Hadron blind RICH Detectors

Roman Gernhäuser, TU-München

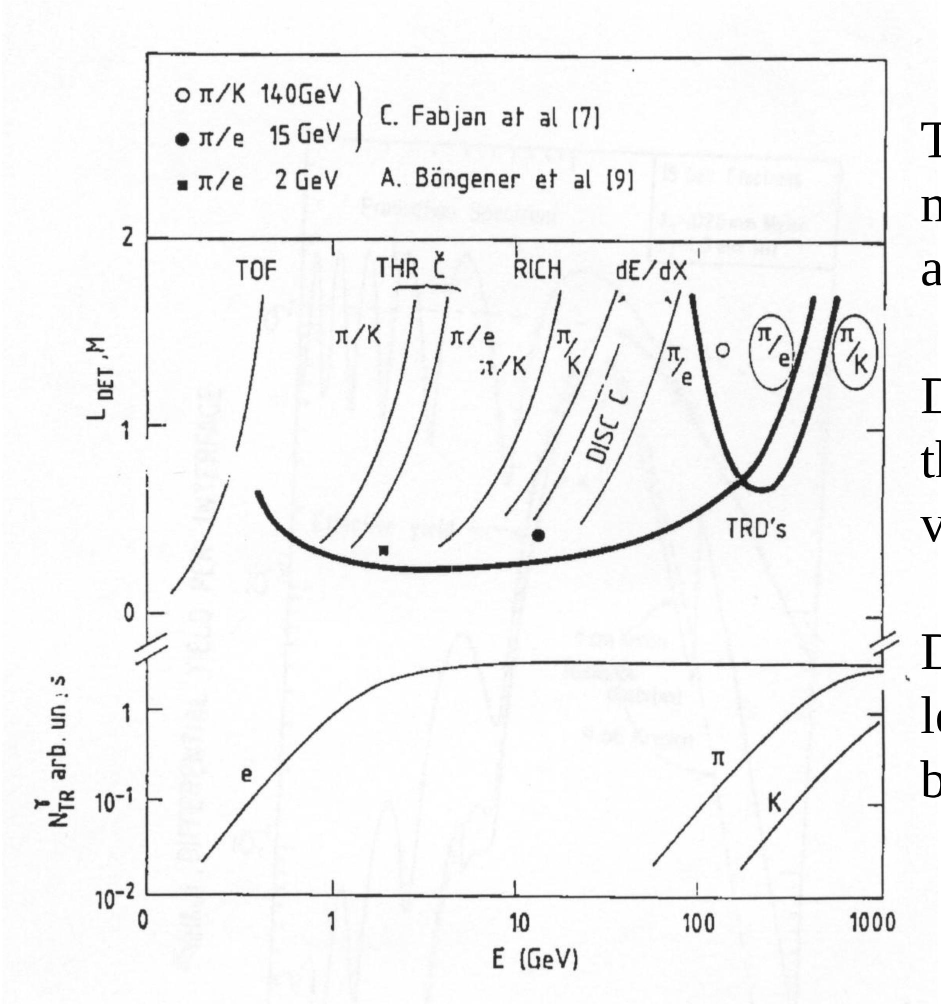
•Introduction or “why do we need HBR?“

•Phenix and HADES

•Combinatorial Background

•Online Data Processing

π / e Separation



There is a number of powerful methods to identify particles over a wide range of momentum

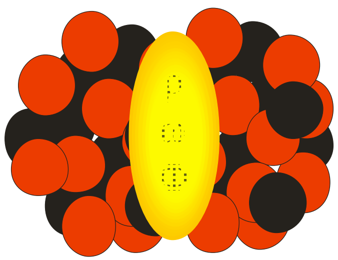
Depending on the environment and the space, the identification power varies significantly.

Do we need RICH detector for lepton ID ⇔ do we need Hadron blind RICH detector

S. Paul CERN/PPE 91-199

Physics Goals

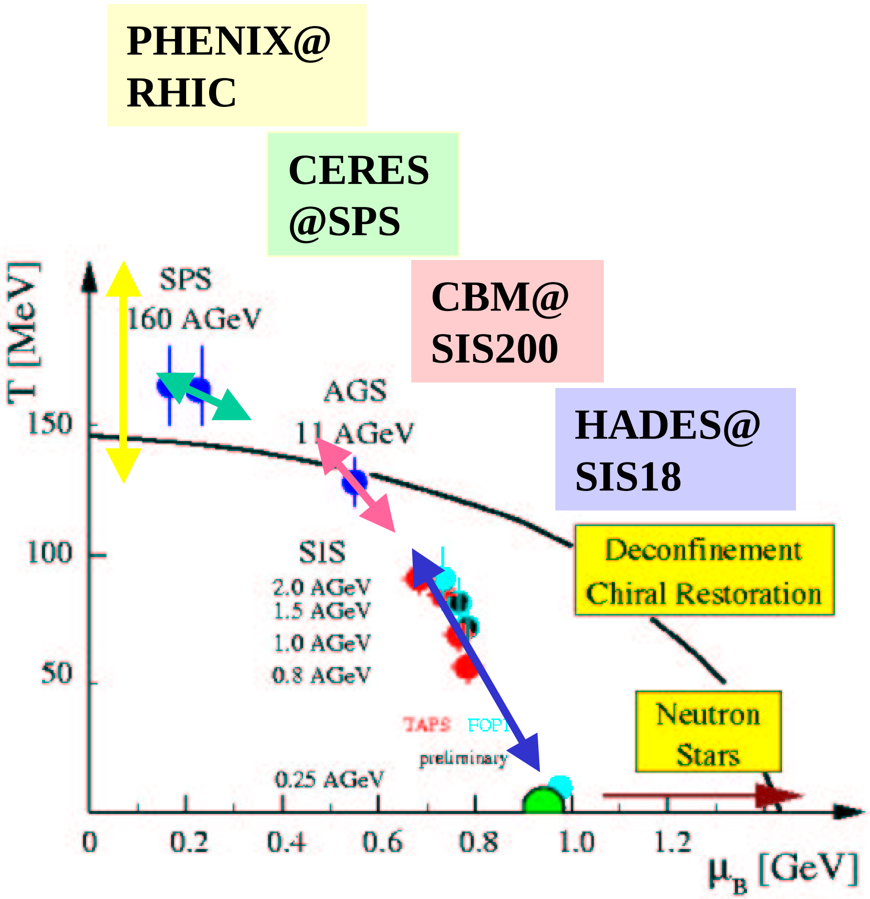
- Study of QCD in extreme conditions
    - heavy ion physics - hot and dense limit
    - origin of the mass
- Heavy Ion Physics
    - Quark Gluon Plasma - characterize its physical properties



Probes:

