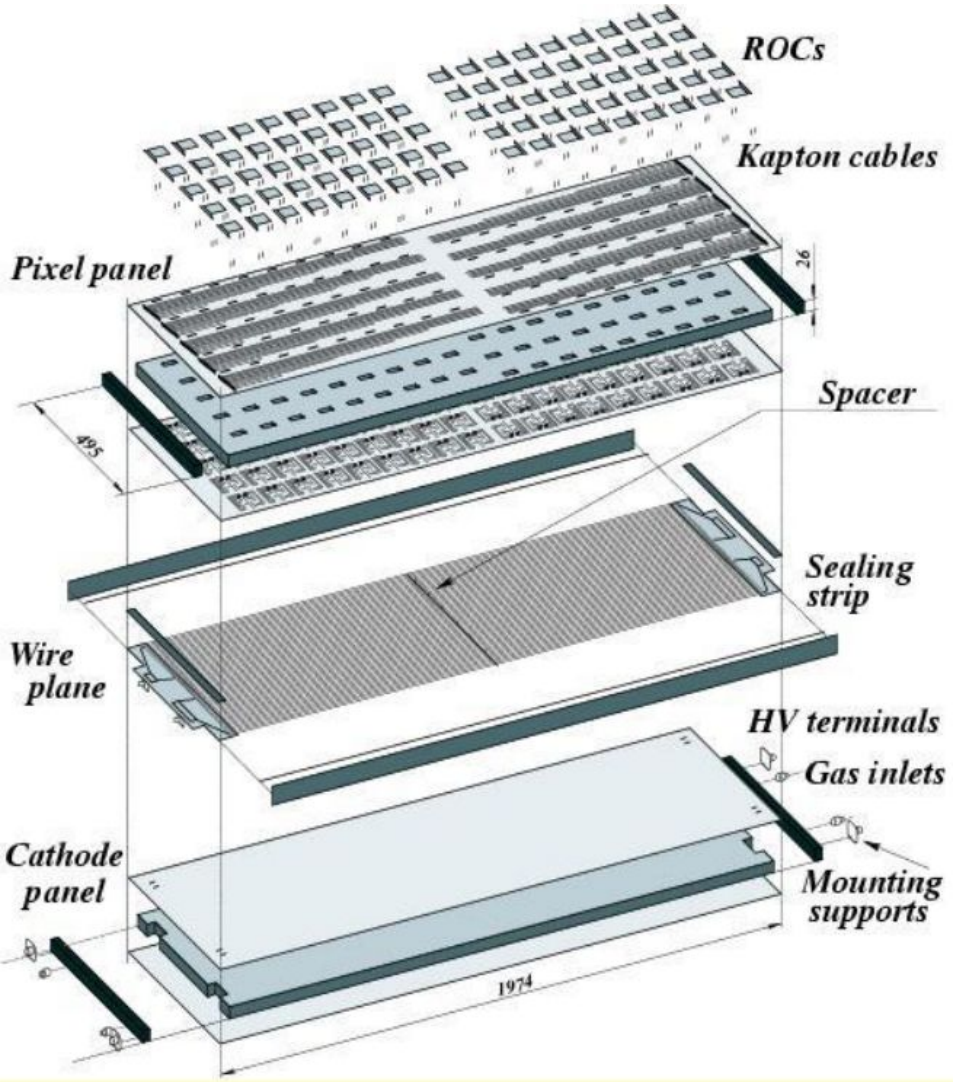


Photo: D. Parker, Science Photo Lab, UK

PHENIX – PC

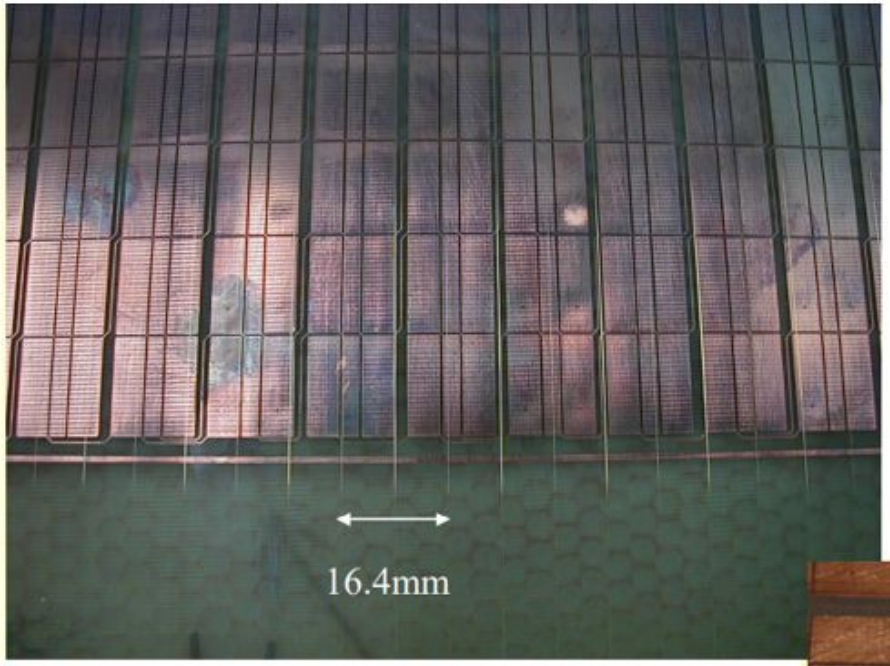
- The role in PHENIX
  - Straight line tracking
  - Z-coordinate from PC1
  - Pattern recognition in 3-D
  - Track verification through central arm for safe PID
  - Charged particle veto in front of Ecal
  - Lvl2 trigger: entrance/exit points for RICH/ECal

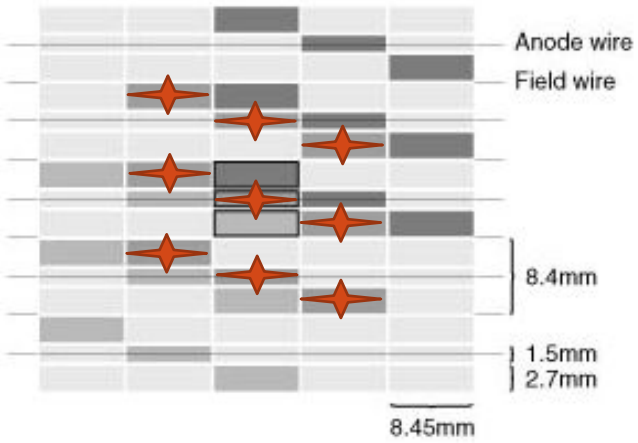
PHENIX – PC

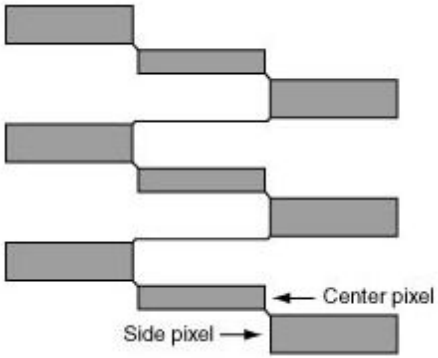


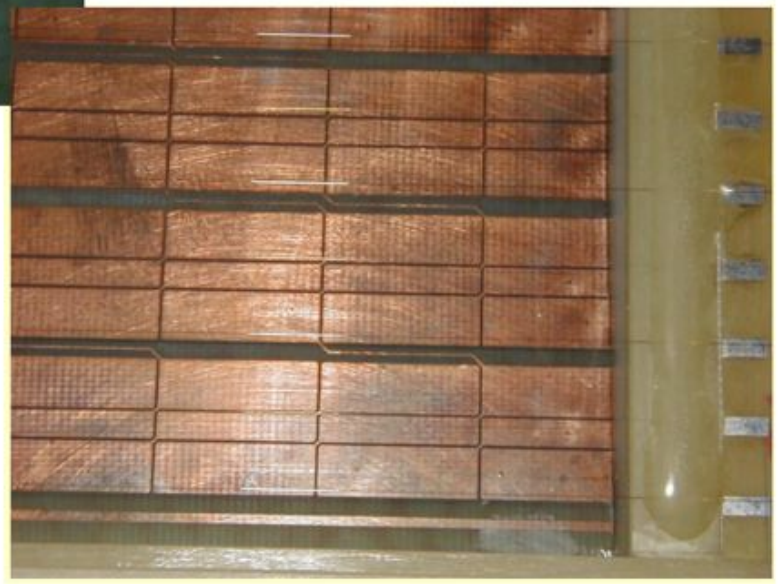
Item	PC1	PC2	PC3
No. of sectors/arm	8	4	4
No. of anode (A) wires	122	238	243
A-wire diameter	20 μm	20 μm	20 μm
A-wire tension	30 g	30 g	30 g
A-A separation	4.0 mm	6.8 mm	7.9 mm
(2·A-Cathode spacing)			
No. of field (F) wires	123	239	244
F-wire diameter	100 μm	100 μm	100 μm
F-wire tension	100 g	100 g	100 g
Chevron width	3.0 mm	5.2 mm	6.3 mm
Ground strip width	0.8 mm	1.4 mm	1.4 mm
Space line width	0.2 mm	0.2 mm	0.2 mm
Active wire length	1777.02 mm	2979.80 mm	3520.85 mm
Panel width	490.0 mm	1619.40 mm	1920.70 mm
Chevron pad length	246.47 mm	417.92 mm	495.20 mm
(apex-apex)			
F value	1.20	1.12	1.10
No. of readout nodes/wire	8	8	8
Readout nodes/panel	976	1904	1944
Readout nodes/arm	7808	7616	7776
Total readout nodes	15,616	15,232	15,552

PHENIX – PC

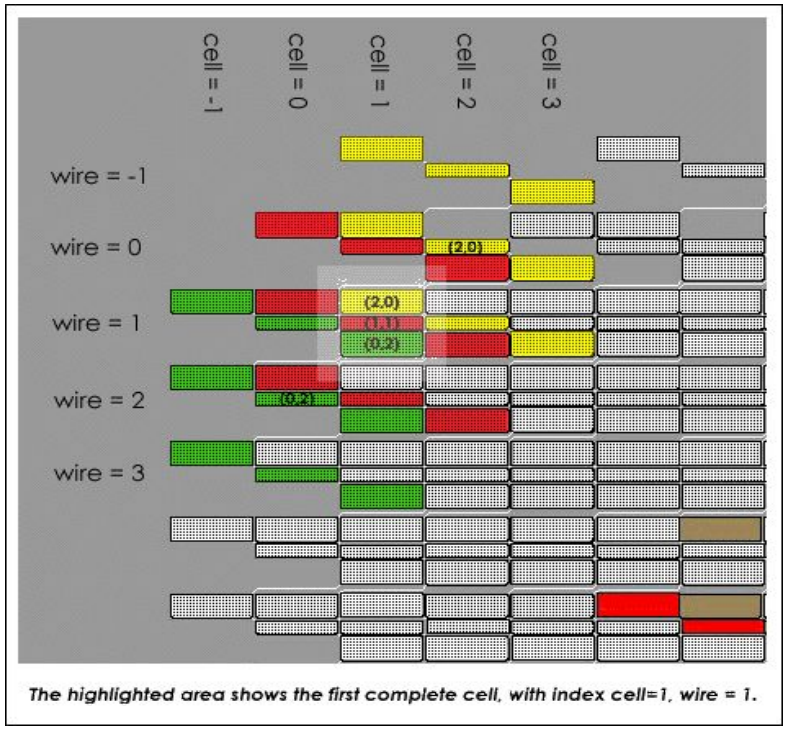

16.4mm


Anode wire
Field wire
8.4mm
1.5mm
2.7mm
8.45mm


Center pixel
Side pixel

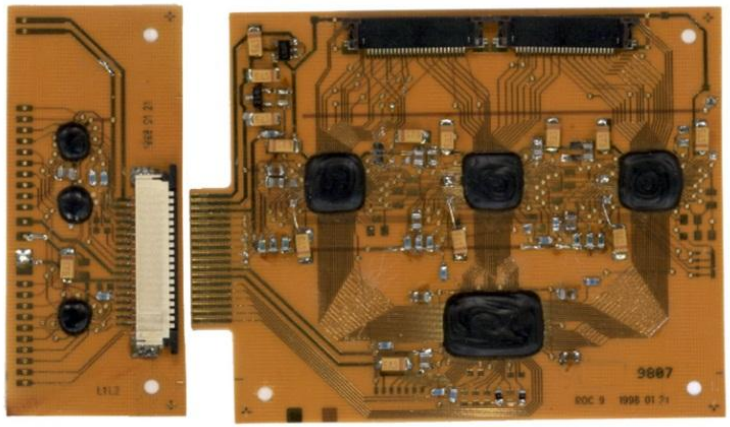


PHENIX – PC



The highlighted area shows the first complete cell, with index cell=1, wire = 1.

PAD CHAMBER READOUT CARD



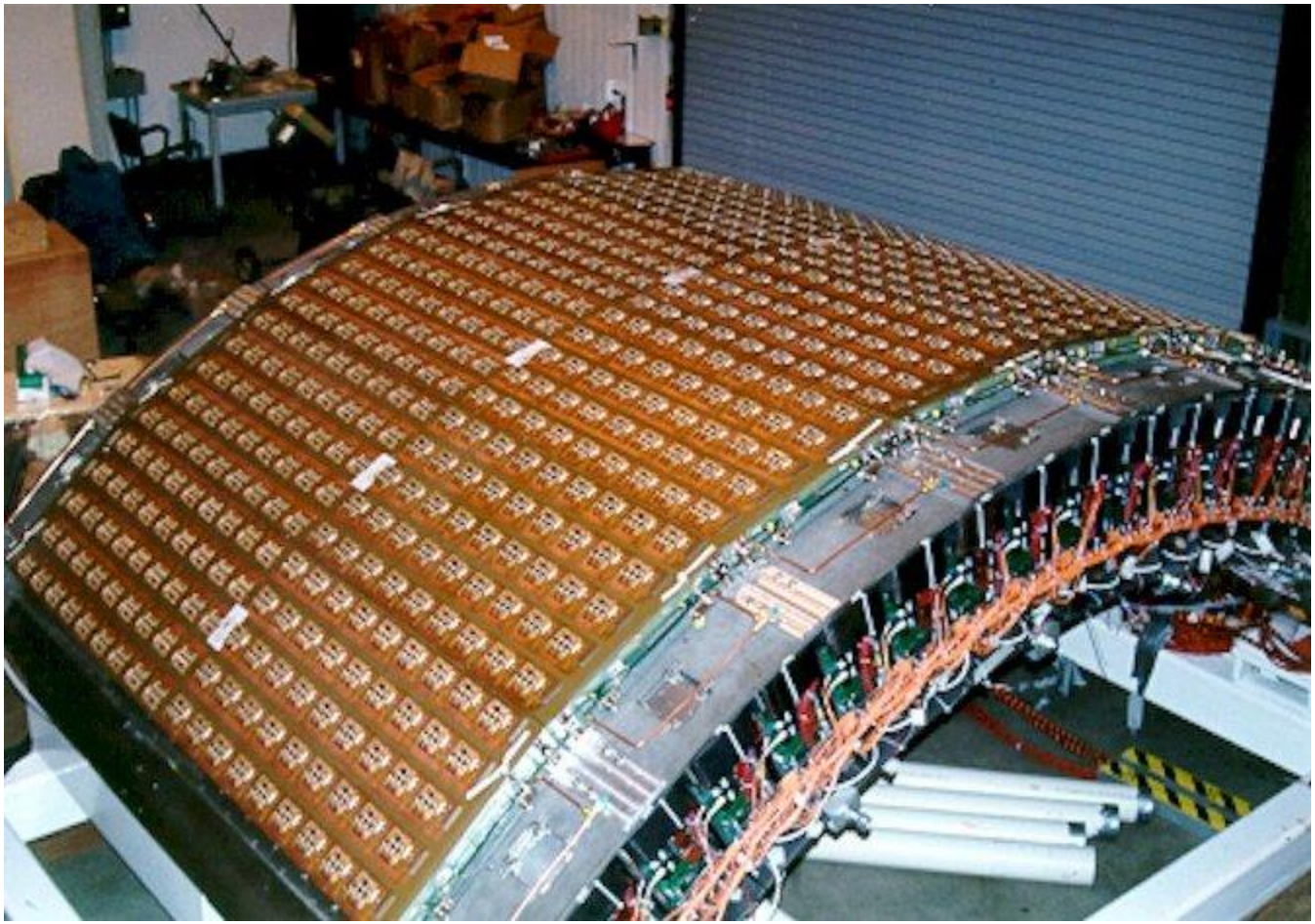
Connector card, solders on chamber.
3 RS485 diff-CMOS translator chips

Readout card, for 48 channels. 3 amplifier/discriminator chips (TGL98) and one Digital Memory chip(DMU). Mounted on 0.1mm fiberglass enforced Kapton. Total weight of whole assembly is 4 grams. Size 55*65mm^2

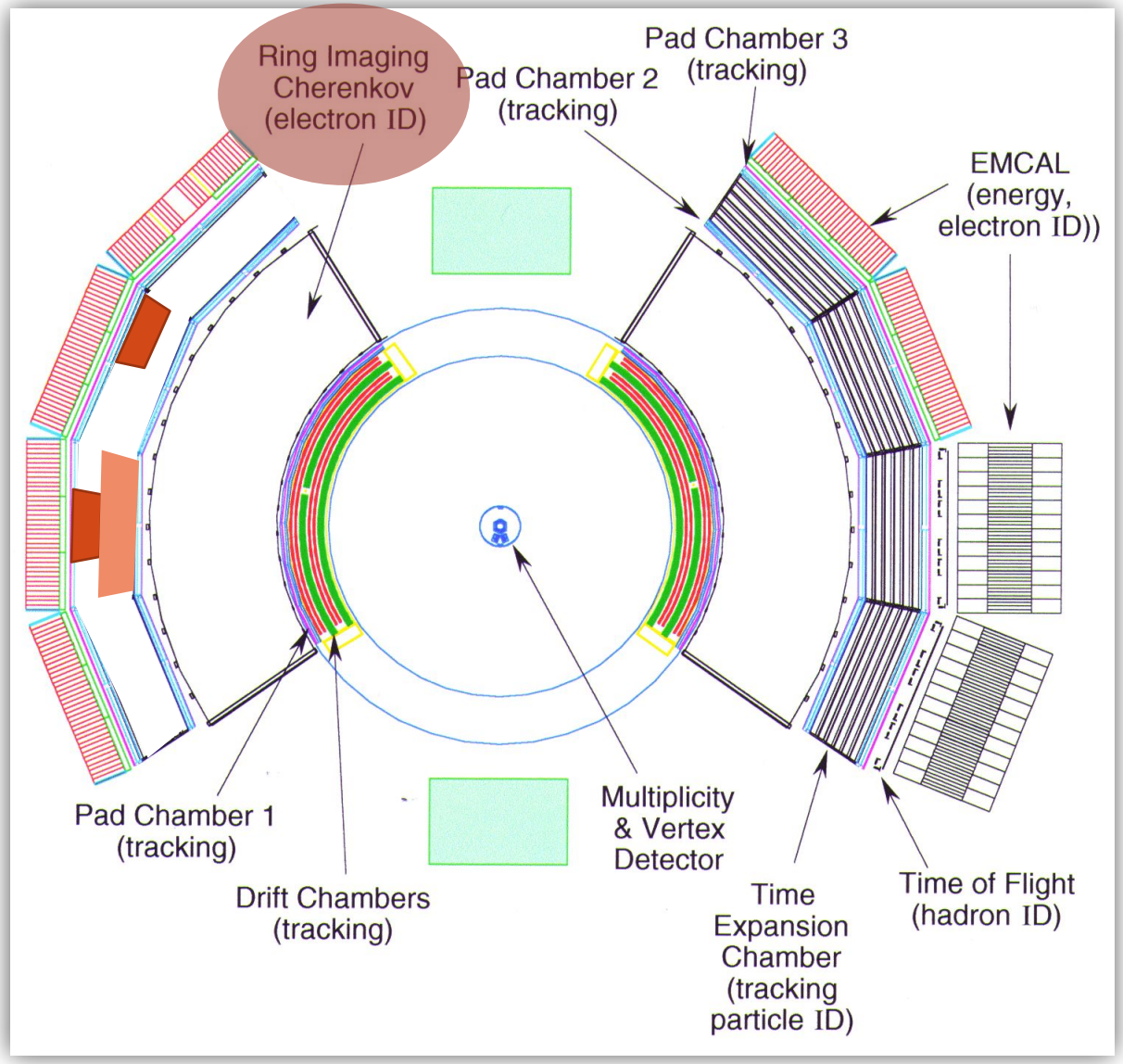
- "PIXEL-PAD": one avalanche on 3 pixels.
- Noise/efficiency (minimum = 2 hits).
- Improves resolution by 3X.
- Read-Out-Card threshold typically 2 fC.
- Bare Si chips wire-bonded to kapton substrates and "capped" w/ epoxy.

PHENIX – PC

Pad chamber mounted on DC



PHENIX – RING IMAGING CHERENKOV RICH



PHENIX – CHERENKOV

- Particle Identification PID is crucial part of many experiments
  - Identify
    - Pions, Kaons, Protons … Electrons, Muons, Tau(on)s …
- How to identify particles?
  - Particles differ from each other through: electric charge → two possibilities $\pm$; Spin → 0, ½, 1, … and others, but these properties are ambiguous and/or hard to measure
  - One (more or less) unique property is: mass
    - $E^2 = m^2 + p^2$ → measure energy and momentum and you get the particle's mass
    - Or, measure other parameters and get the particle's mass
      - E.g., $\frac{p}{E} = \frac{p}{\sqrt{m^2+p^2}} = \frac{1}{\sqrt{1+\left(\frac{m}{p}\right)^2}} = \beta$

PHENIX – CHERENKOV

- $\frac{1}{\sqrt{1+\left(\frac{m}{p}\right)^2}} = \beta \rightarrow$ how to measure β ? Use Cherenkov effect
- A charged particle that traverses a dielectric medium with a speed that is greater than the phase-velocity of light within that medium emits photons
- The charged particle "polarizes" the molecules of that medium, which then turn back rapidly to their ground state, emitting radiation in the process
- Under normal circumstances these photons destructively interfere with each other hence no radiation is detected
- These photons constructively interfere with each other when the "creating" particle travels faster than their speed → photonic shock wave analogous to sonic boom
- Reason: refractive index n of dielectric medium

PHENIX – CHERENKOV

- Refractive Index can be viewed as a result of scattering with scattering amplitude A(0)

$$n = c / v$$

$$n^2 = 1 + \frac{A_0}{1 - \left(\lambda_0^2 / \lambda^2\right)}$$

$$n - 1 = \frac{2\pi N \rho (Z / A)}{k^3} A(0)$$

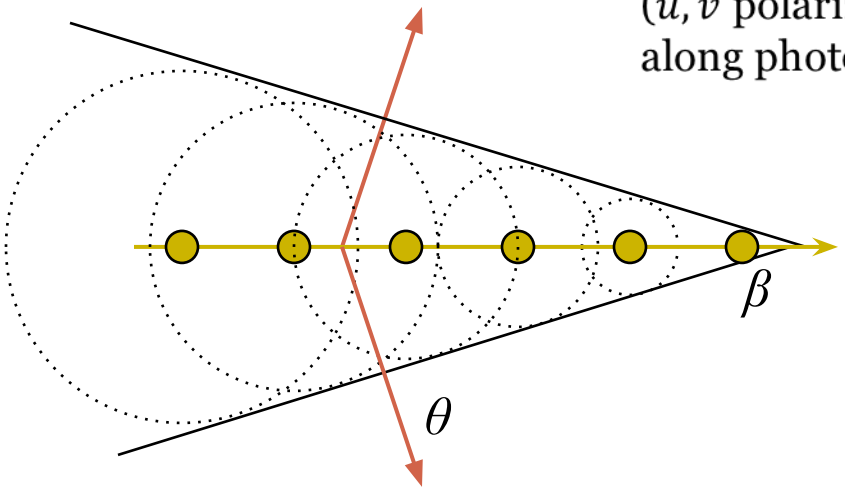
PHENIX – CHERENKOV

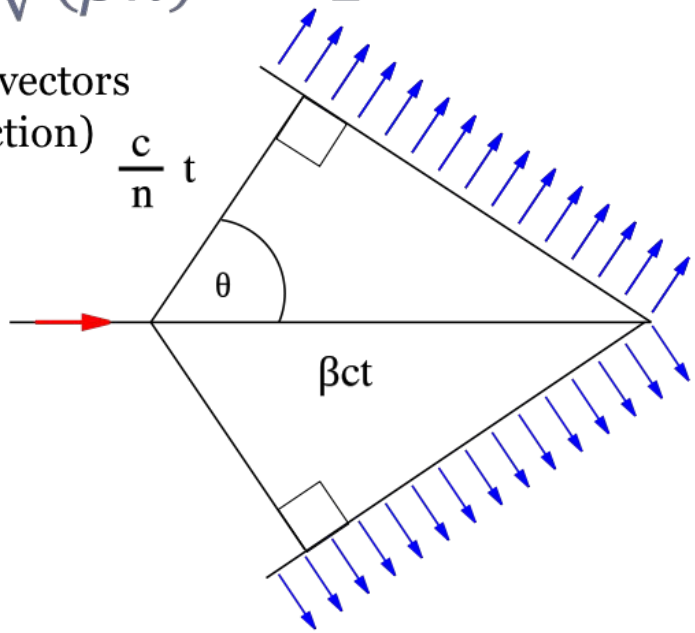
- Faster than light

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

$$\text{Polarization } \vec{p} = (\hat{u} - \beta n \hat{v})/\sqrt{(\beta n)^2 - 1}$$

($\hat{u}, \hat{v}$ polarization, and unit vectors along photon/particle direction)





PHENIX – CHERENKOV

- Distinguish particles by imaging its radiated cone
  - Differential Cherenkov Counter
  - Ring Imaging Cherenkov Counter RICH
  - Cherenkov Ring Image CRID
- Measurement of ring radius of projected Cherenkov cone surface
- Charged particle "produces" Cherenkov photons all along its trajectory within radiator → in general only disk with a maximum radius projected
- Need to focus "individual" radiation → mirror

PHENIX – CHERENKOV

- Focus “individual” cone-surfaces with a mirror

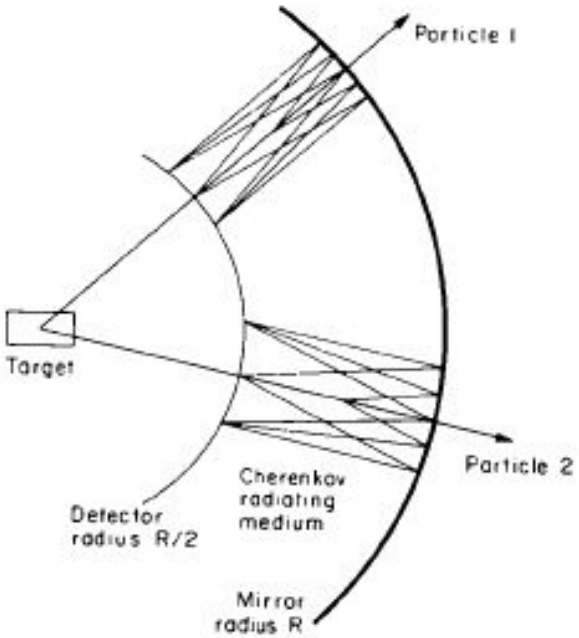


PHOTO-IONIZATION AND CHERENKOV RING IMAGING

J. SEGUINOT* and T. YPSILANTIS†

CERN, Geneva, Switzerland

Received 17 December 1976

We have investigated the photo-ionization process in gases and shown that single photon pulse counting in multiwire proportional chambers (MWPC) is possible with about 50% quantum efficiency for photons above 9.5 eV. An application of this technique in imaging the Cherenkov ultra-violet (UV) radiation is presented.

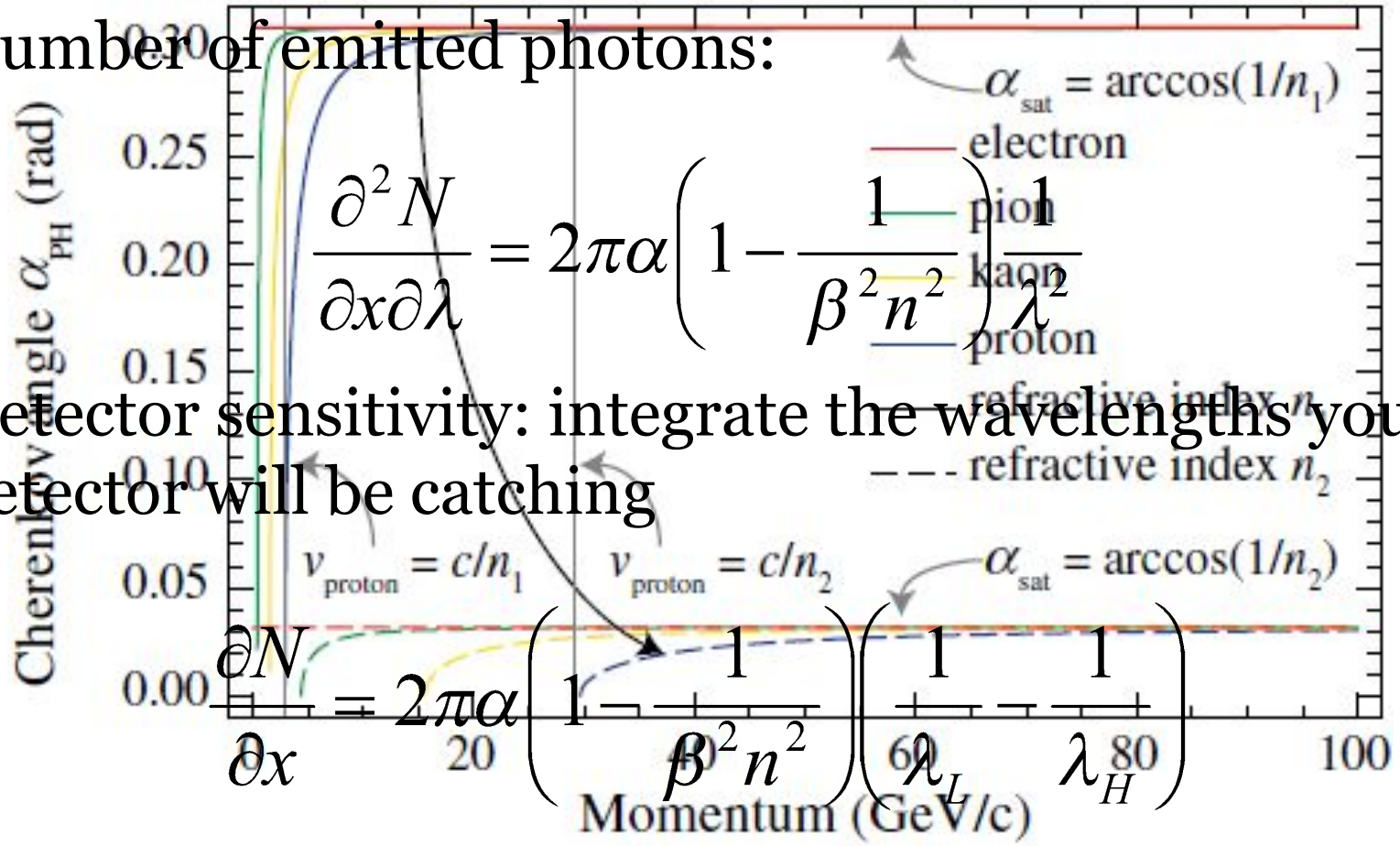
PHENIX – CHERENKOV

- Number of emitted photons:

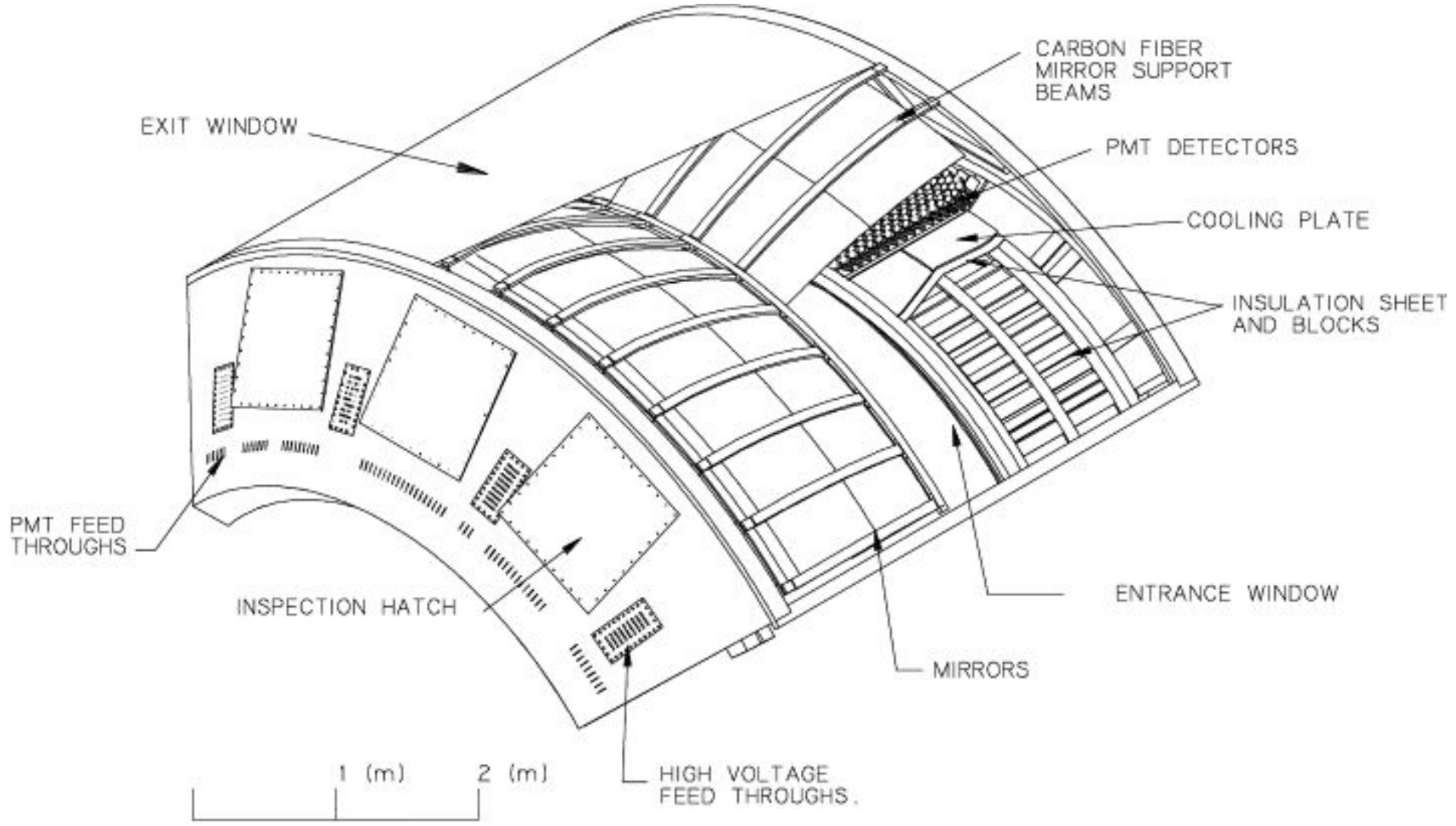
$$\frac{\partial^2 N}{\partial x \partial \lambda} = 2\pi\alpha\left(1 - \frac{1}{\beta^2 n^2}\right)\frac{1}{\lambda^2}$$

- Detector sensitivity: integrate the wavelengths your detector will be catching

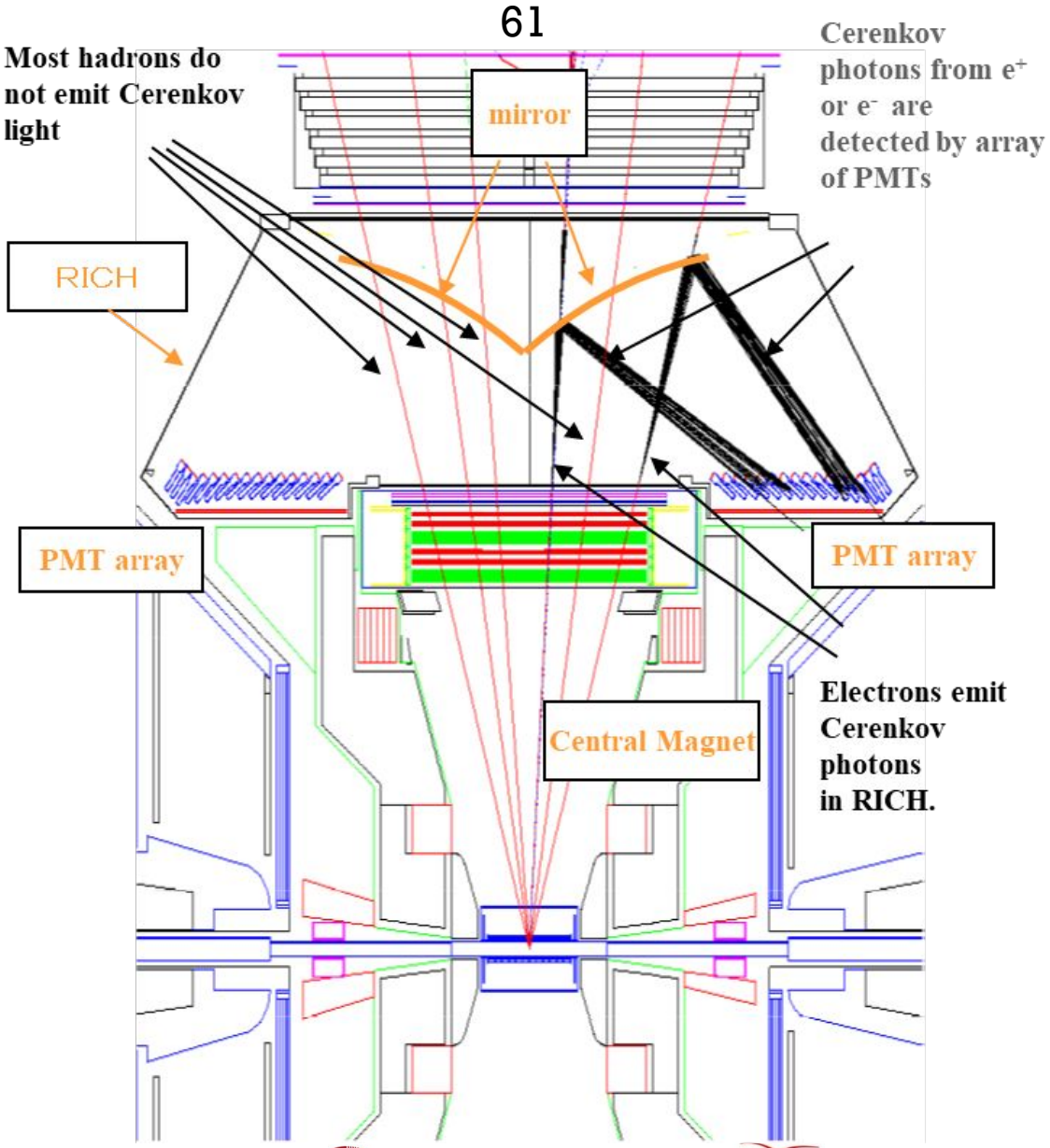
$$\frac{\partial N}{\partial x} = 2\pi\alpha\left(1 - \frac{1}{\beta^2 n^2}\right)\left(\frac{1}{\lambda_L} - \frac{1}{\lambda_H}\right)$$