γ, γ^* => $e^+ e^-$

weak final state interaction

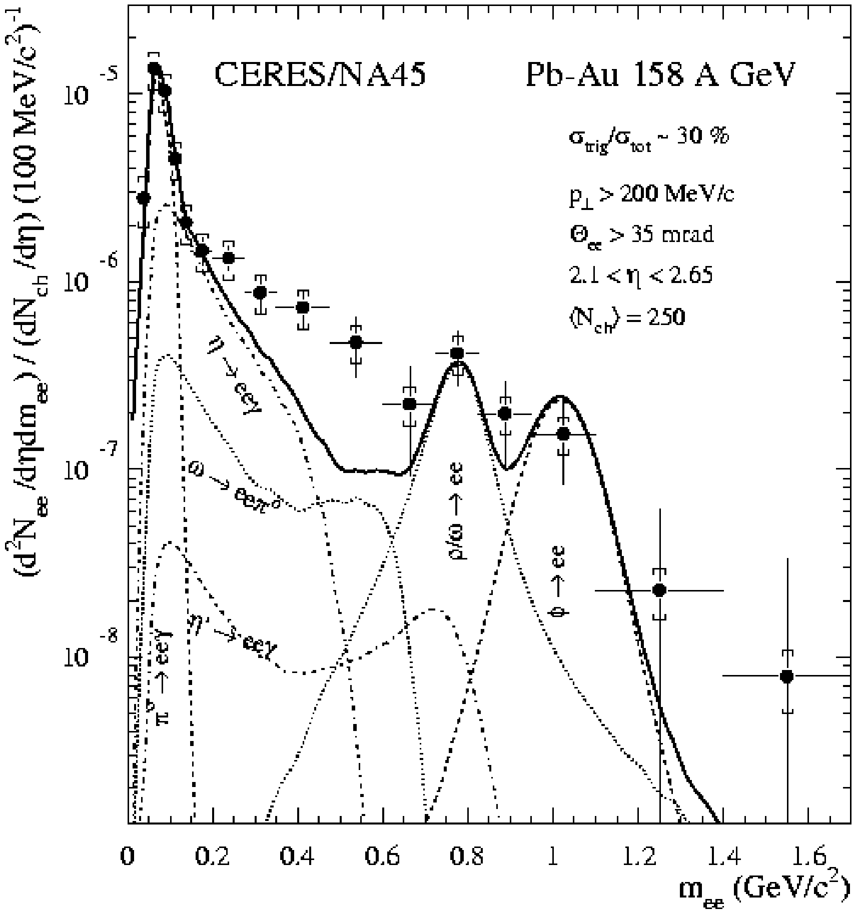


Shopping List

- Observe vector meson decaying into e^+e^-
  - Modification of the peak position or width of invariant mass spectra as a result of partial restoration of chiral symmetry in hot dense medium
  - $\phi \rightarrow e^+e^-$, $\omega \rightarrow e^+e^-$, $\rho^0 \rightarrow e^+e^-$, etc.
- Observe J/ψ decaying into e^+e^-
  - First observation in high energy heavy ion collisions
  - Prediction of the suppression (dissociation of *c*-*c*bar) or enhancement

    (another coalescence of *c*-*c*bar?) of J/ψ in hot dense medium.
- Observe direct photon via conversion electrons (γ + stuff $\rightarrow e^+e^-$)
- Observe low-mass dilepton continuum ($\gamma^* \rightarrow e^+e^-$)
  - Same property to the direct <u>real</u> photon. Thermal emission from QGP state
- Observe semi-leptonic decay of open charm or beauty
  - $D \rightarrow e$+X, $B \rightarrow e$+X
  - Charm or Bottom enhancement in hot dense medium

Low Mass Dilepton Continuum



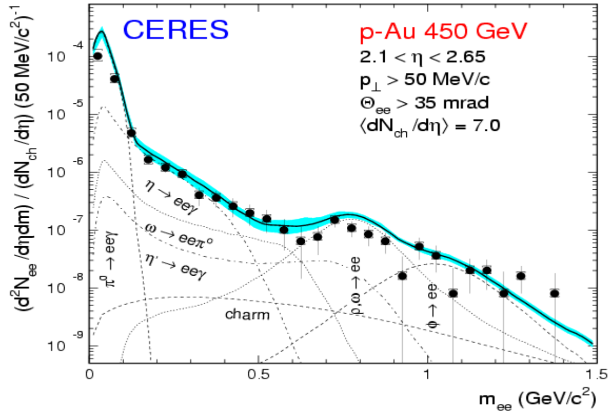
Strong enhancement of low-mass e^+e^- pairs in A-A collisions

(wrt expected yield from known sources

Enhancement factor **(.25 <m<.7GeV/c^2) :**

2.6 ± 0.5 (stat) ± 0.6 (syst)

No enhancement in pp and pA collisions



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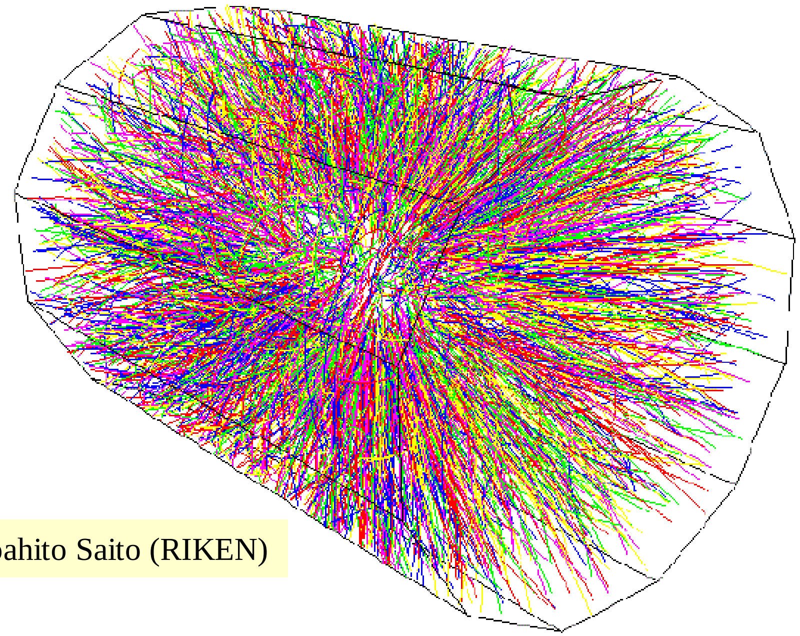
HI Collision in STAR



Noahito Saito (RIKEN)

Access high temperature and density
=> highest multiplicity events
up to 5000 / 4π Au +Au @ 200GeV
up to 200 / 4π Au +Au @ 2GeV