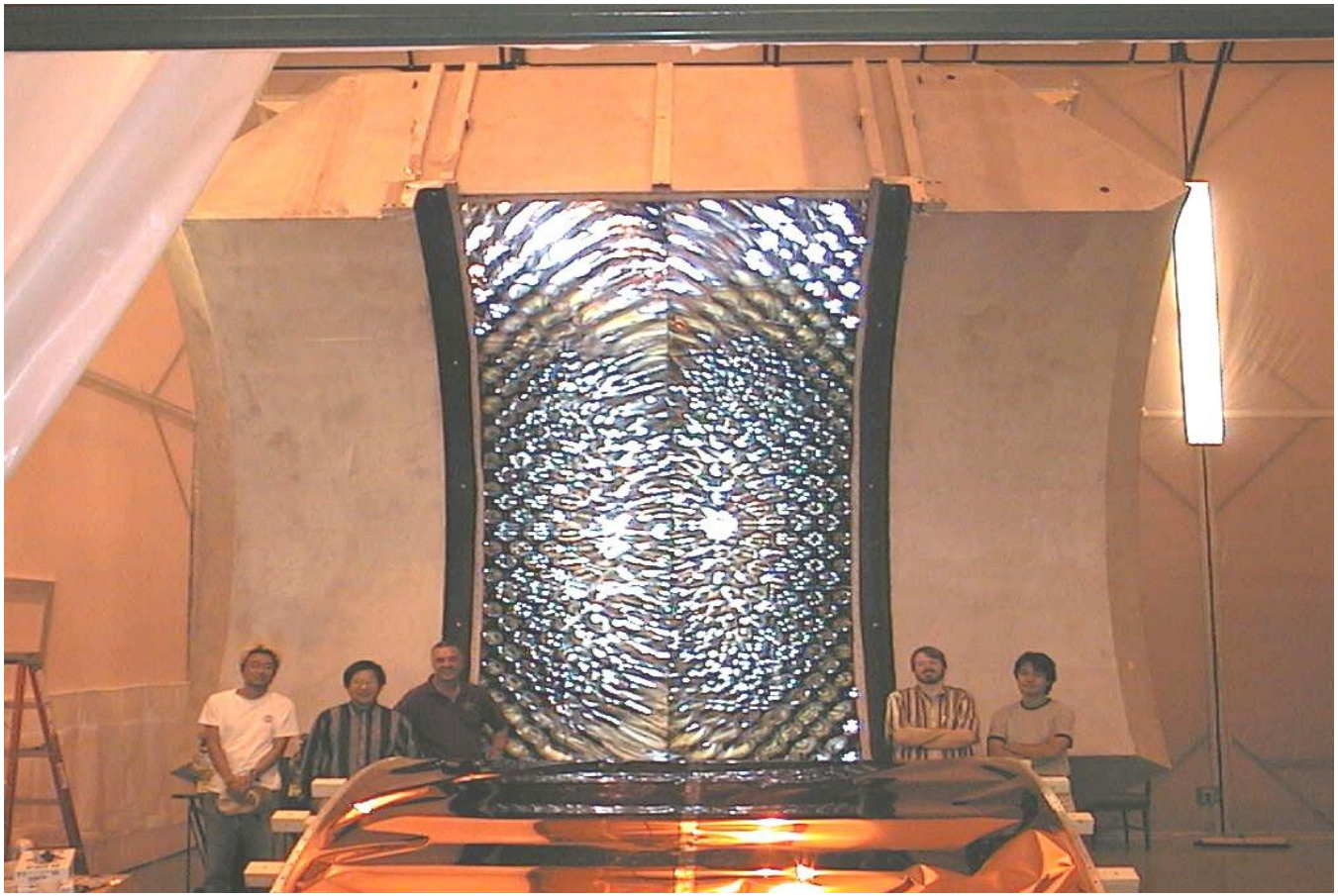
PHENIX – RICH


CARBON FIBER
MIRROR SUPPORT
BEAMS
EXIT WINDOW
PMT DETECTORS
COOLING PLATE
INSULATION SHEET
AND BLOCKS
PMT FEED
THROUGHS
INSPECTION HATCH
ENTRANCE WINDOW
MIRRORS
1 (m)
2 (m)
HIGH VOLTAGE
FEED THROUGHS.

PHENIX – RICH


Most hadrons do not emit Cerenkov light
mirror
Cerenkov photons from e+ or e- are detected by array of PMTs
RICH
PMT array
PMT array
Central Magnet
Electrons emit Cerenkov photons in RICH.

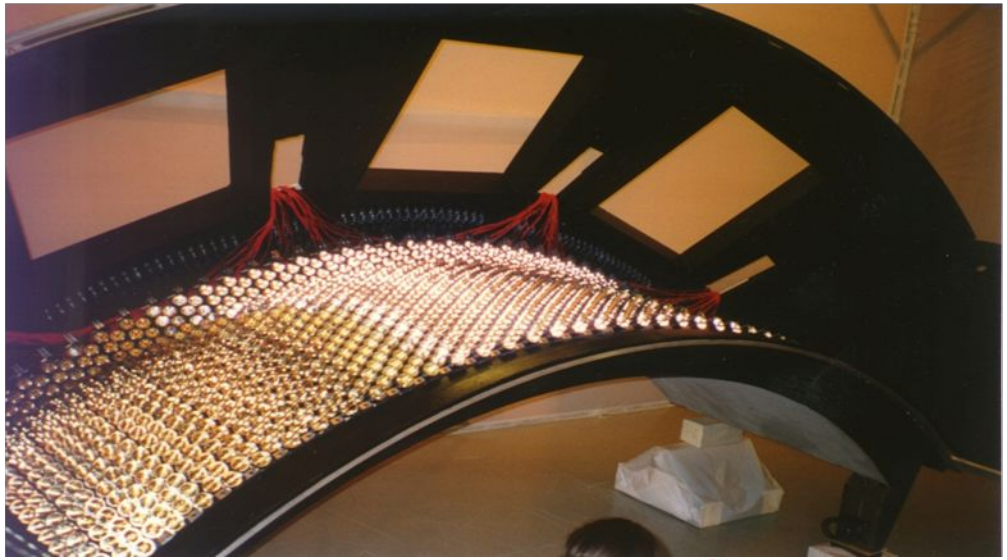
PHENIX – RICH



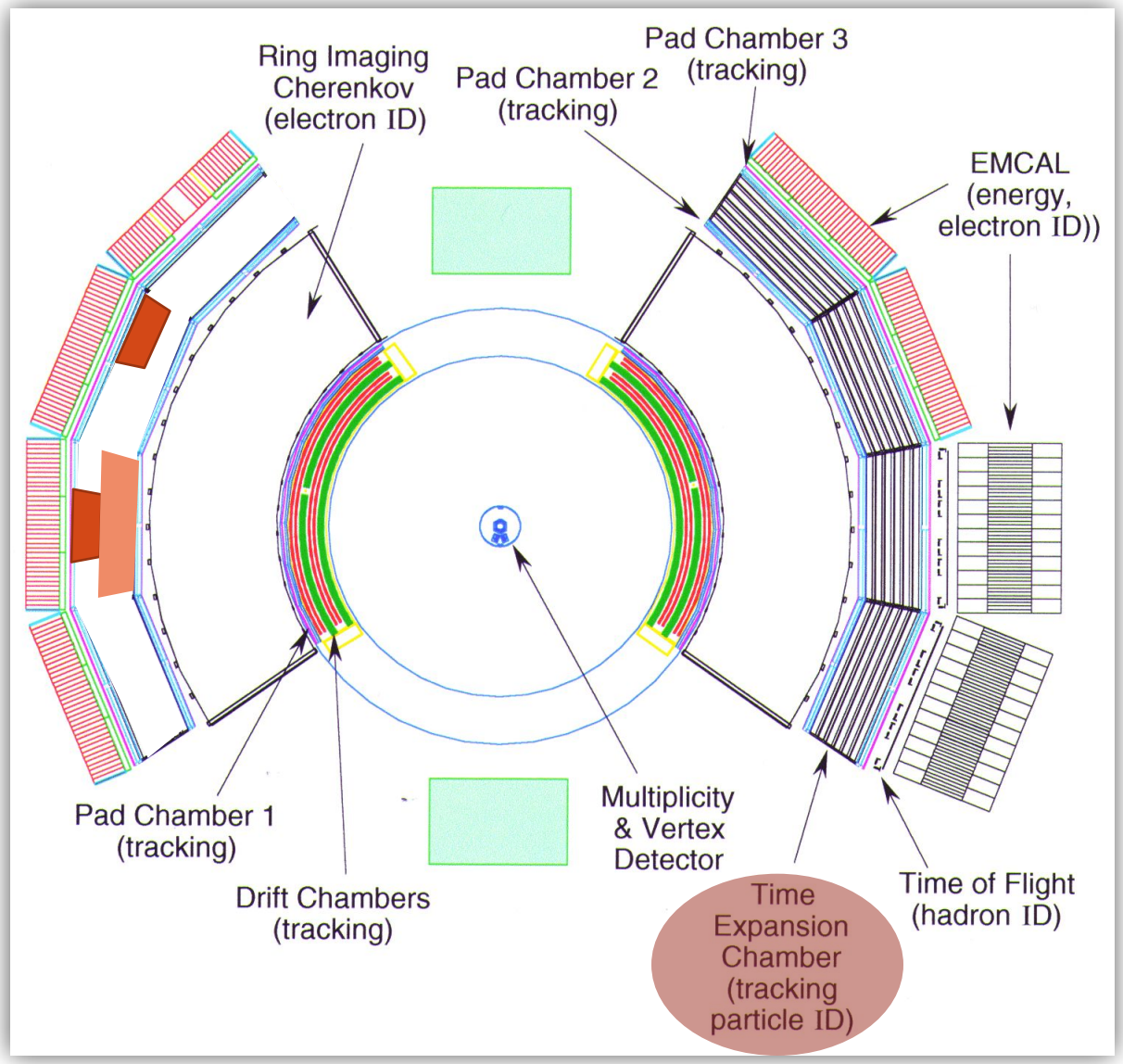
- Two spherical mirrors reflect light onto arrays of PMT's.
- Magnet poles shield the PMTs from collision products.
- Offset focal plane has ellipse rather than circular images.

PHENIX – RICH

- 2560 PMTs, 10^7 gain.
- ~~Ethane~~ CO_2 radiator.
- 10^4 charge pion rejection.
- 1 degree ring res.
- N_0= 118.
- 12-18 p.e./ring
- C-fiber/Rohacell mirror 0.3% X_0



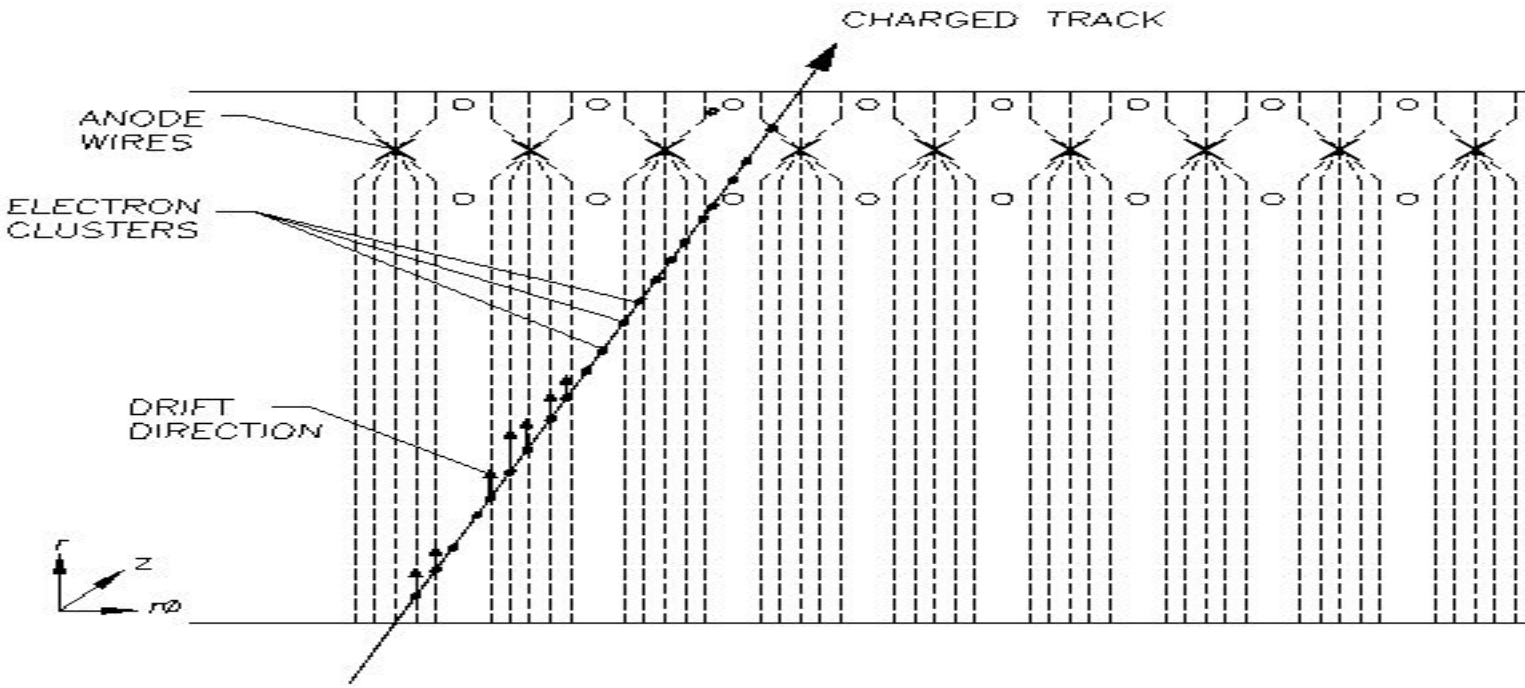
PHENIX – TIME EXPANSION CHAMBER TEC



PHENIX – TEC

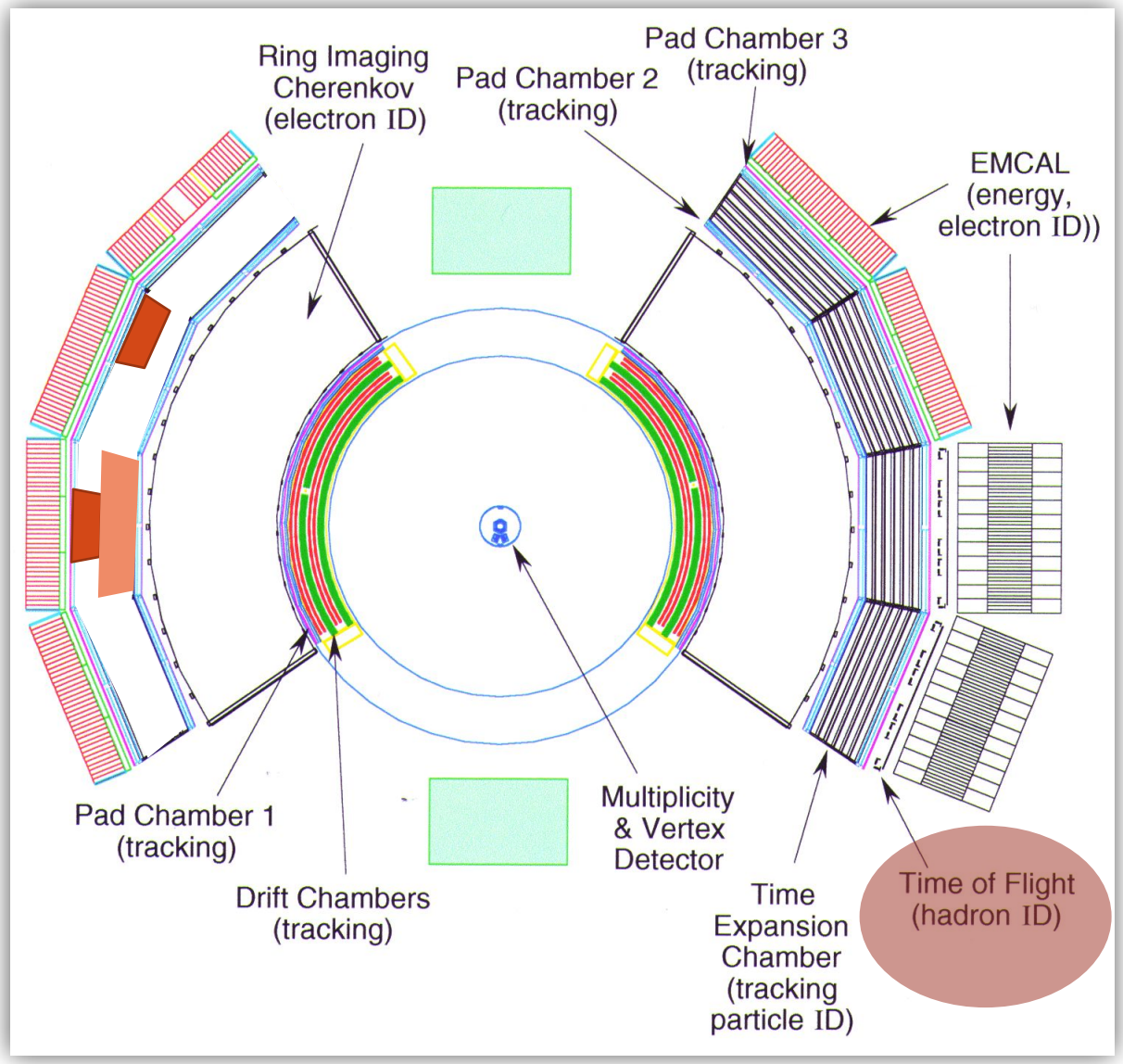
- TEC drift region well separated from amplification region
  - Low field in drift region
  - High field in amplification region
- Separate drift velocities expand time
  - Clusters of track crossing chamber ~ parallel to drift field arrive at grid in time intervals larger than in ordinary chamber
  - Anode signal has not been slowed down relative time expansion achieved

PHENIX – TEC



- Drift direction primarily along track.
- Wire signal sampled at 40 MHz using 5-bit non-linear FADC (non-linear allows TRD upgrade).
- Maximum samples leads to excellent dE/dx meas.
- Single point res ~250 μm, 2-track separation ~5 mm.
- With Xe in gas and foam becomes TRD.

PHENIX – TIME OF FLIGHT



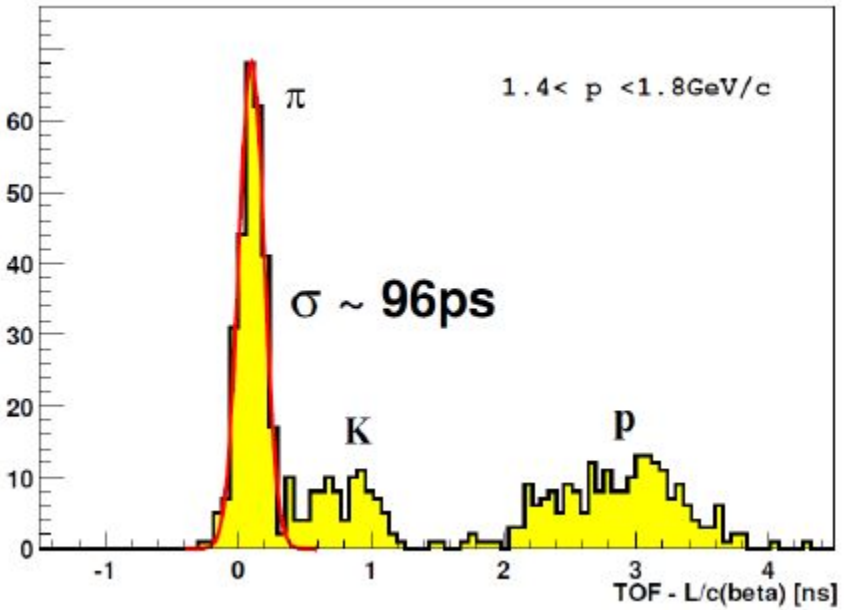
PHENIX – TIME OF FLIGHT TOF

- PHENIX TOF houses ~1000 scintillator slats □ fast decay time, light generated by passage of charged particles transmitted through light guides to photomultiplier tubes (PMT)
- PMT pairs @ bar ends w/ prism readout □ Δt used for determining x along the slat
- < 100 ps TOF resolution and at 5 meters □ π/K separation up to 2.4 GeV/c

$$\beta = \frac{p}{\sqrt{p^2 + m^2}} \qquad T = \frac{L}{c \cdot \beta}$$

$$t_1 - t_2 = \frac{L}{c}\left(\sqrt{1 + \frac{m_1^2}{p_1^2}} - \sqrt{1 + \frac{m_2^2}{p_2^2}}\right)$$

$$L = 5\ m, t_i \text{ and } p_i \text{ measured}$$



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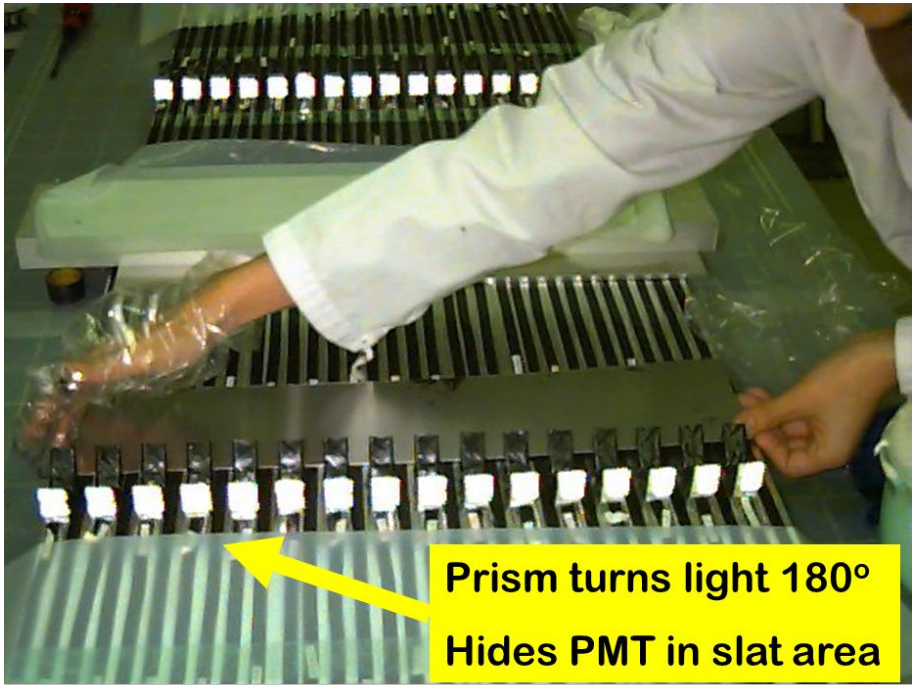
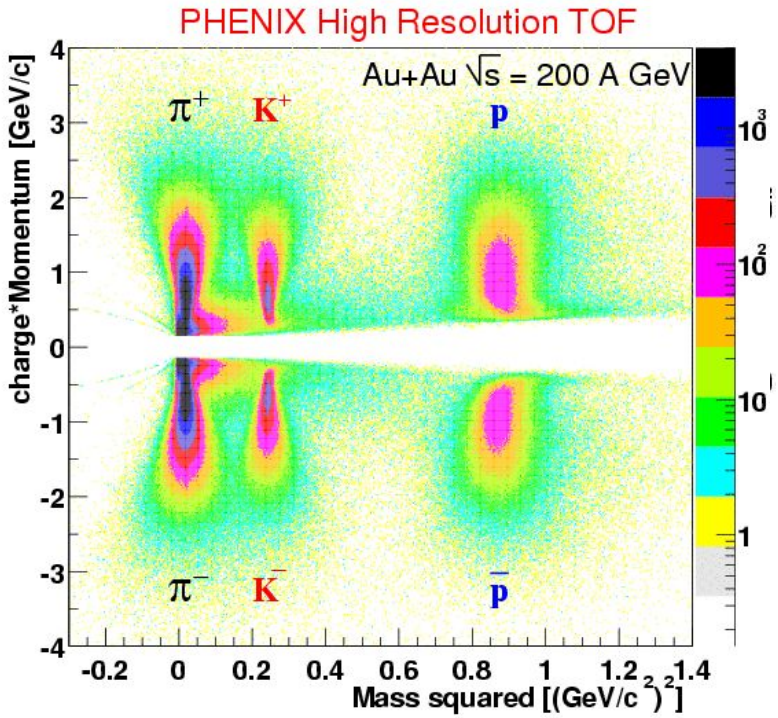
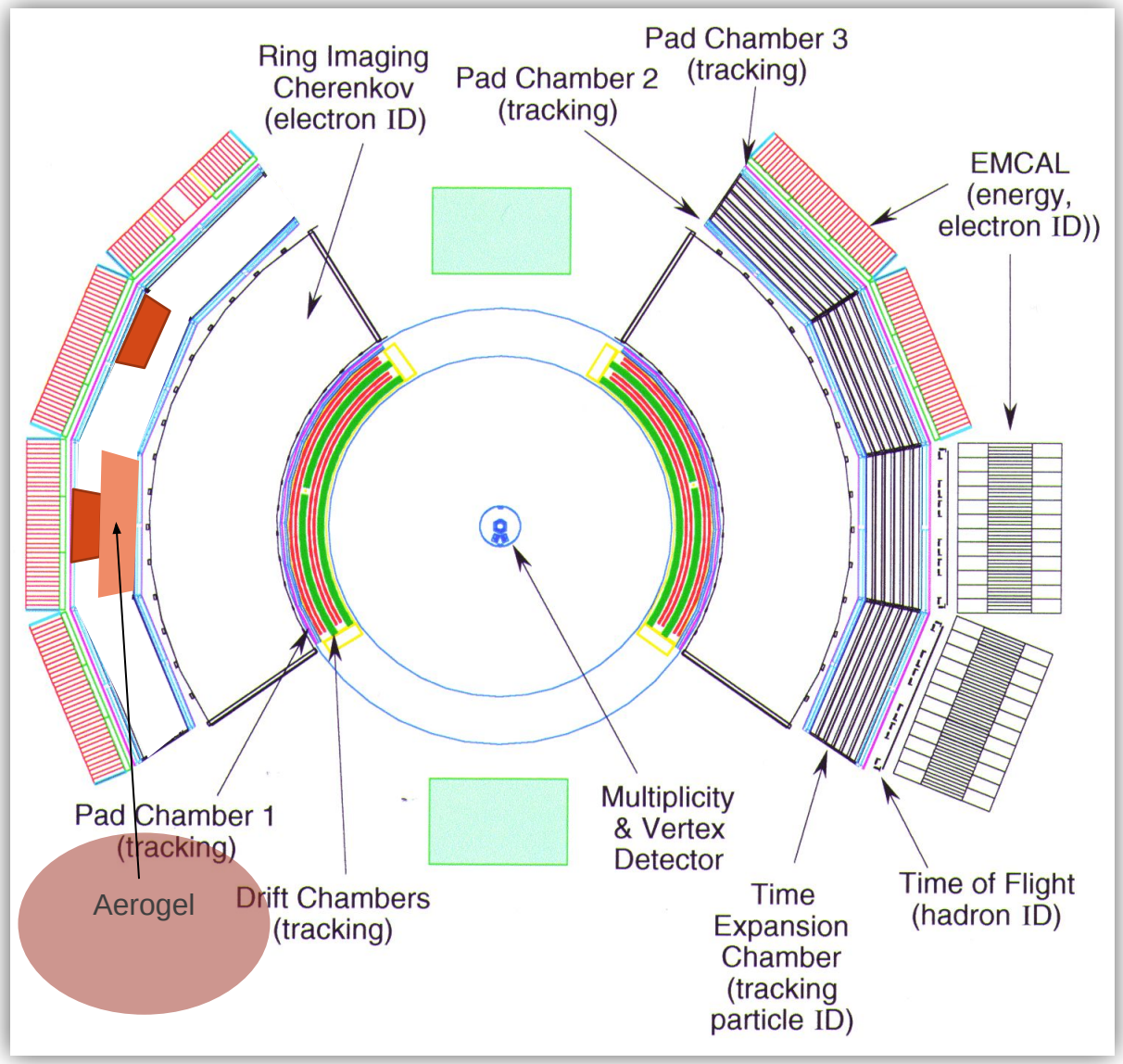


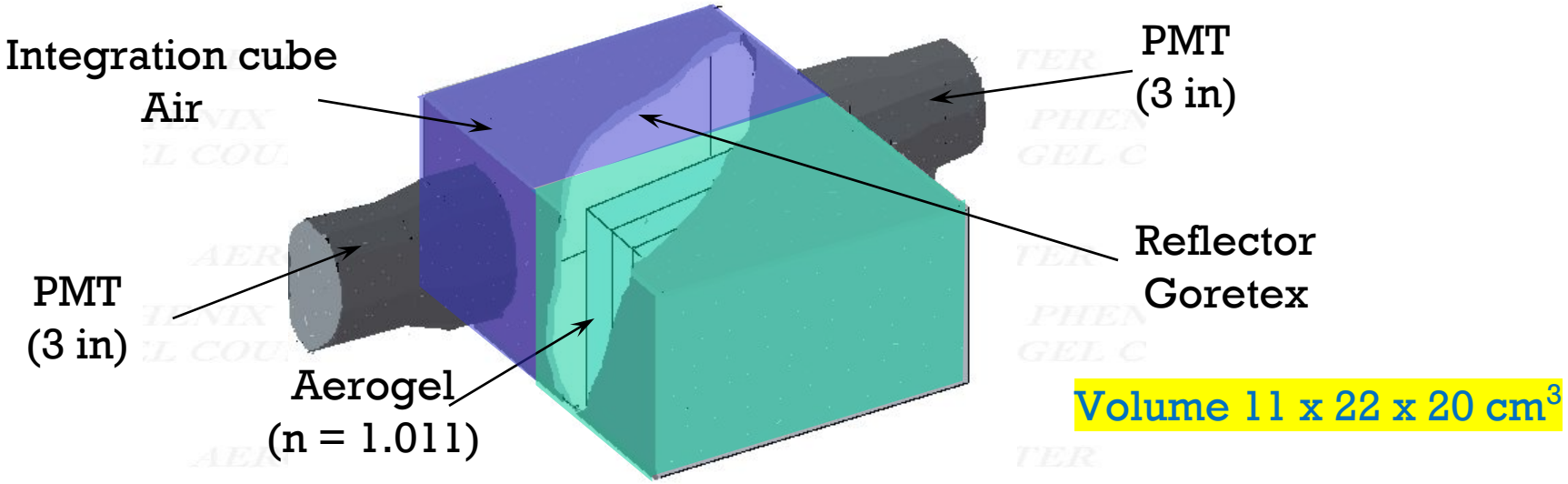


PHENIX – AEROGEL ACC



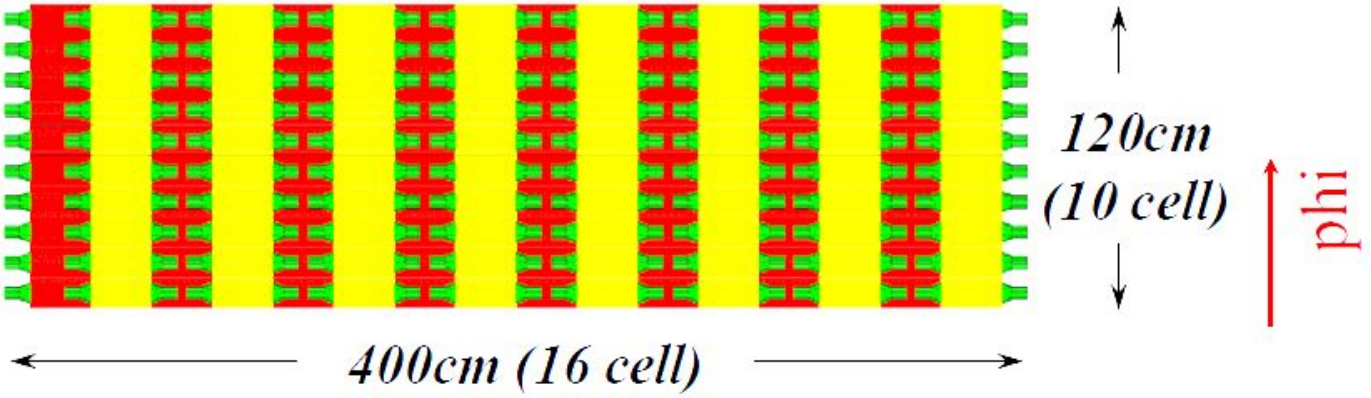
PHENIX – AEROGEL

- Cherenkov counter
  - Cherenkov radiator is Silica Aerogel
  - Photon is detected by 2 PMTs
  - All inner surface is covered with DRP Reflector
  - Integration cube for uniformity of light yield