>>Hadron Blind <<

Meson	Mass (MeV/c^2)	Γ (MeV/c^2)	dominant decay	$\Gamma e^+e^-/\Gamma$
ρ	769	150	2π	**$4.5\ 10^{-5}$**
ω	783	8.5	2π	**$7.1\ 10^{-5}$**
φ	1019	4.5	2K	**$2.9\ 10^{-4}$**
J/Ψ	3096	0.087	hadron	**$5.9\ 10^{-2}$**

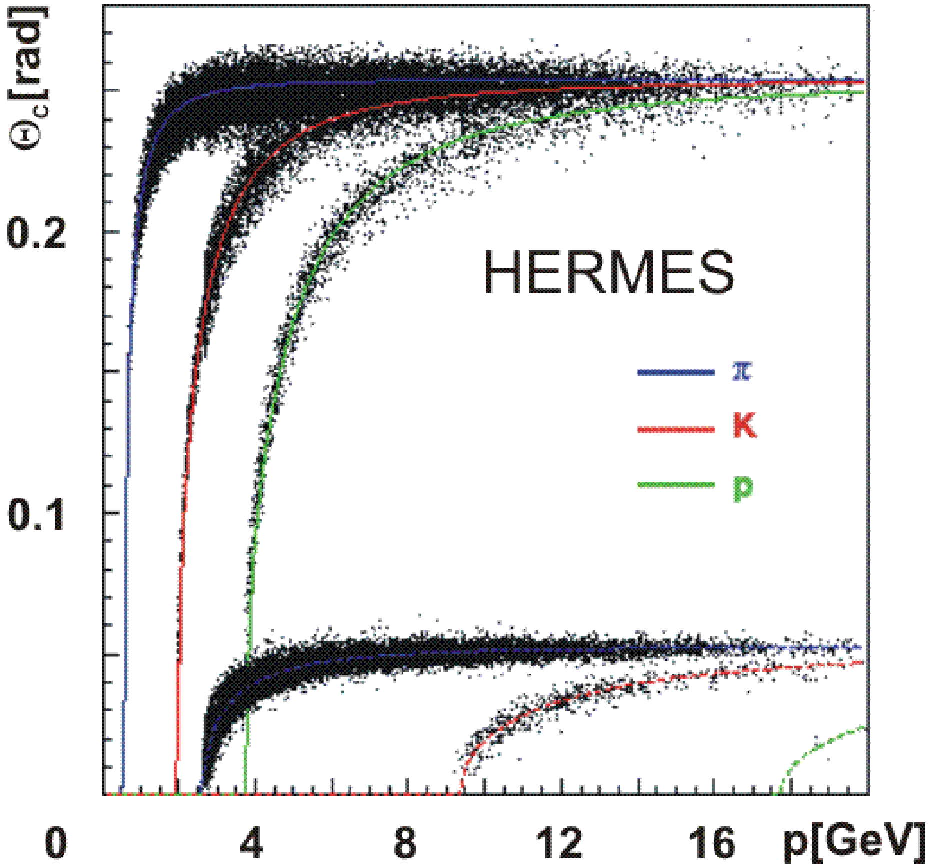
Access rare probes
=> highest reaction rates up to
10 MHz (CBM), 1MHz (HADES),
400kHz (PHENIX)

>>Lepton Trigger <<

Cherenkov Ring Radii and γ_{thr}

$$\cos\Theta_C = \frac{1}{\beta \cdot n}; \quad \Rightarrow \quad \gamma_{thr} = \frac{1}{\sqrt{1 - 1/n^2}}$$

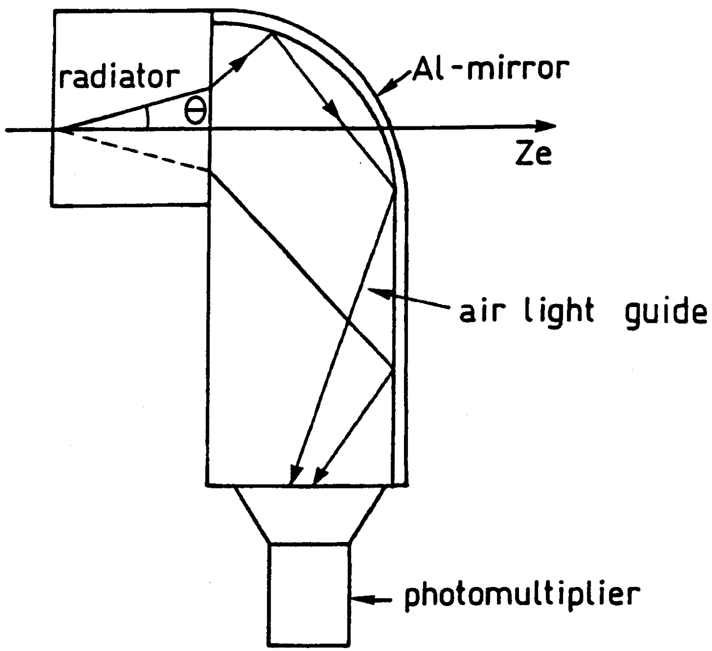
Radiator	$\gamma_{threshold}$	λ threshold [nm]	n-1 [10^{-4}]	Θ_C [deg.] max.
He	120	<125	0.35	0.4
Ne	64	<125	3.0	1.4
N2	41	<140	2.98	1.4
CH4	33.6	145	4.44	1.7
C4F10	18	145	15.1	3.15
Aerogel	3-5	>350	300-600	13 - 22
L_C_4F_{10}	1.63	145	2660	37.8
L_C_6F_{14}	1.60	160	2770	38.8
MgF_2	1.39	130	4373	45.9
Quartz	1.29	165	5880	51

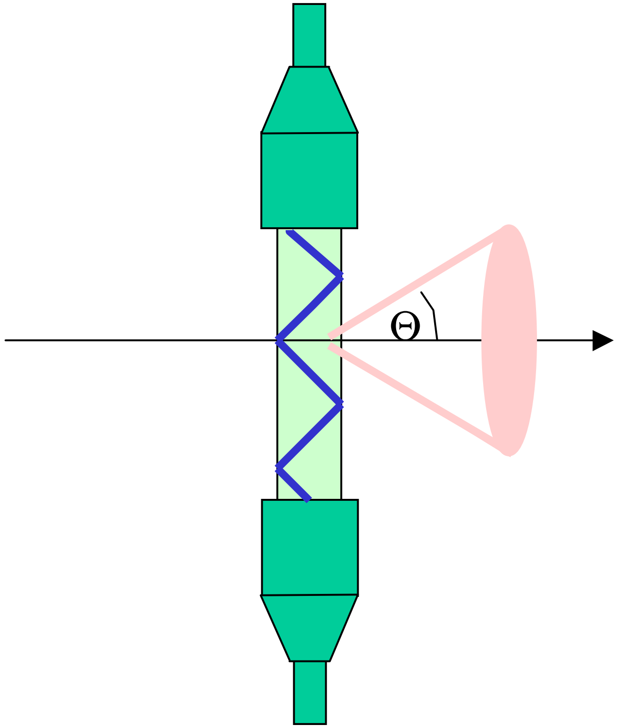


n1=1.03 (Aerogel)
n2=1.00151 (C4F10)