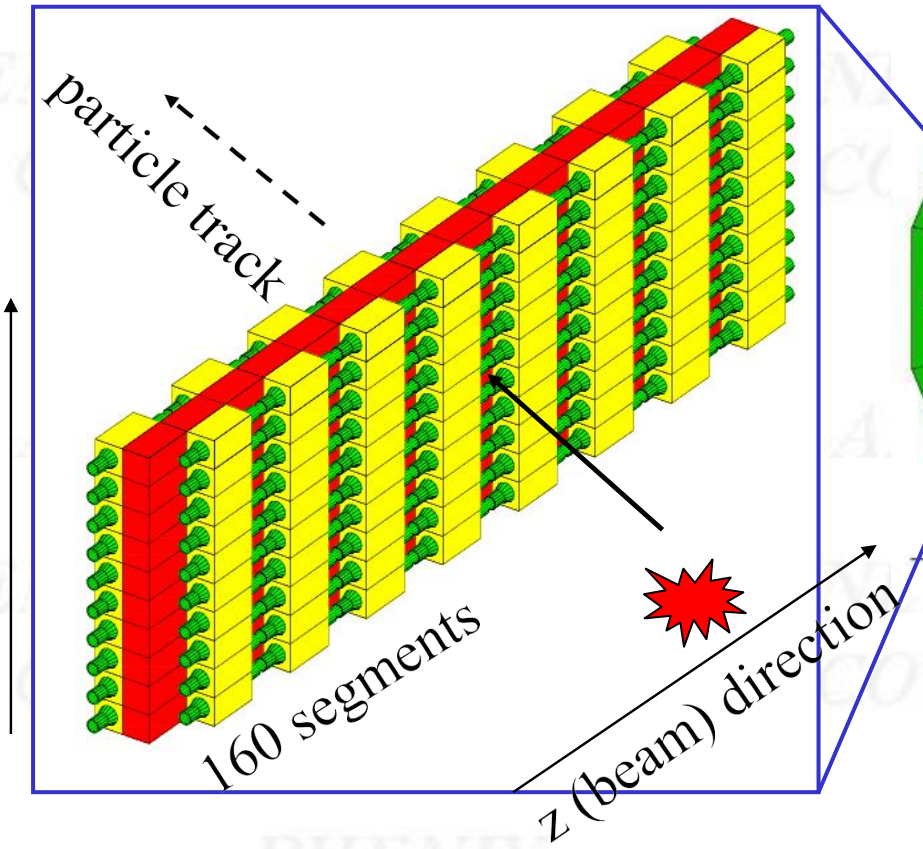
PHENIX – AEROGEL

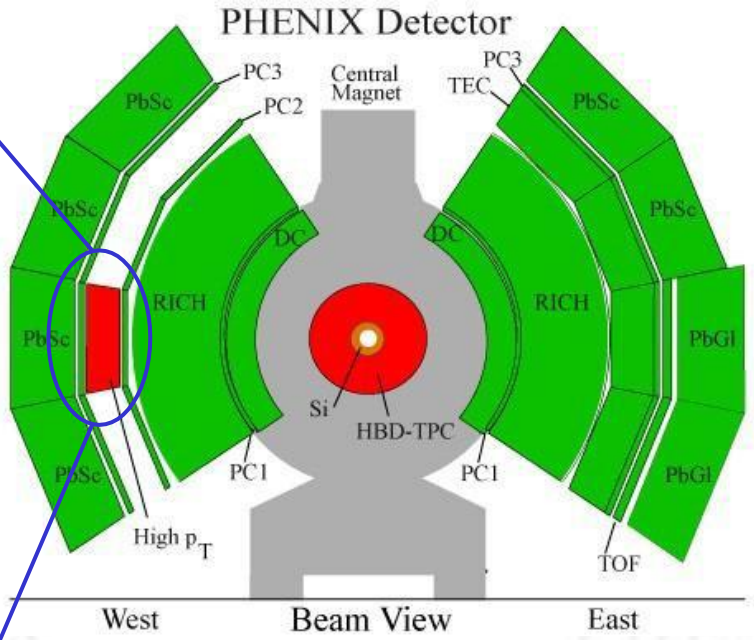
~ Side view ~



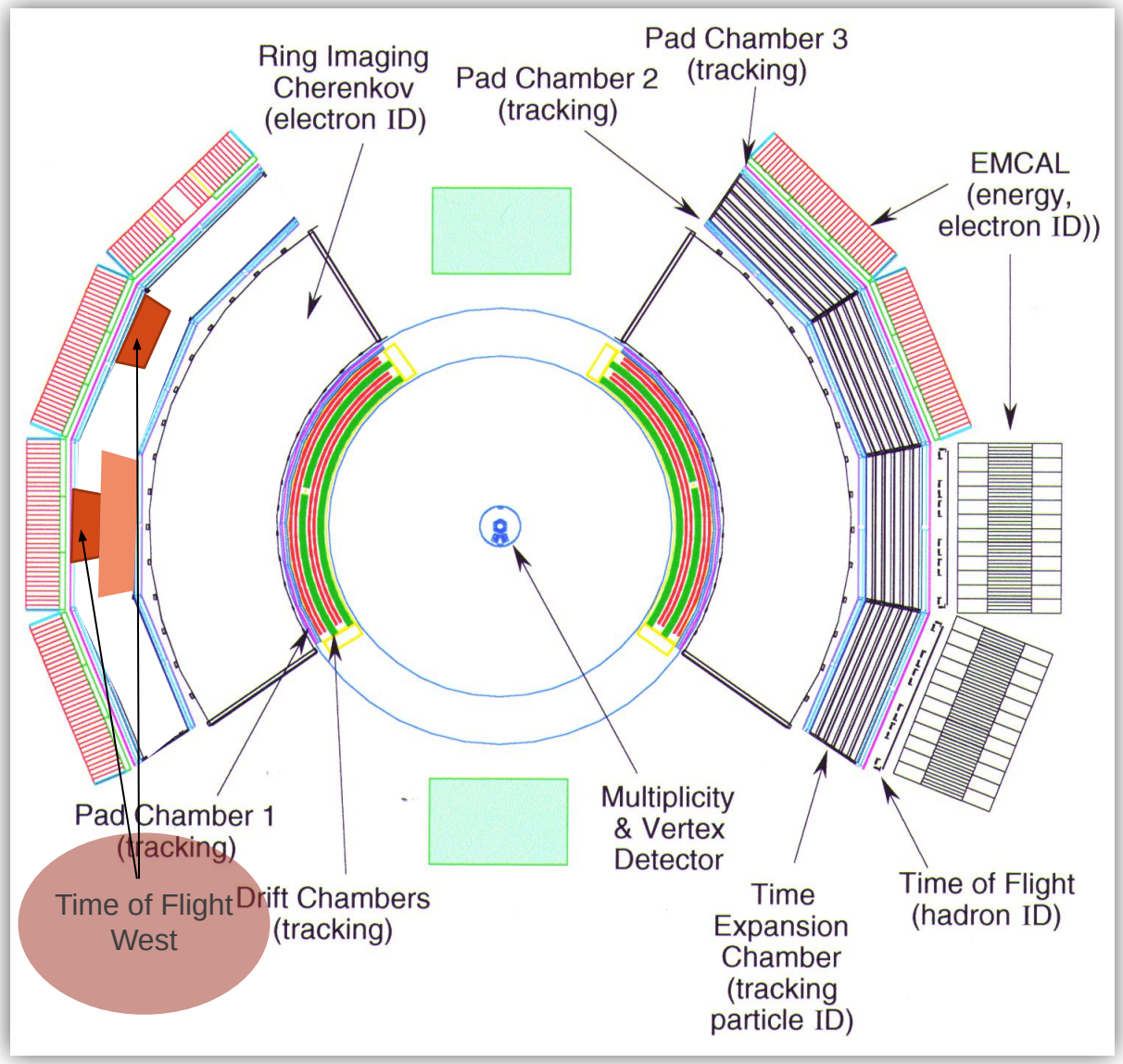
~ Top view ~

PHENIX – AEROGEL



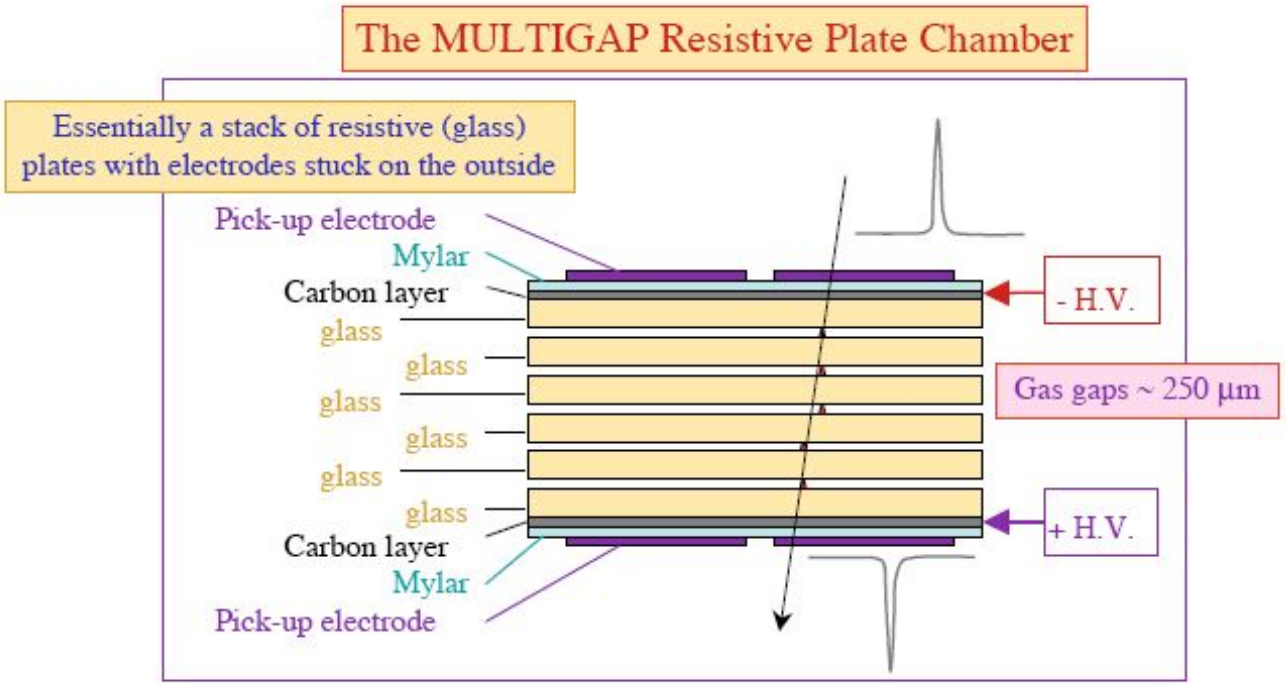


PHENIX – TIME OF FLIGHT WEST



PHENIX – TIME OF FLIGHT WEST

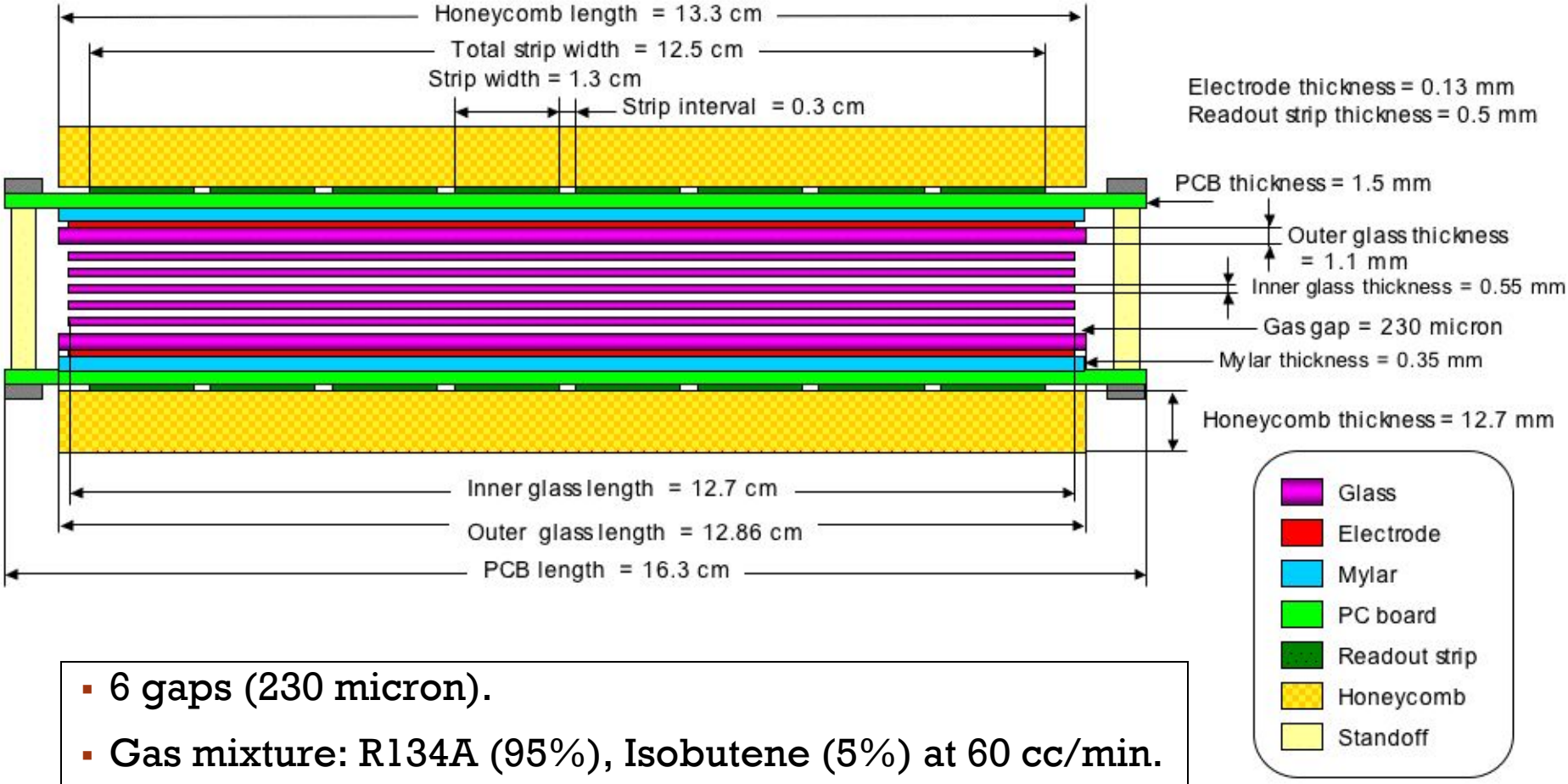
- TOF.West with ACC and with RICH
  - PID extension to 5 GeV/c and more
- Coverage in West Arm ~ 4 m^2



PHENIX – TIME OF FLIGHT WEST

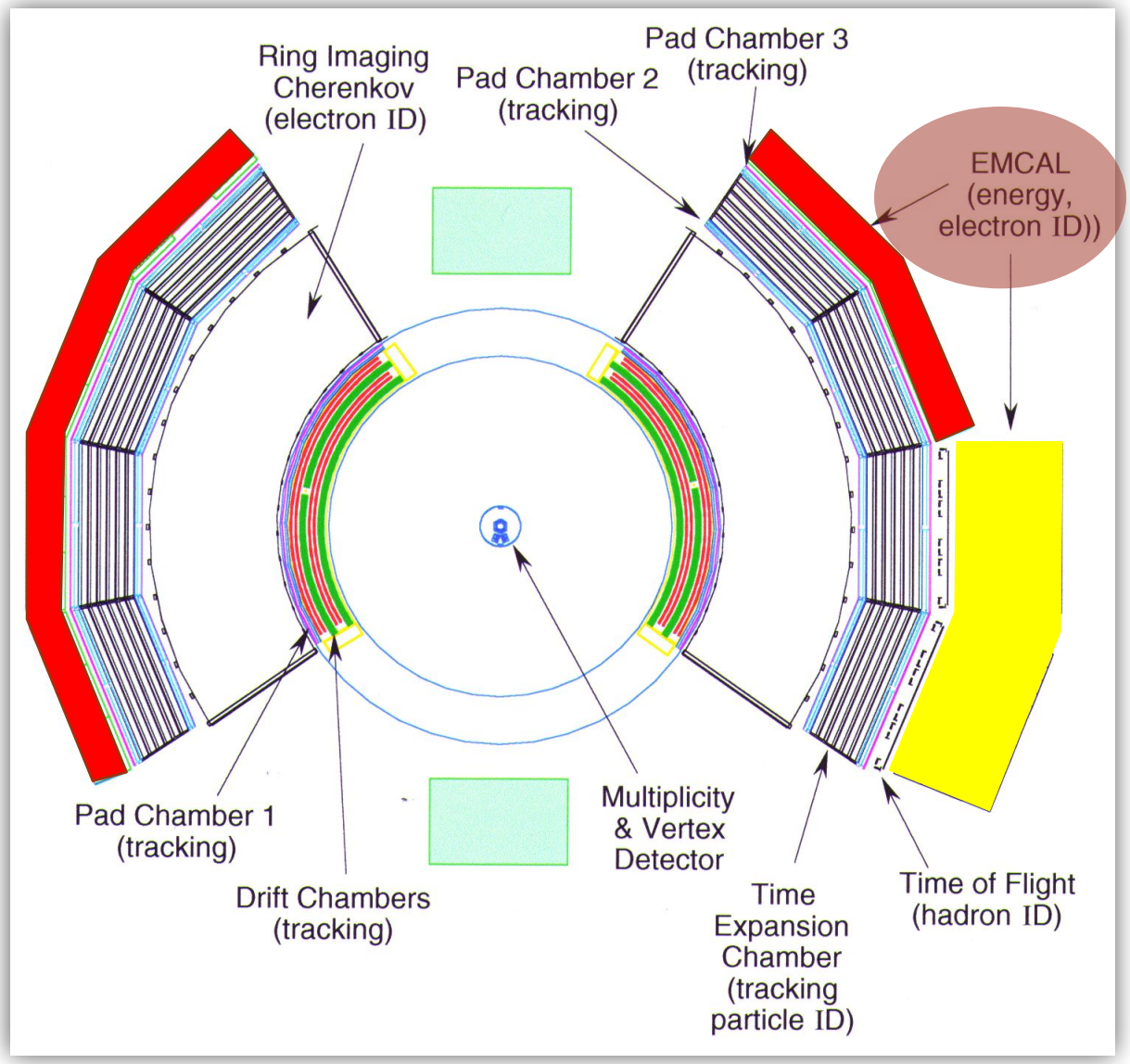
- Multi-gap resistive plate chamber
  - Stack of resistive plates (glass) with electrodes connected on the outside
  - Internal glass plates electrically floating, take and keep correct voltage by electrostatics and flow of electrons and ions produced in gas avalanches
  - Resistive plates transparent to fast signals, induced signals on external electrodes is sum of signals from all gaps (also, equal gain in all gaps)
  - Operated in avalanche mode for TOF detector

PHENIX – TIME OF FLIGHT WEST



- 6 gaps (230 micron).
- Gas mixture: R134A (95%), Isobutene (5%) at 60 cc/min.
- HV: ±7.5 kV

PHENIX – ELECTROMAGNETIC CALORIMETER EMCAL



PHENIX – EMCAL

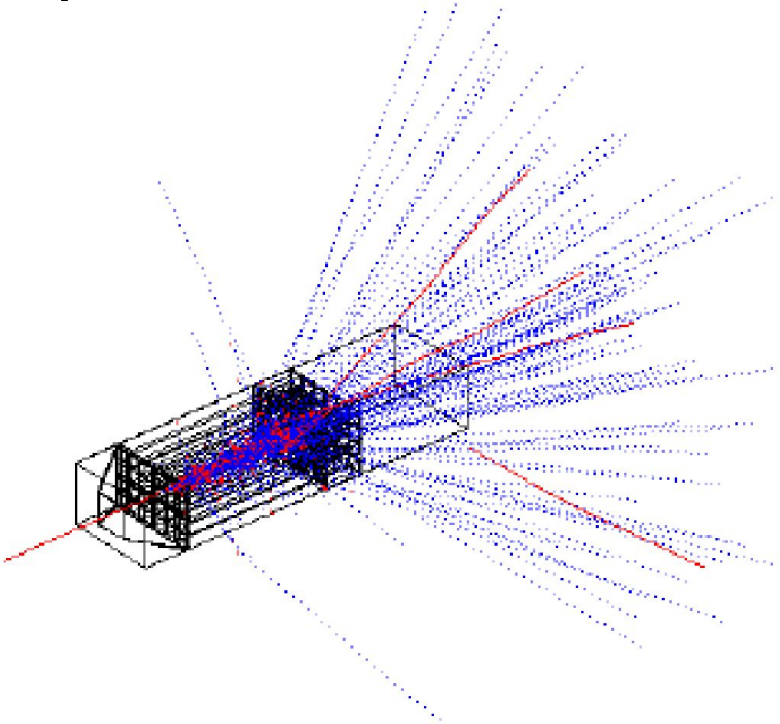
- Electromagnetic Calorimeter at mid-rapidity
- PbSc – Lead Scintillator detector
- PbGl – Lead Glass detector
- Acceptance CA: $|\eta| < 0.375$ and $\Delta\varphi = 90° \times 2$
- 4 Sectors in each arm
  - 6 Sectors PbSc, covering all of West Arm and top of East Arm
    - 15552 channels total
  - 2 Sectors PbGl, covering bottom of East Arm PbGl
    - 9216 channels total

PHENIX – EMCAL

- Electrons and Photons electromagnetically interaction (bremsstrahlung and pair production)
- Hadrons strongly interact hadronic shower/MIP
- Purpose of Calorimeter
  - Measure deposited energy
  - Measure position
  - Measure TOF
- Photons as detectable objects measured by photosensitive detectors

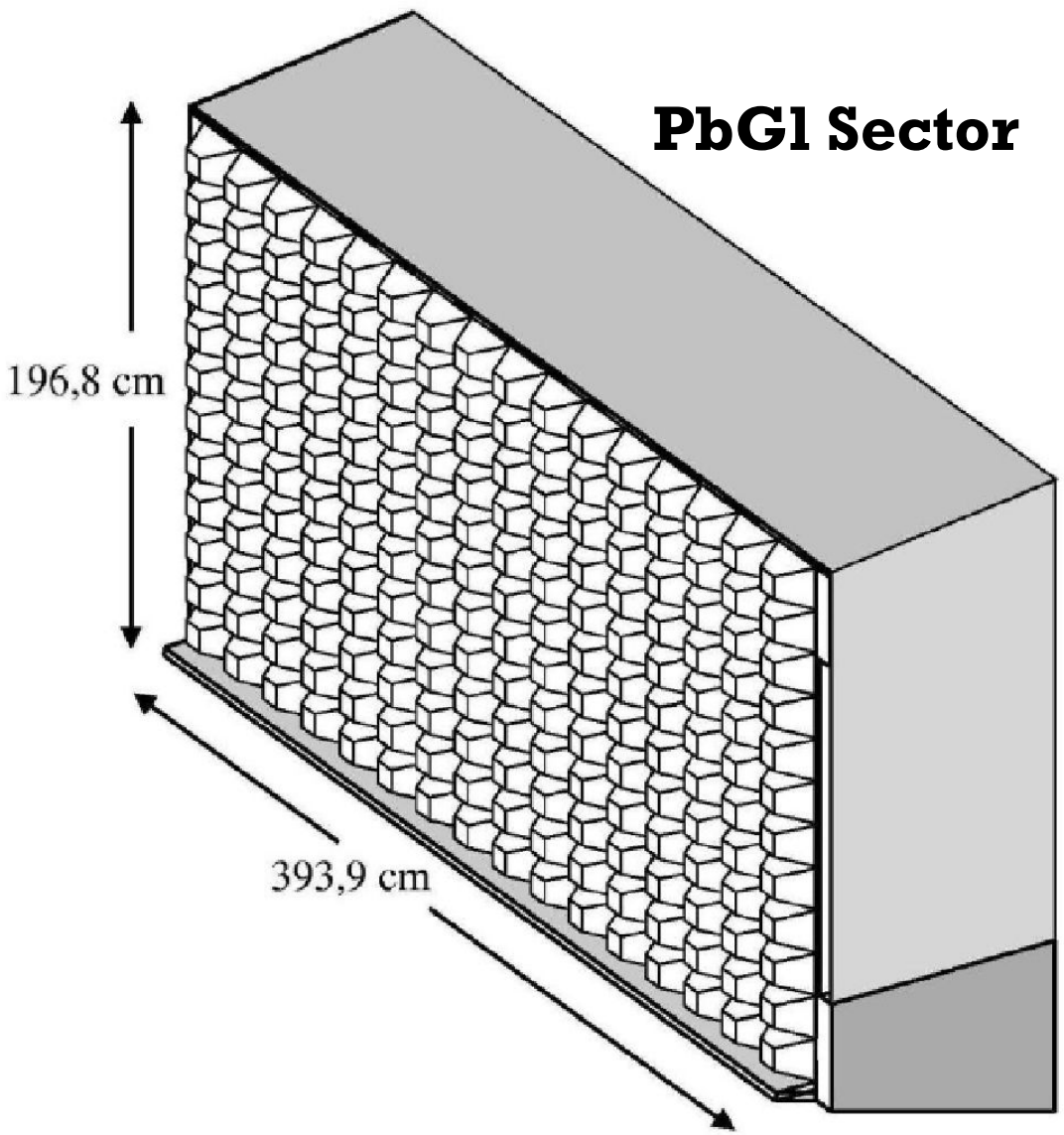
PHENIX – EMCAL PBGL

- Charged shower particles generate Cherenkov photons in the PbGl
- The Cherenkov Photons propagate with a wavelength dependent attenuation to the PMT
- $N_\gamma \sim E_0$

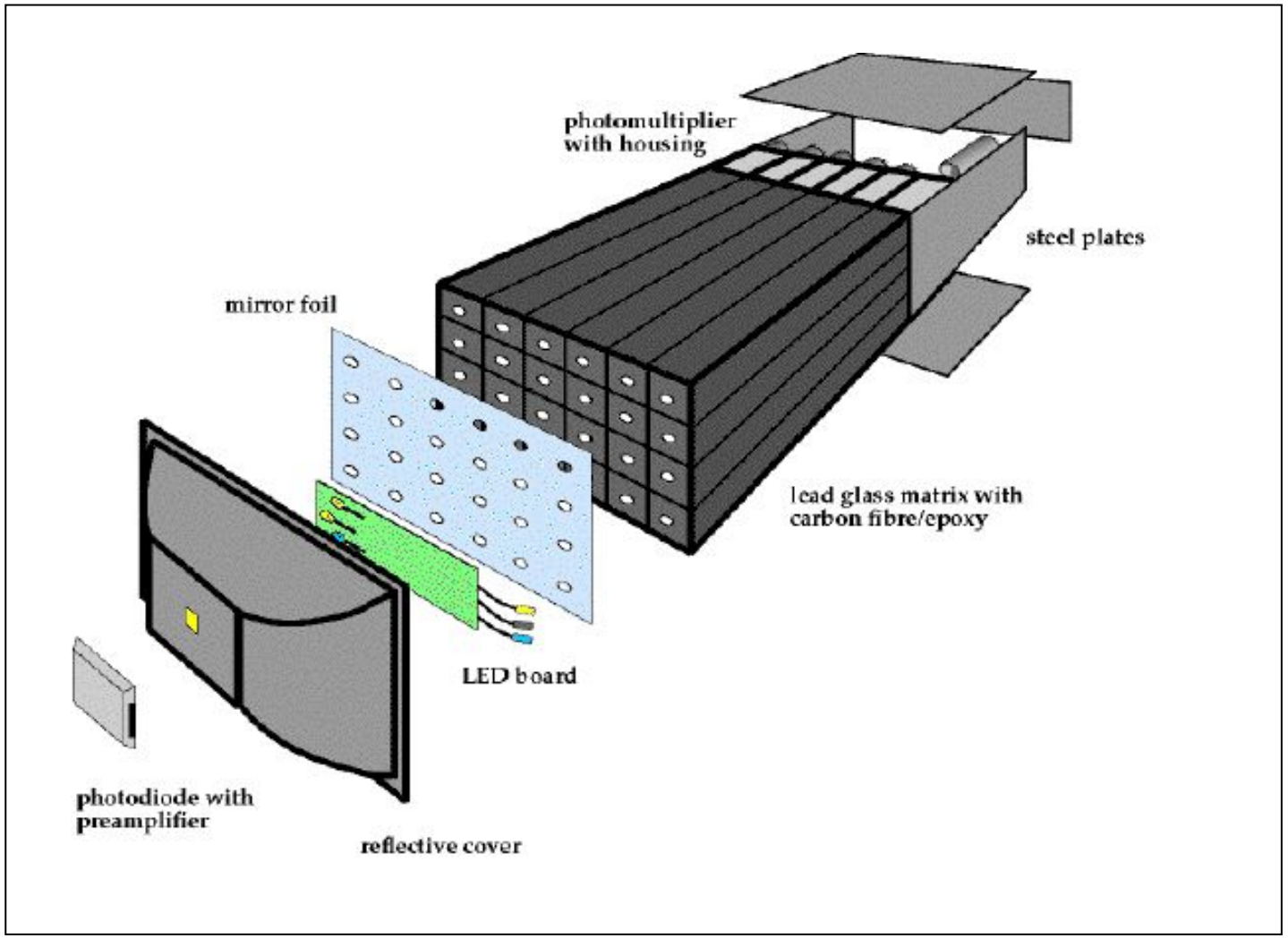


PHENIX – EMCAL PBGL

- 2 Sectors PbGl
  - 1 PbGl Sector
    - 16x12 super-modules (SM)
  - 1 PbGl SM
    - 6x4 towers
  - 1 FEM
    - Reads out 2x3 SM or 12x12 towers

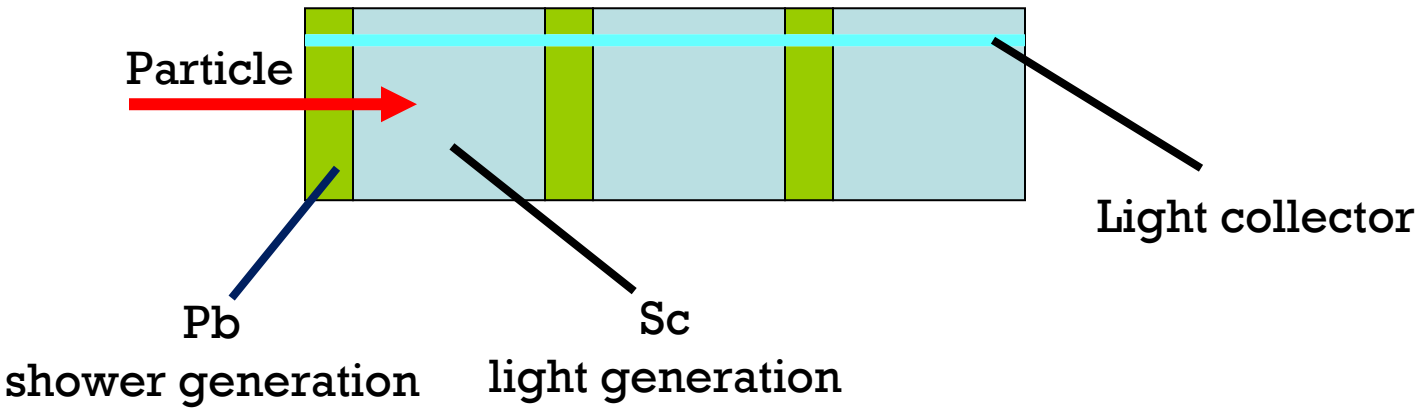


PHENIX – EMCAL PBGL



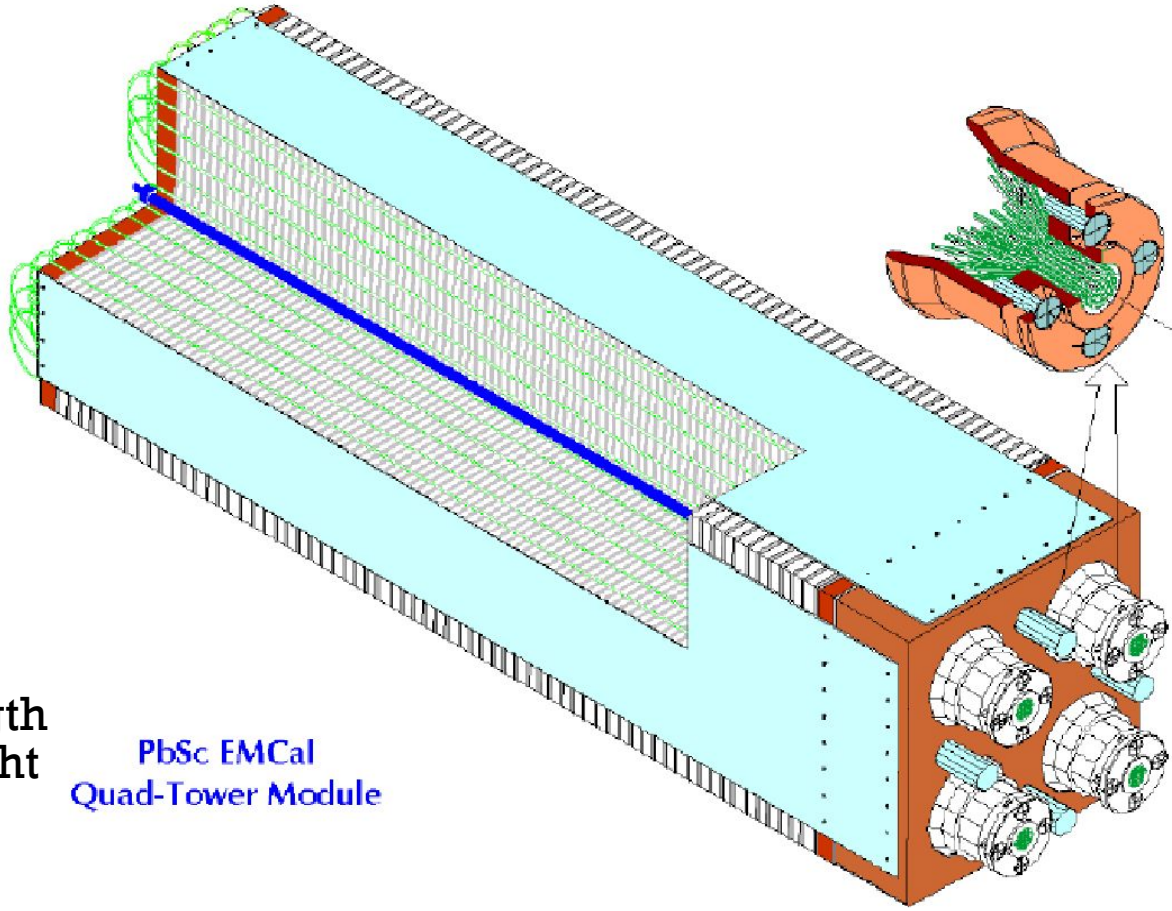
PHENIX – EMCAL PBSC

- Shower generation in sandwiched structure Pb-Sc-Pb □ sampling calorimeter
- Photons collected via lightguide to the PMT

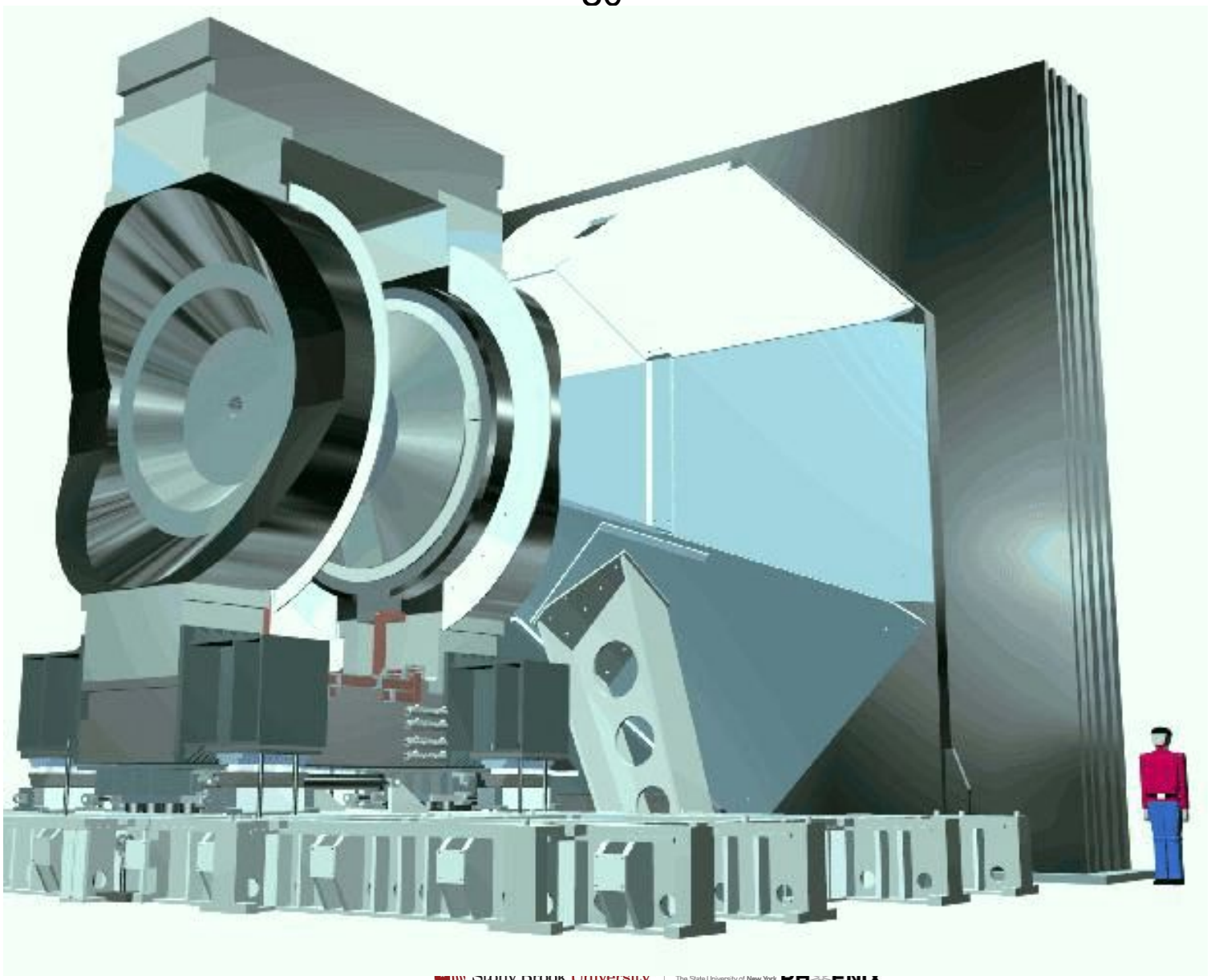


PHENIX – EMCAL PBSC

- 6 Sectors PbSc
  - 1 PbSc Sector
    - 6x3 SM
  - 1 PbSc SM
    - 12x12 towers
  - PbSc towers
    - 5.52 x 5.52 x 33 cm^3
  - 1 PbSc tower
    - 66 sampling cells
  - 1 sampling cell
    - 1.5 mm Pb, 4 mm Sc
    - Ganged together by penetrating wavelength shifting fibers for light collection



PHENIX – FORWARD DETECTORS



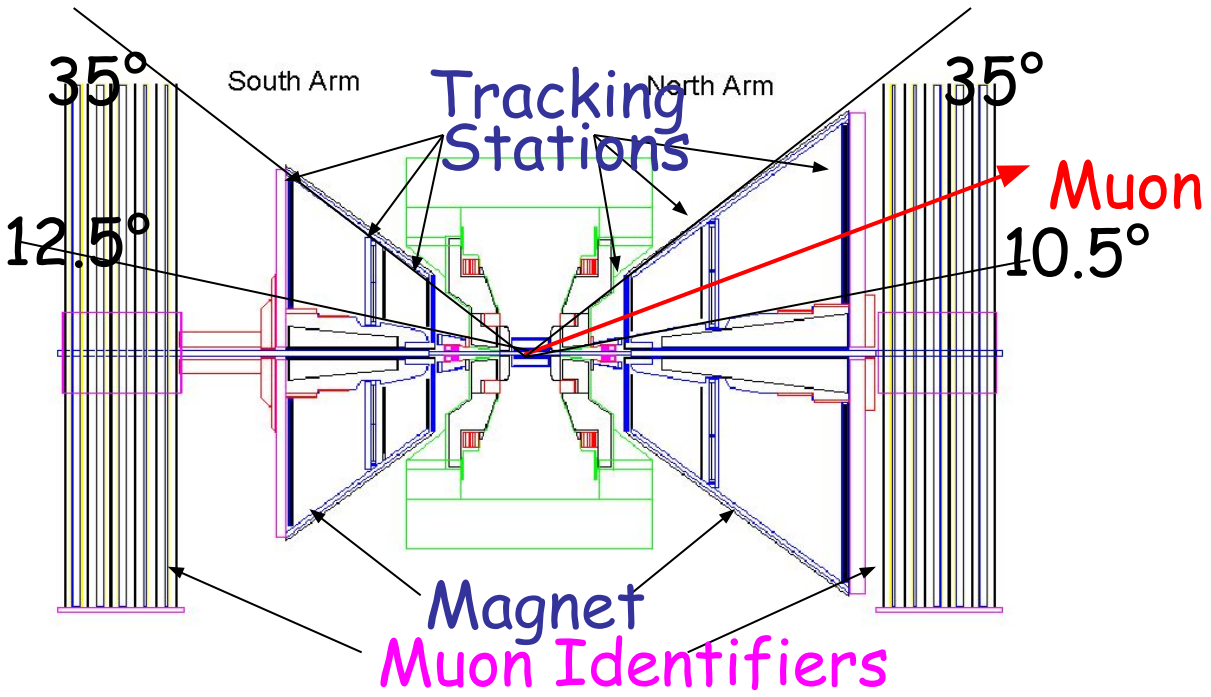
PHENIX – FORWARD DETECTORS

2 Muon Trackers =

2x3 stations

2 Muon Identifiers

= 2x5 planes



South Arm:

Began operations

in 2001: Run-2.

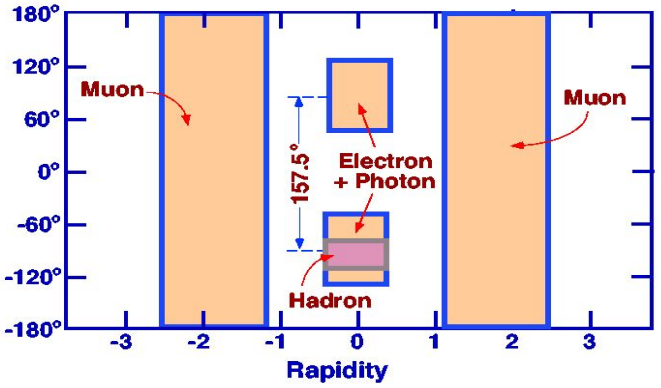
North Arm:

Installed in 2002.

Acceptance : $1.2 < |\eta| < 2.4$

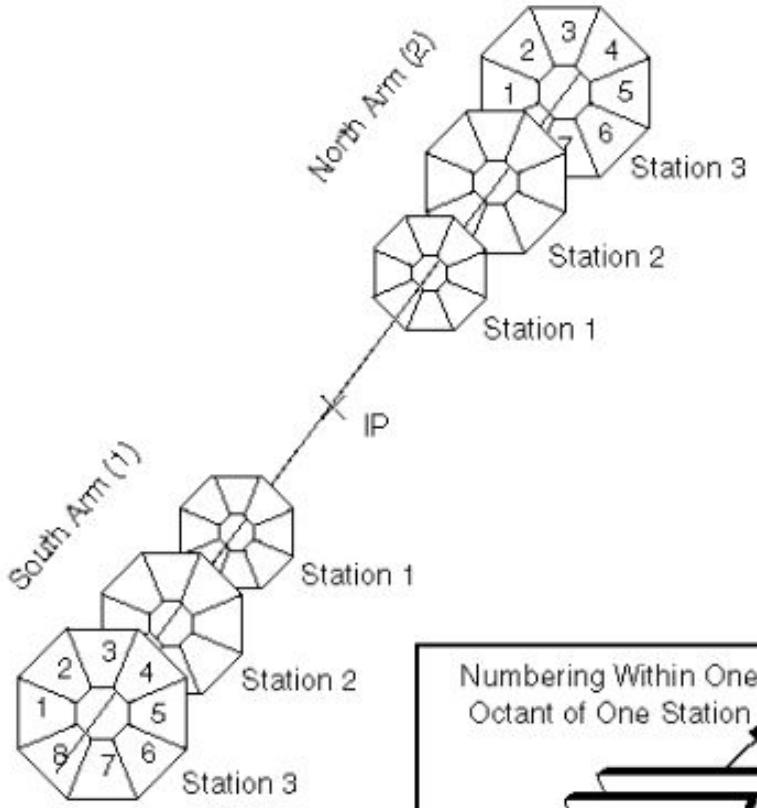
$\Delta\Phi = 2\pi$

Muon minimum momentum ~ 2 GeV/c



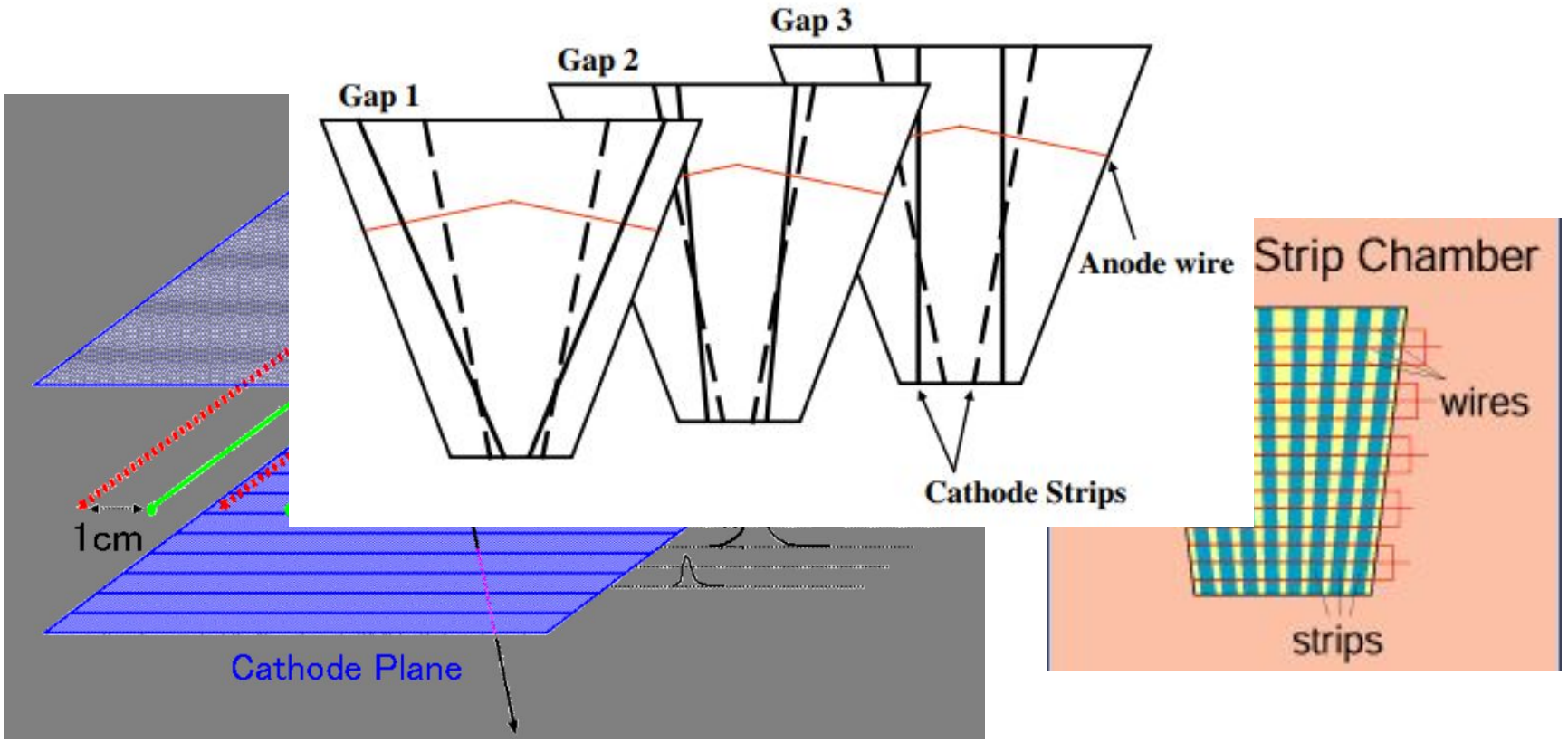
PHENIX – FORWARD DETECTORS MUTR

- Each MuTr consists of three cathode strip detectors
- Each detector is composed of three layers gaps
  - Gaps sandwich of cathode strips, anode wires, cathode strips
- Octagonal structure eight octants per layer