T. Ekelöf, CERN-EP/84-168

Threshold Cherenkov Counter





Performance at the threshold limits thr. Cherenkov counters:

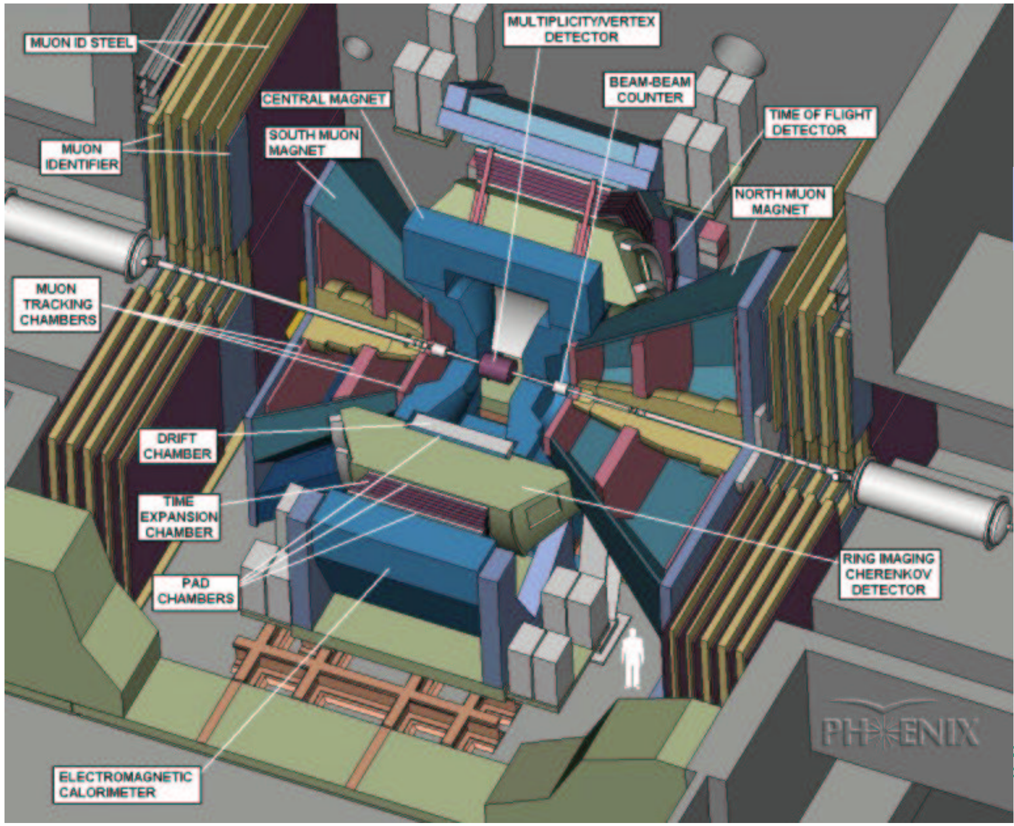
- δ-electron, from particles $\beta < \beta_{th}$
- scintillation light
- direct hits of particles
- dispersion smears out the threshold

moderate
hadron suppression

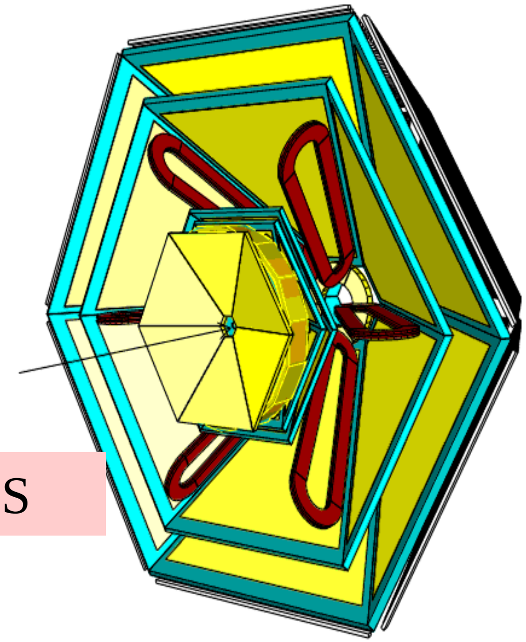
Two Hadron Blind RICH Detectors

1. photon detector out of active area
2. low material budget
3. low signal occupancy
4. clear signature
5. good position resolution
6. online hadron suppression

- ➢ significant space requirement
- ➢ challenging mirror technology
- ➢ no material around target
- ➢ high granularity
- ➢ high gain photon detector
- ➢ fast readout



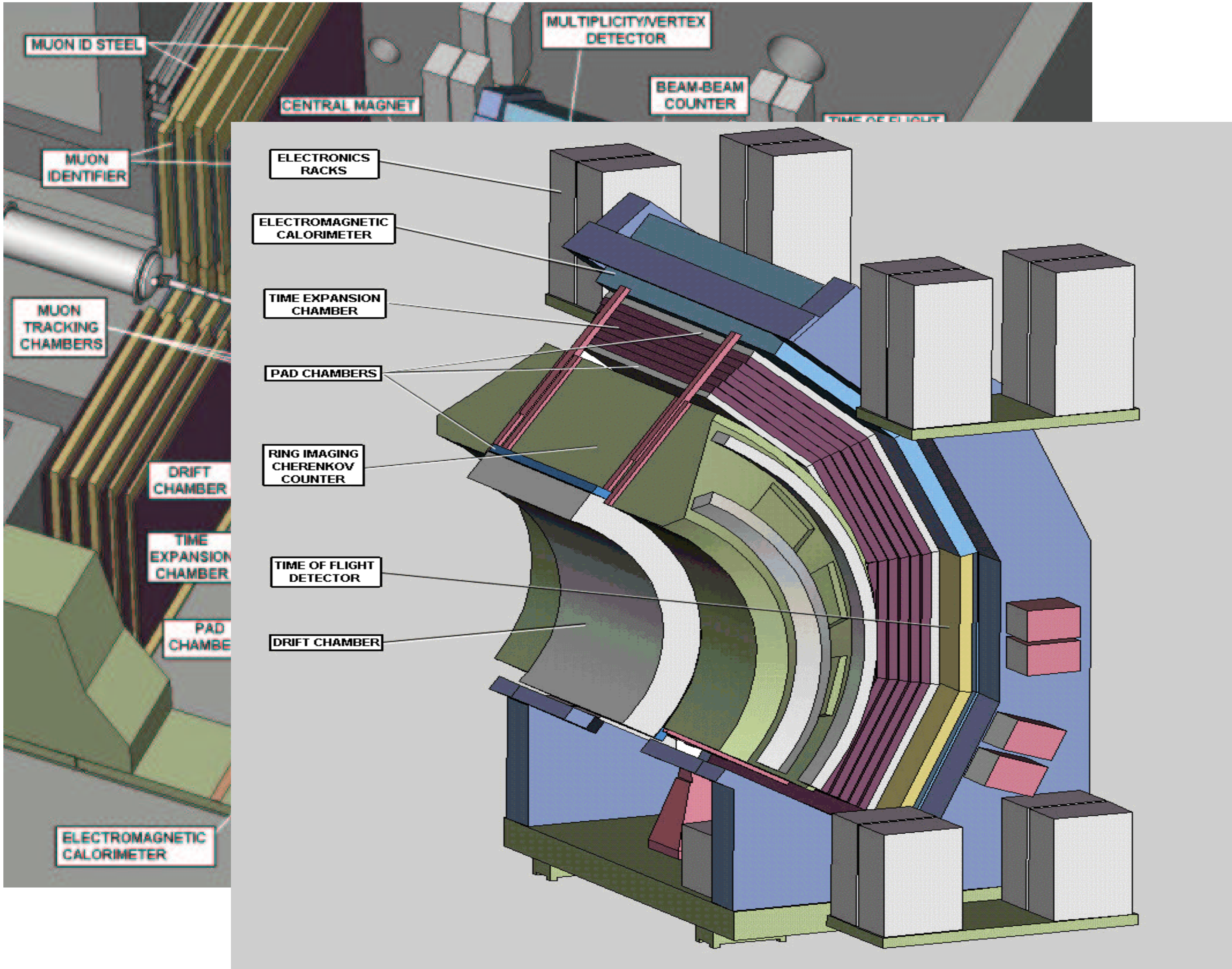
PHENIX



HADES

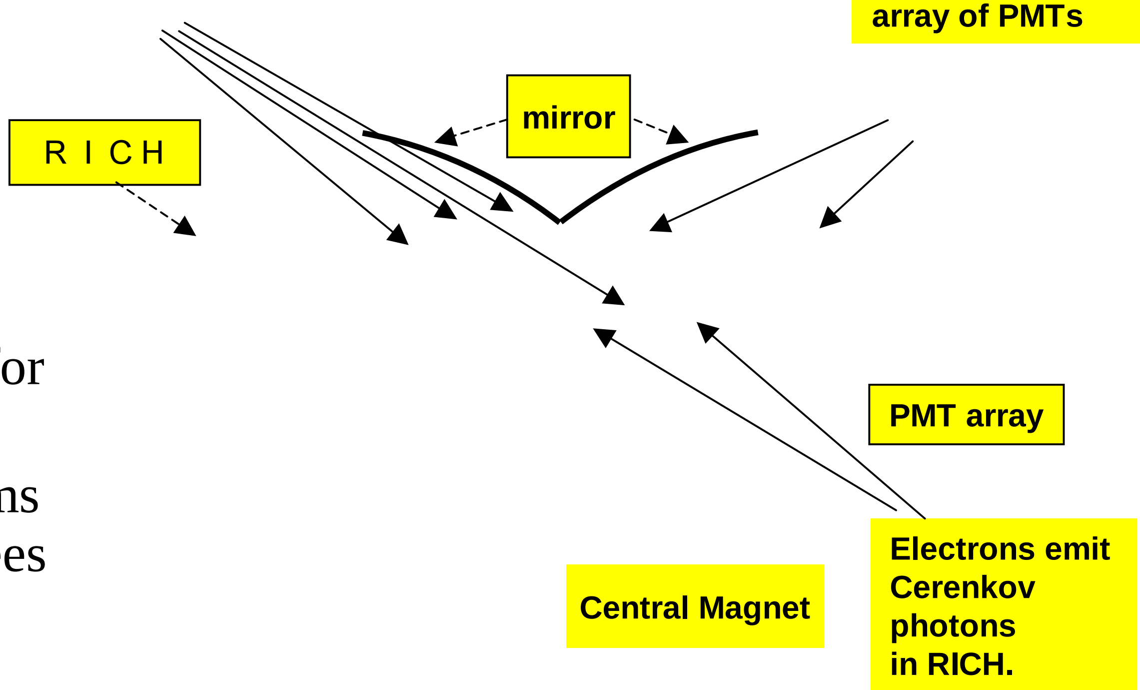
@ERICE

Phenix


MUON ID STEEL
MULTIPLICITY/VERTEX DETECTOR
CENTRAL MAGNET
BEAM-BEAM COUNTER
MUON IDENTIFIER
MUON TRACKING CHAMBERS
DRIFT CHAMBER
TIME EXPANSION CHAMBER
ELECTROMAGNETIC CALORIMETER
ELECTRONICS RACKS
ELECTROMAGNETIC CALORIMETER
TIME EXPANSION CHAMBER
PAD CHAMBERS
RING IMAGING CHERENKOV COUNTER
TIME OF FLIGHT DETECTOR
DRIFT CHAMBER