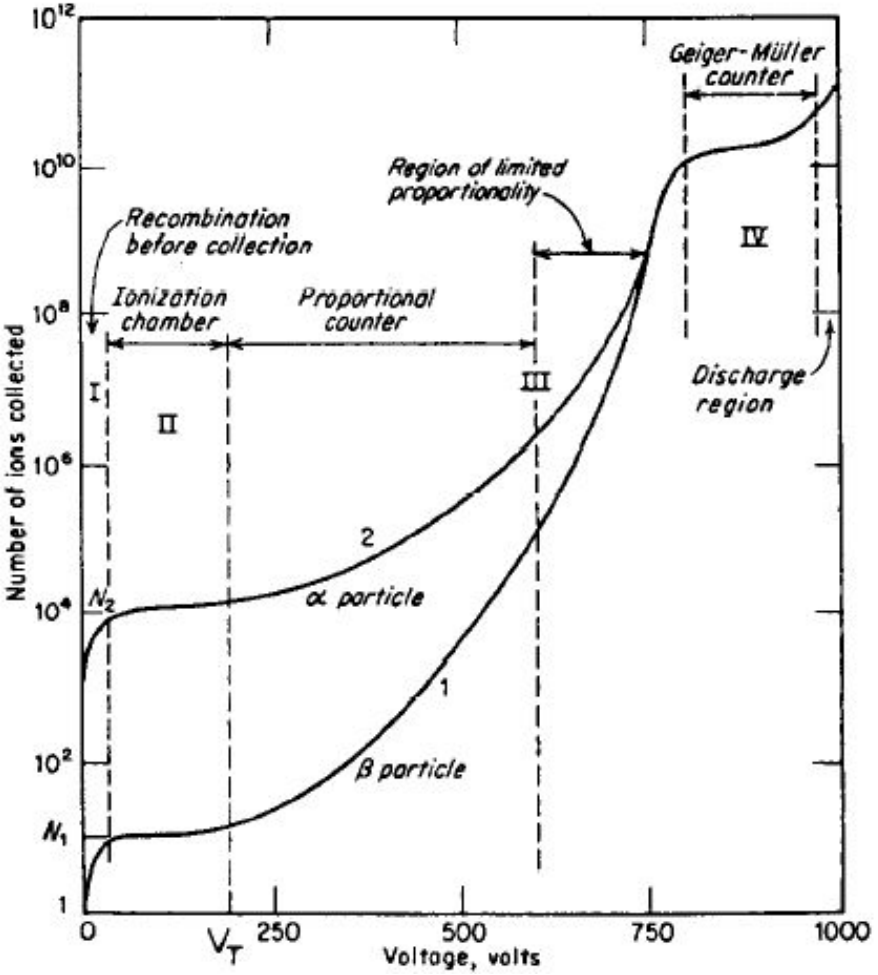
PHENIX – MUTR

- Precise position coordinate determined from induced signal on cathode strips $\perp$ to sense wires



PHENIX – FORWARD DETECTORS MUID

- Iarocci tubes
  - Single wire drift chambers in the outer layers of large detectors to detect muons
  - Tubes usually run in streamer mode self-quenching discharge operation

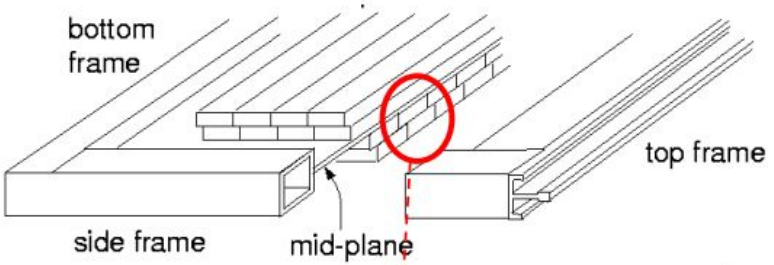


PHENIX – MUID

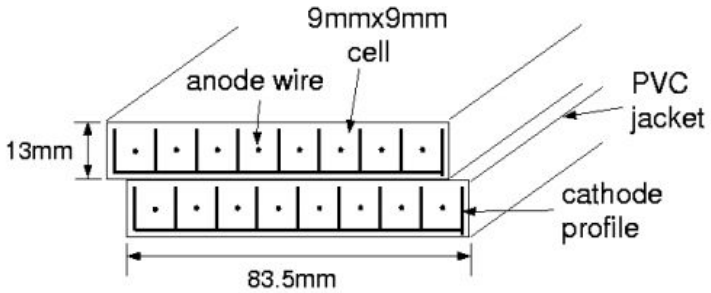
Muon Identifier

5 gaps per arm filled with planes of transversely oriented plastic proportional (Iarocci) tubes

- 4 large panels and 2 small panels in one layer (gap)
- In a panel, Iarocci tubes with 2.5~5.6m length and 8.4cm width run both horizontally and vertically
- 6340 tubes (3170 channels) / Arm



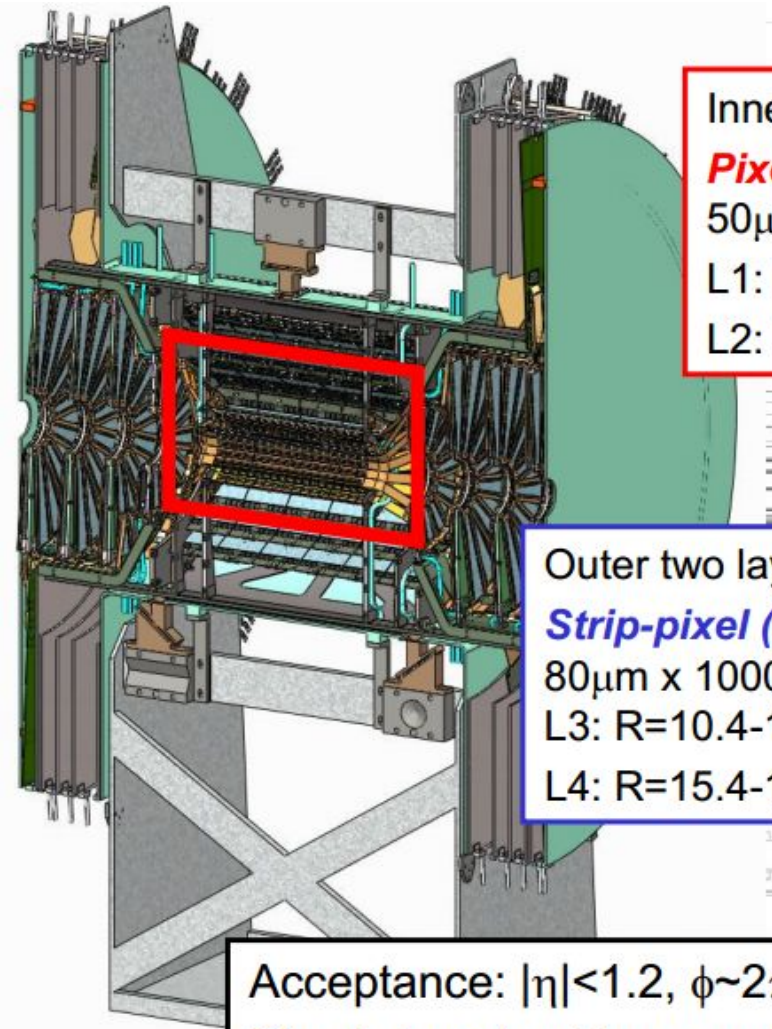
Cross section of the MuID panel



Cross section of the plastic tube(2-pack)

- One channel consists of two staggered tubes for better efficiency and faster drift time
- Those two layers are in different HV and gas chains to minimize dead channels

PHENIX – UPGRADES VTX



Inner two layers:

Pixel detector

50μm x 425μm pixel pitch

L1: R=2.5cm Δz=±10cm

L2: R=5.0cm Δz=±10cm

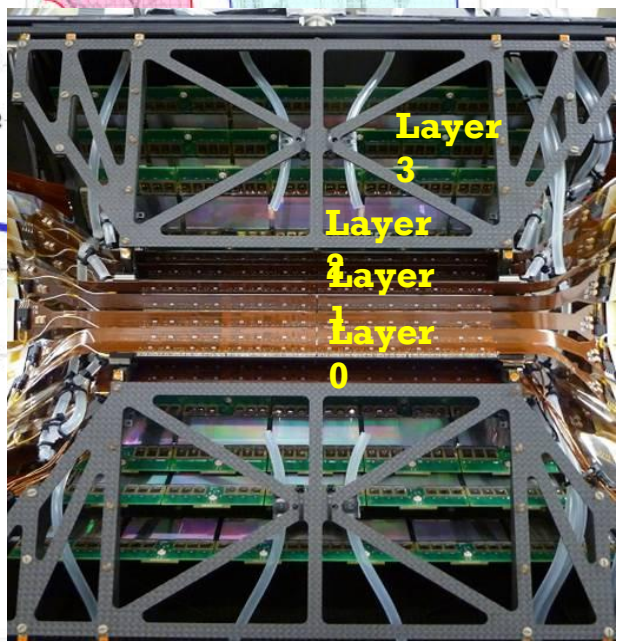
Outer two layers:

Strip-pixel (Stripixel) detector

80μm x 1000μm pixel pitch

L3: R=10.4-12.8cm Δz=±16cm

L4: R=15.4-17.6cm Δz=±19cm



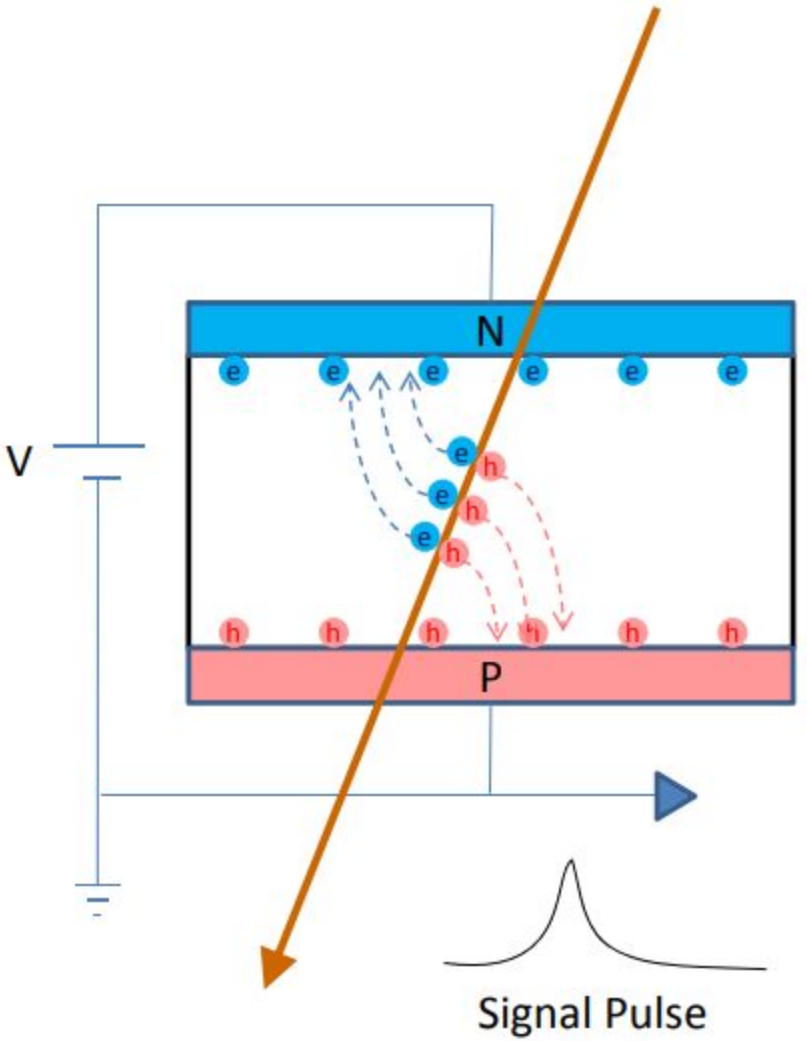
Acceptance: $|\eta|<1.2$, $\phi\sim 2\pi$ (145°/each arm)

Standalone tracking capability

Installation in Fall 2010

PHENIX – UPGRADES VTX

- Charged particle traversing PN junction creates electron-hole pairs
- Electron and hole drift to opposite electrodes
- Superior position resolution precision physics

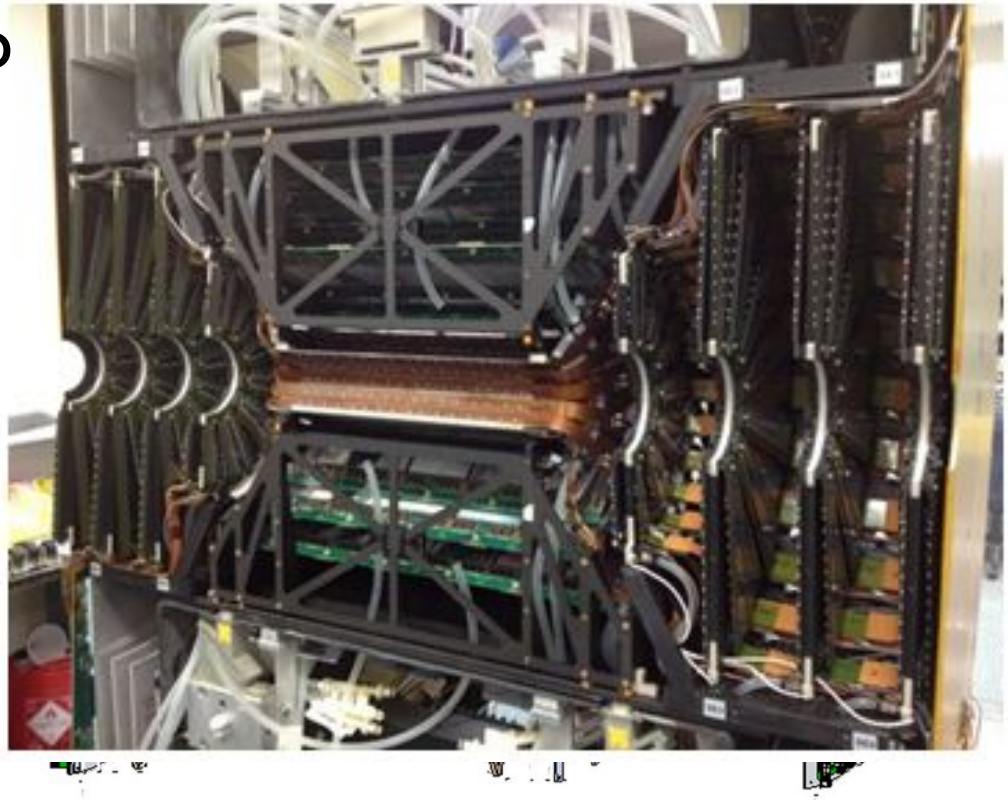


PHENIX – UPGRADES FVTX

94

Silicon sensor thickness (μm)	320
Strip pitch (μm)	75
Nominal operating sensor bias (V)	+70
Strips per column for small, large wedges	640, 1664
Inner radius of silicon (mm)	44.0
Strip columns per half-disk (2 per wedge)	48
Mean z-position of stations (mm)	±201.1, ±2
Silicon mean z offsets from station center (mm)	±5

- Four planes per end-cap
- Coverage
  - $1.2 < |\eta| < 2.4$
  - 2π in azimuth
  - 18.5 cm < |z| < 38 cm
- Resolution
  - Hit < 25 μm
  - DCA < 200 μm



PHENIX – UPGRADES HADRON BLIND DETECTOR HBD

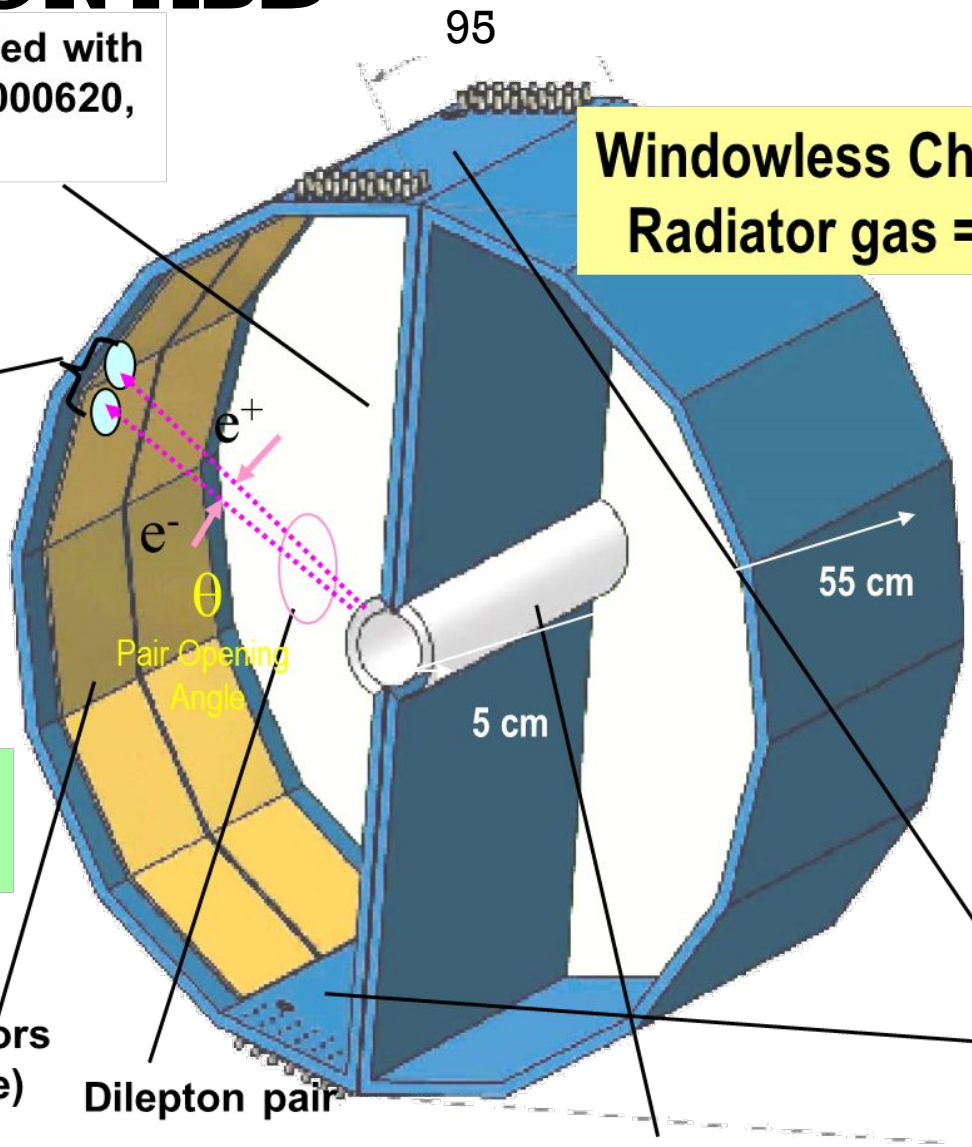
HBD Gas Volume: Filled with CF_4 Radiator (n_{CF4}=1.000620, L_{RAD}=50 cm)

Windowless Cherenkov Detector
Radiator gas = Avalanche Gas

Cherenkov light forms "blobs" on an image plane (r_{BLOB}~3.36cm)

Pcb pad readout (~ 2x2 cm^2)

CsI photocathode covering GEMs



Electrons radiate, but hadrons with P < 4 GeV/c do not

Triple GEM detectors (12 panels per side)