The Phenix RICH

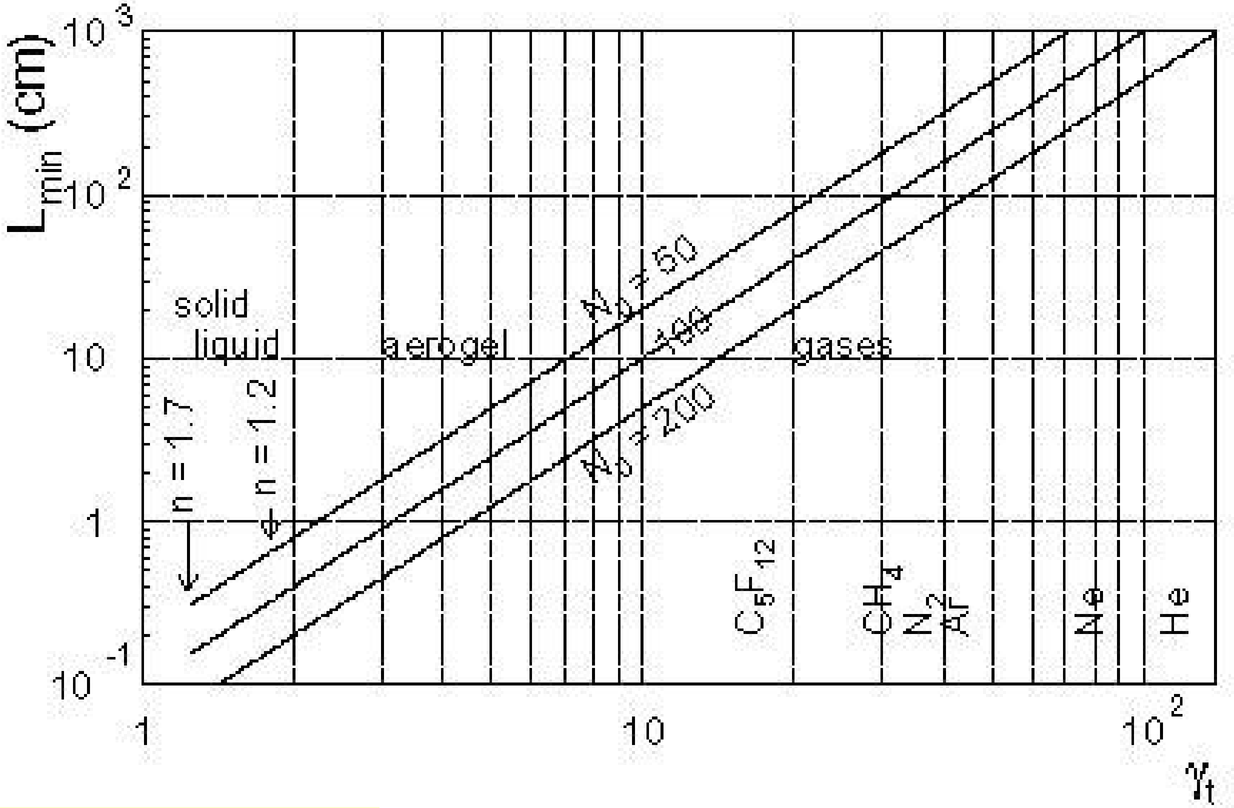
1. photon detector out of active area
2. low material budget
3. low signal occupancy
4. clear signature
5. good position resolution
6. online hadron suppression



- Primary electron ID device of PHENIX
- Hadron rejection at 10^4 level for single track
- Full acceptance for central arms
  - $|y| < 0.35$; $\delta\phi = 90$ degrees
- Threshold gas Cherenkov
  - Using CO_2($\gamma_{th} \sim 35$)
  - eID p_t range : 0.2 ~ 4.9 GeV/c
- PMT array readout
  - pixel size ~ 1 deg. x 1 deg.

Minimum Radiator length

$$N_{det} \approx N_0 \cdot l_{rad} \cdot \frac{1}{\gamma_{thr}^2} \quad > \quad 10$$



P. Glässel, RICH98

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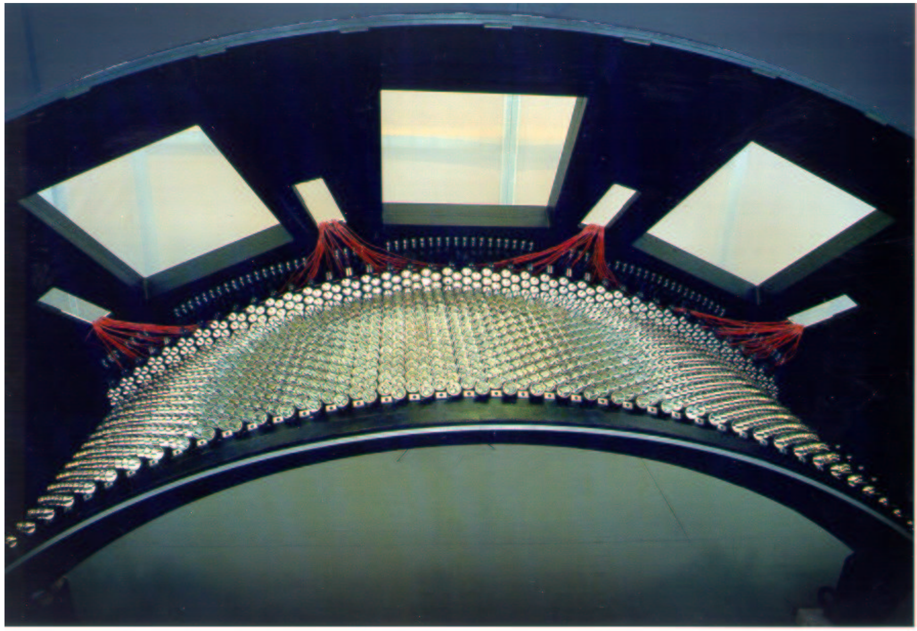
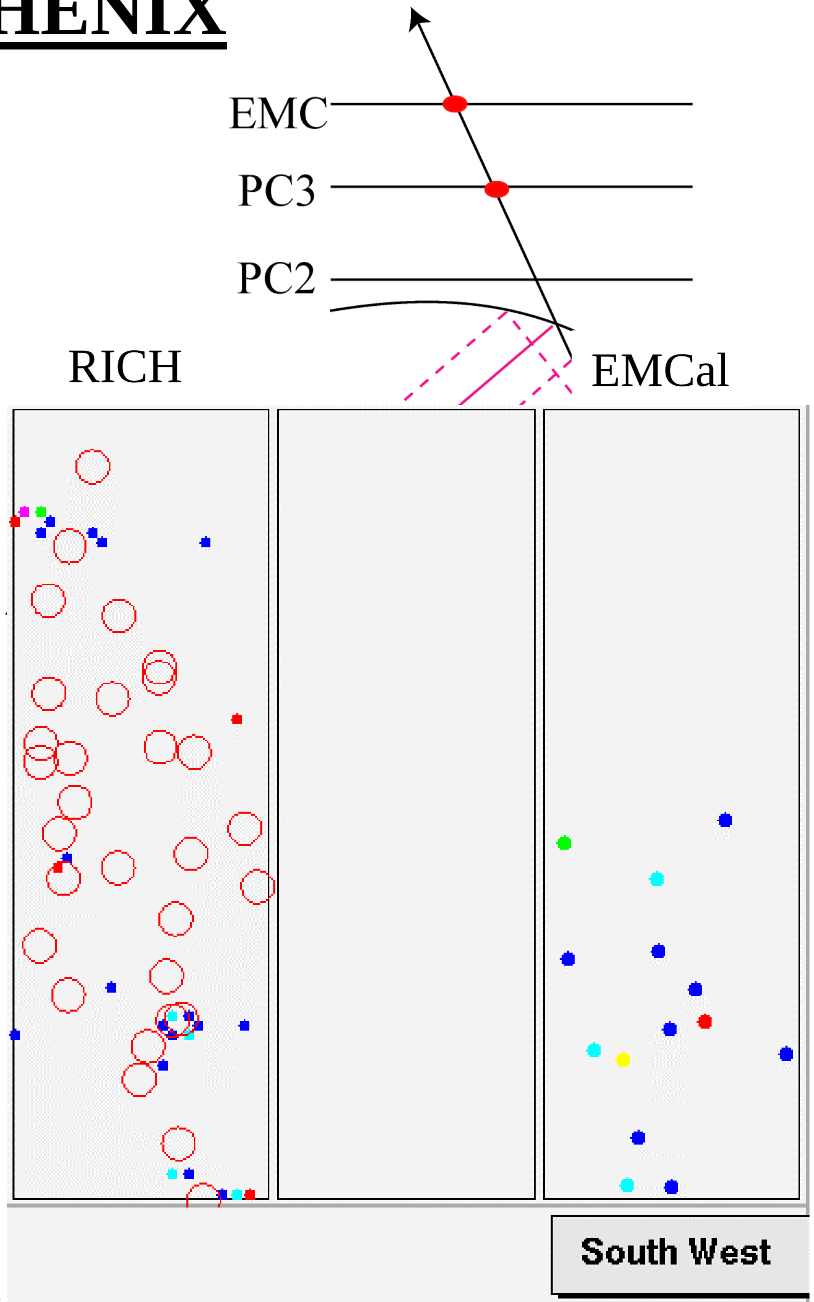
Lepton ID @ PHENIX

- Supermodule (2x16 PMTs grouped) are installed in RICH vessel
- 40 super-modules per one side of a RICH vessel, i.e., 16x80 array = ***1280 PMTs/sector***
- Two arrays per RICH vessel, 4 arrays in two arms.

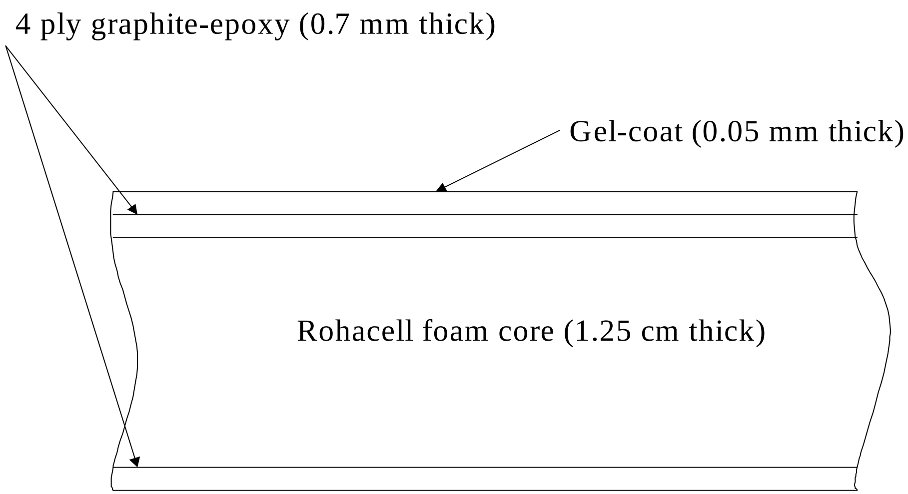
  Total number of PMTs: 5120
- ***8 PMTs*** share the same HV channel





The PHENIX Mirror

- Radiation length
  - –CO_2: 0.41%
  - –Windows: 0.2%
  - –Mirror panels: 0.53%
  - –Mirror support: 1.0%
  - –Total: 2.14%