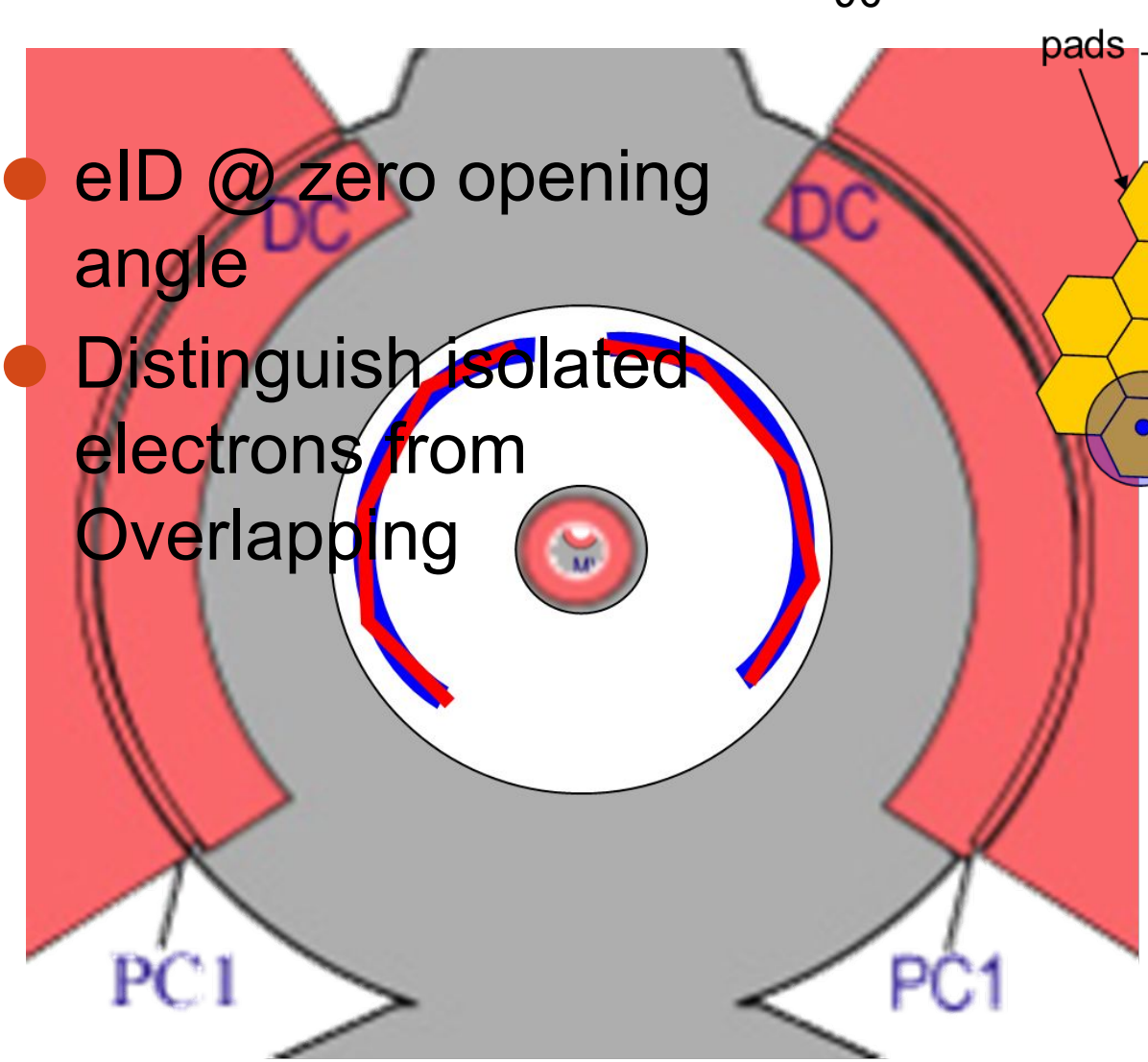
Dilepton pair

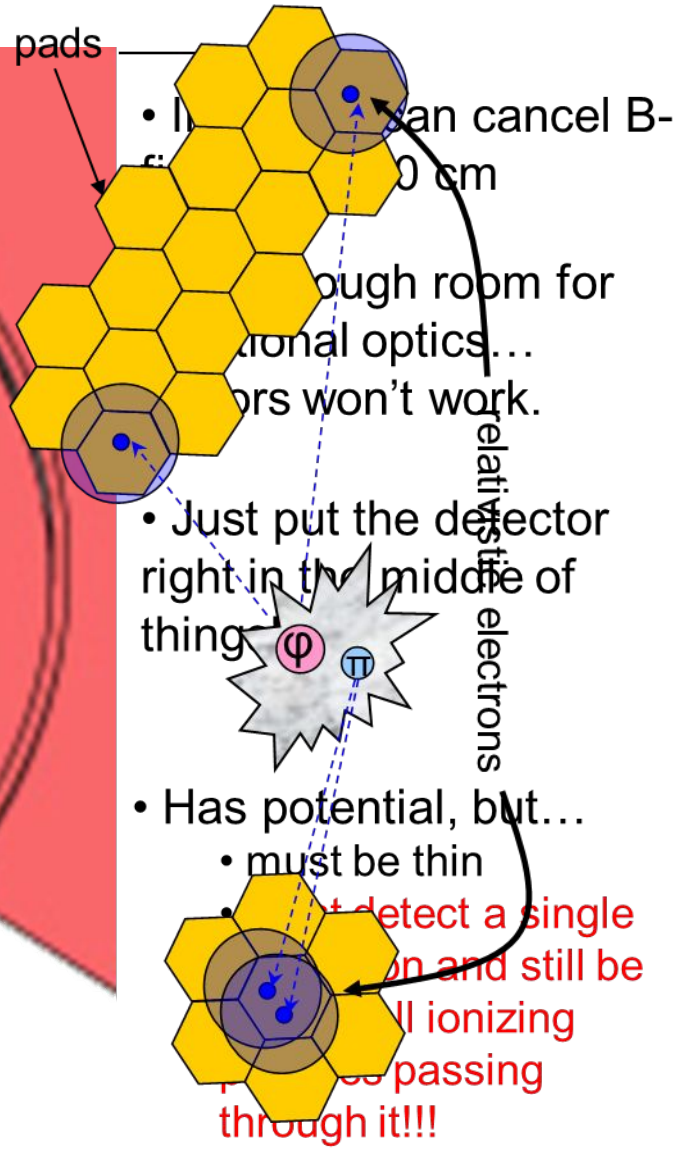
Beam Pipe

Space allocated for services

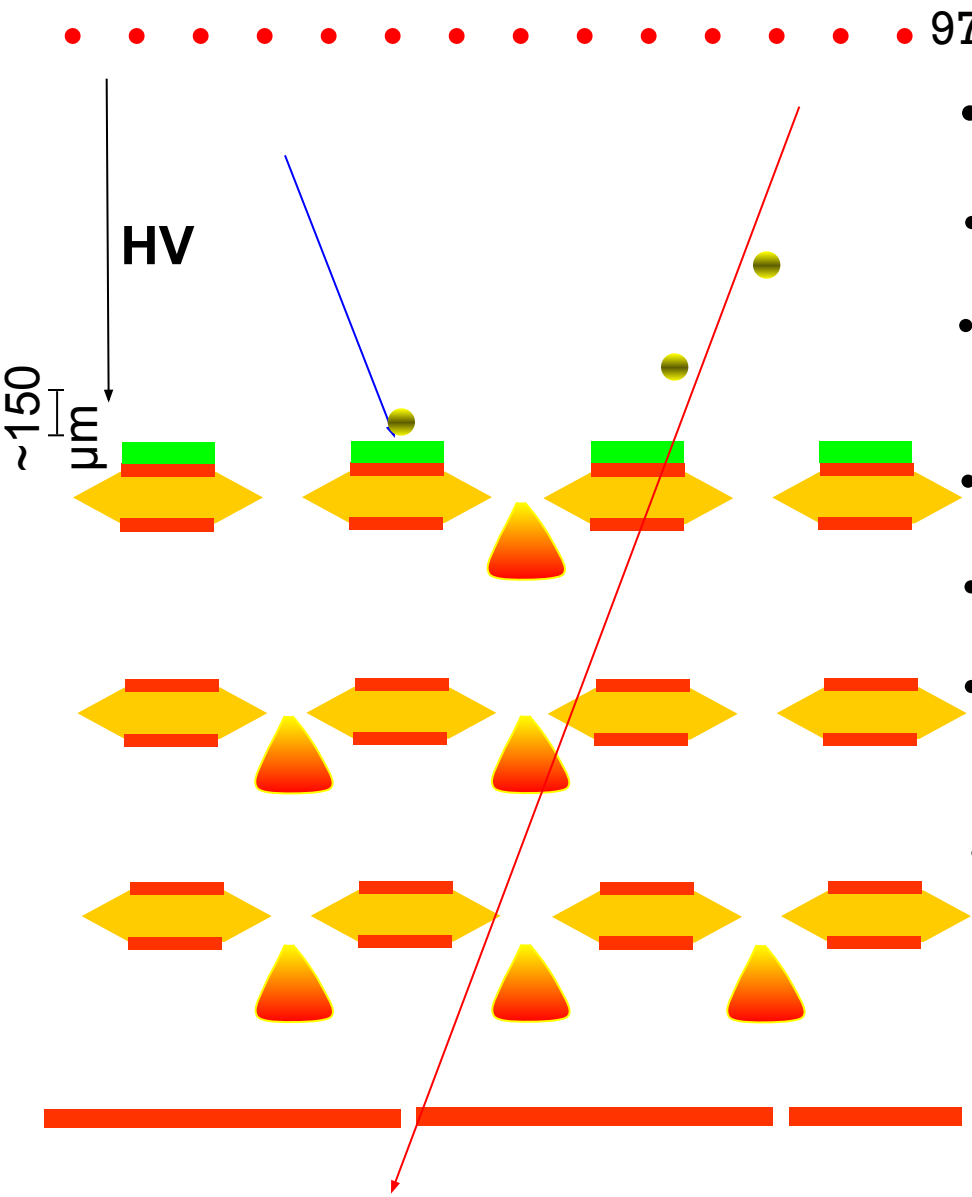
PHENIX – HBD

- eID @ zero opening angle
- Distinguish isolated electrons from Overlapping





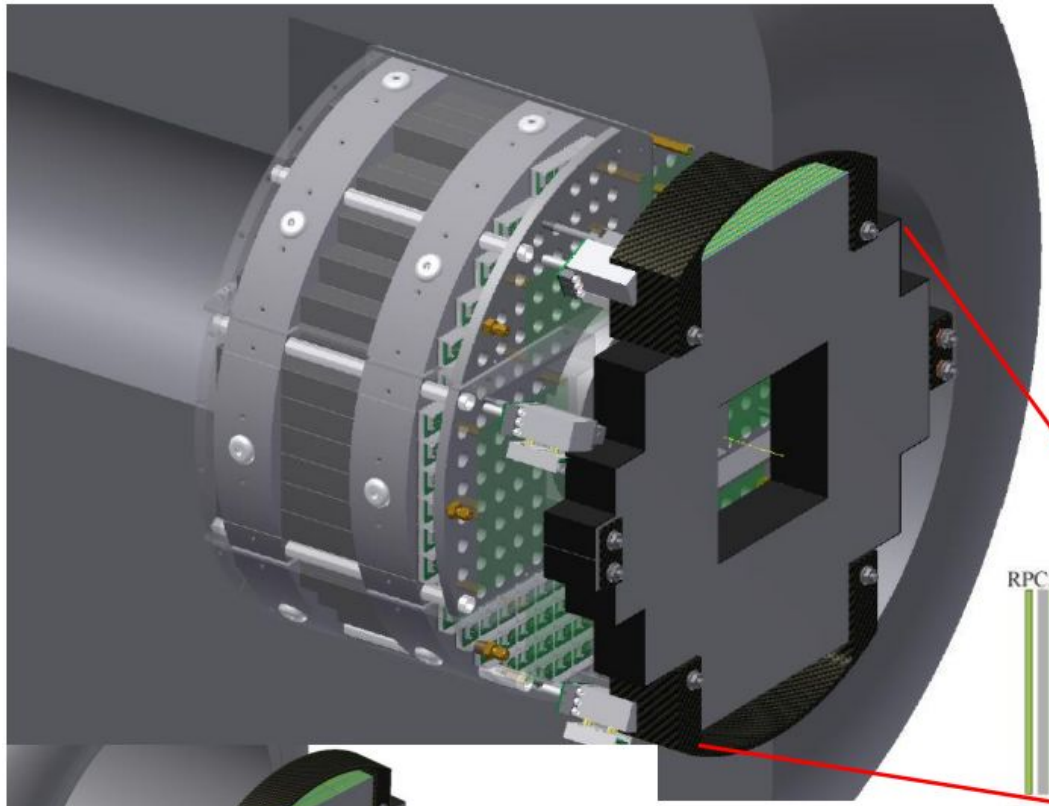
PHENIX – HBD

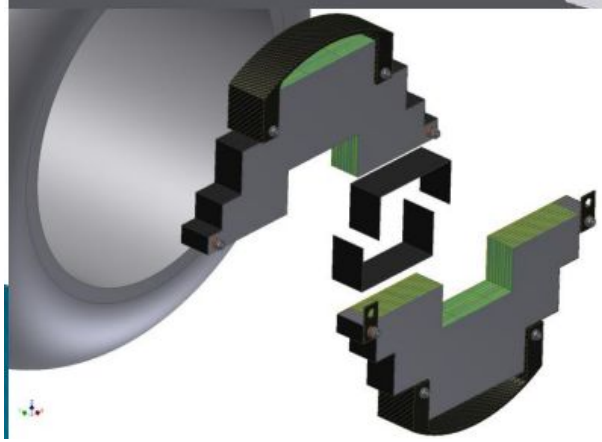


By T. K. Hemmick

- Start with a GEM
- Put a photocathode (CsI) on top
- photoelectron from Cherenkov light avalanches in the high density E-field
- Use more GEMs for larger signal
- Pick up the signal on pads
- What about ionizing particles (hadrons)?
- We need a mesh with a reverse voltage on it to blow electrons away!!!
- We have a detector sensitive to UV and ~blind to ionizing particles!

PHENIX – UPGRADES MPC-EX

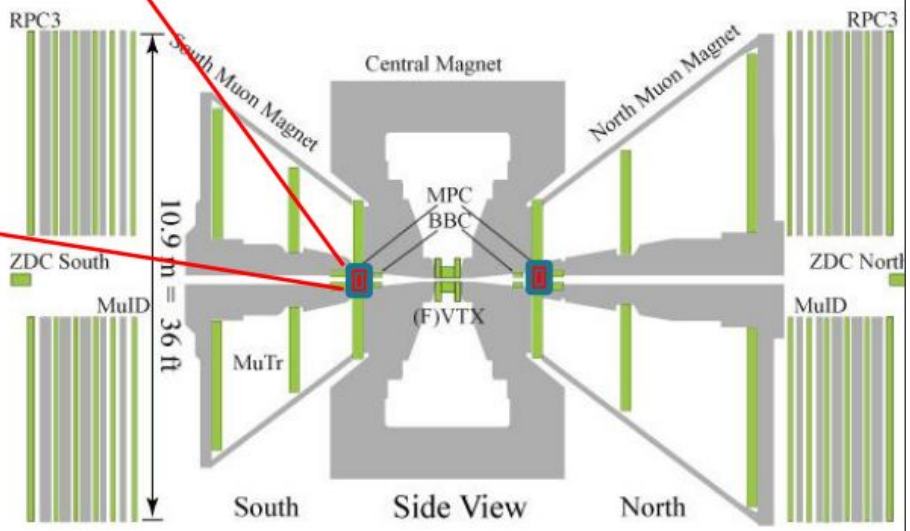




A combined charged particle tracker and EM preshower detector – dual gain readout allows sensitivity to MIPs and full energy EM showers.

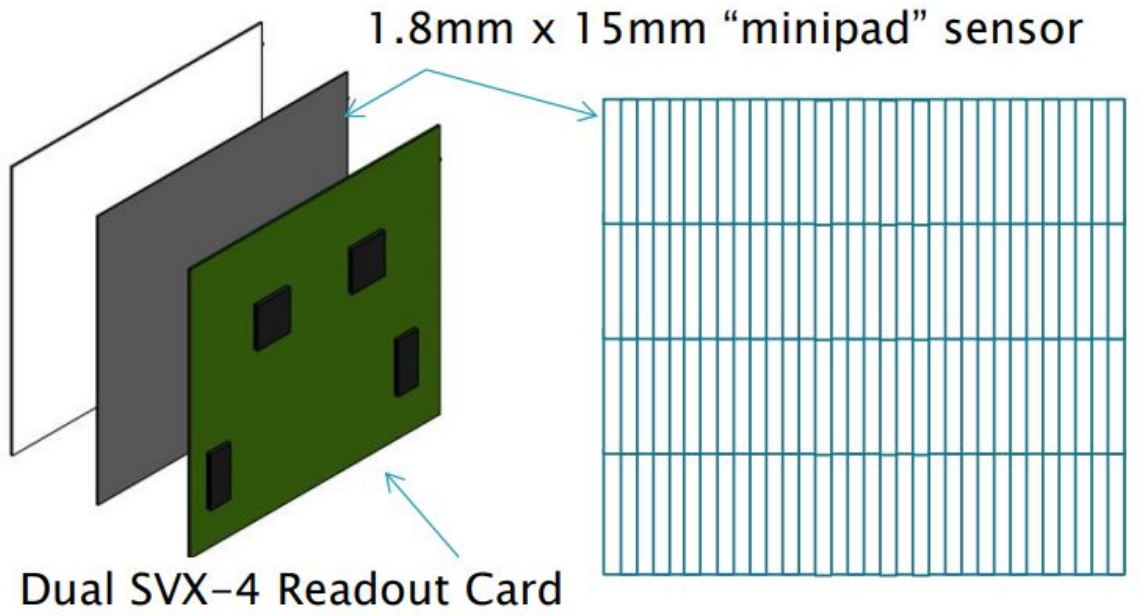
- π^0 rejection (direct photons)
- π^0 reconstruction out to >80GeV
- Charged track identification

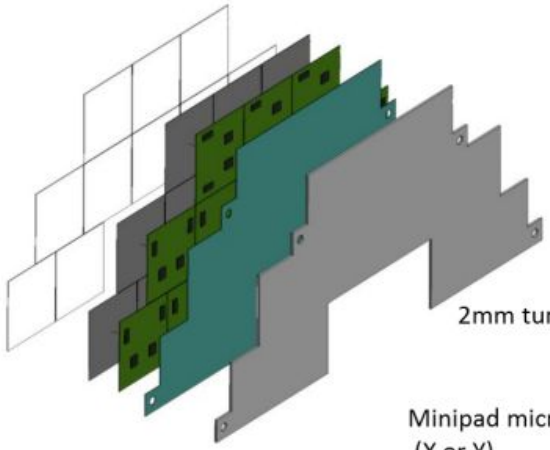
$3.1 < \eta < 3.8$



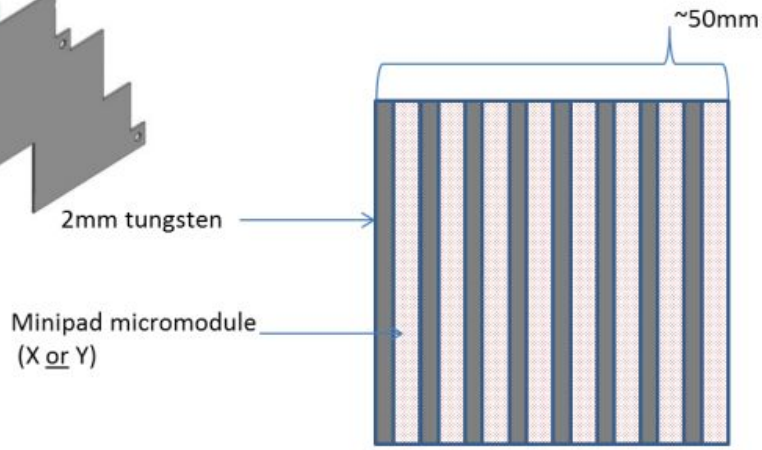
PHENIX – MPC-EX

Detector elements are Si "minipad" detectors, one layer per tungsten gap, oriented in X and Y (alternating layers).





Cross-Section View:



PHENIX – ENJOY YOUR ANALYSIS