- Ring center deviation with reference to track: $\Delta\phi = 0.5°$

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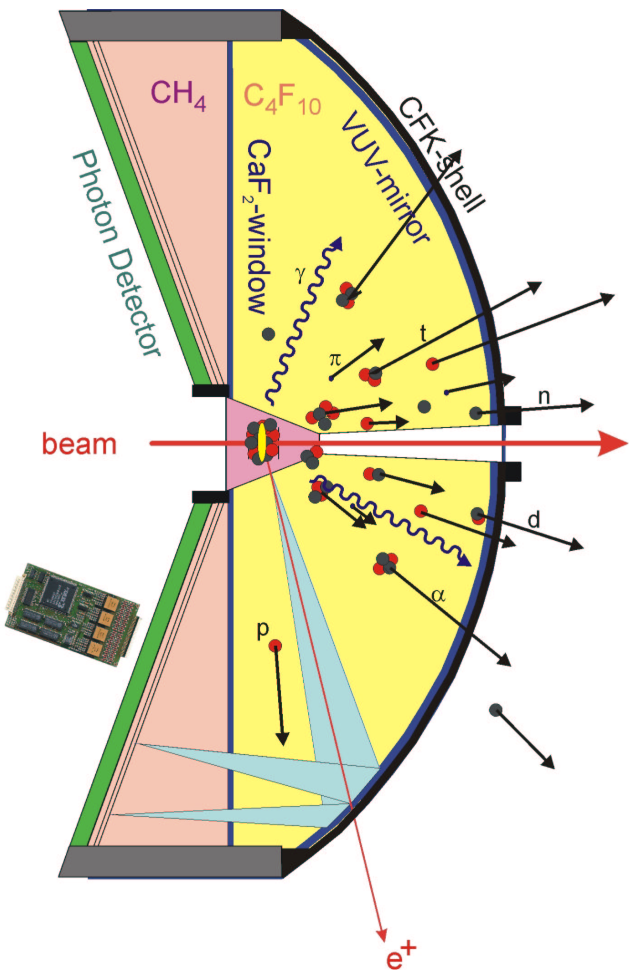
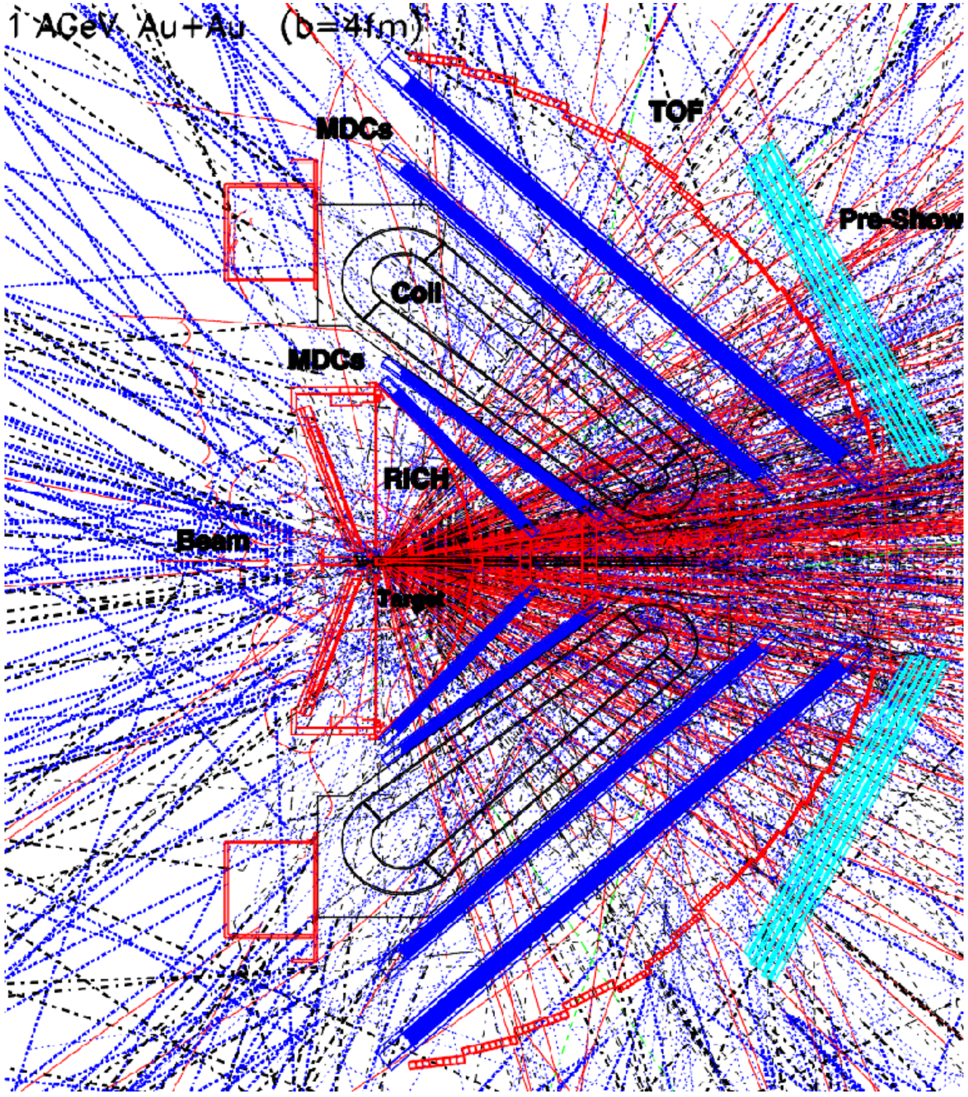
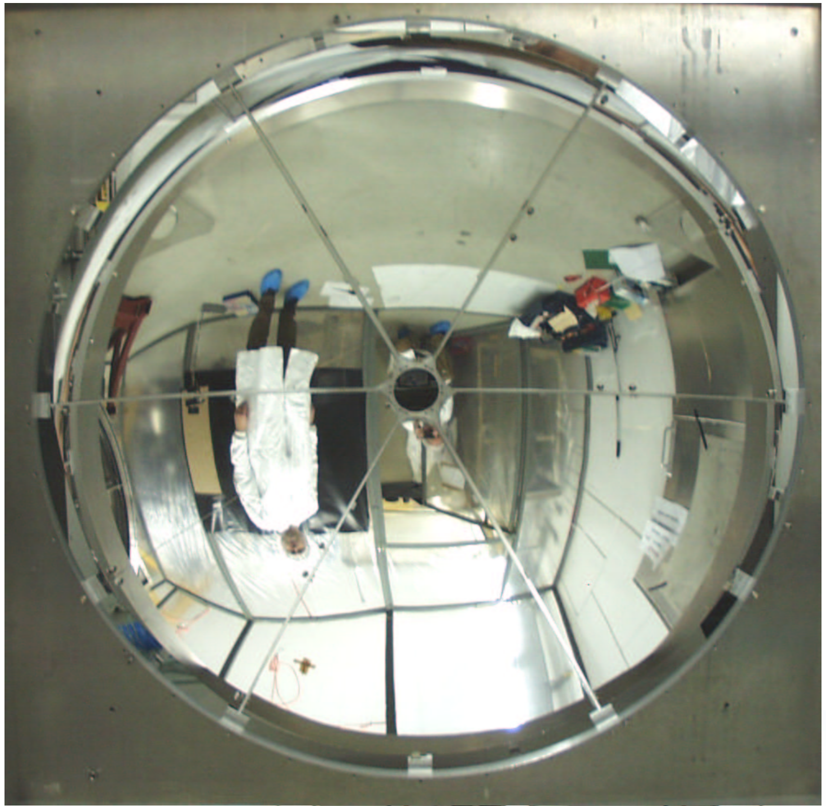
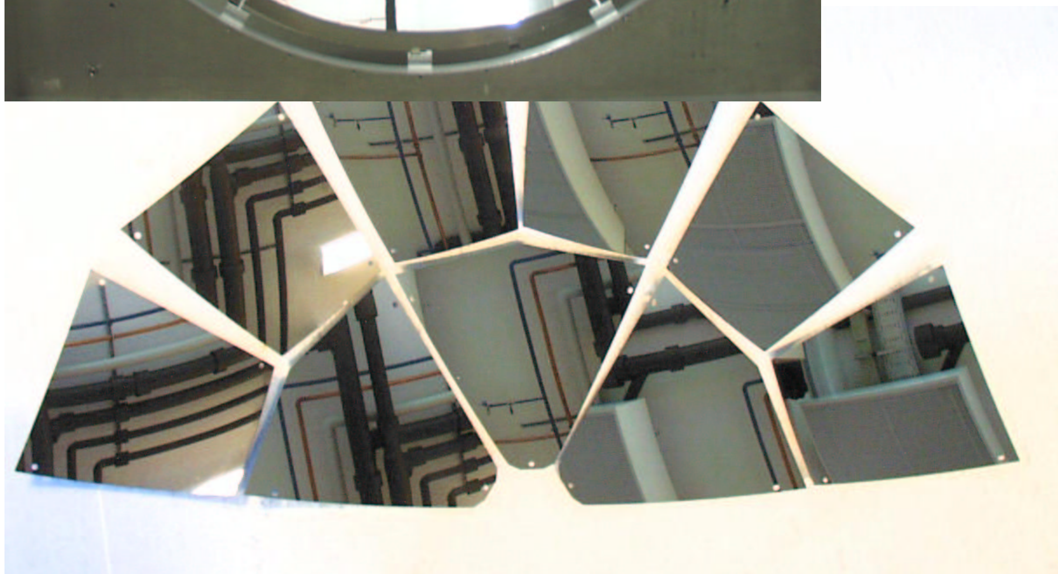
HADES RICH





The HADES Mirror





•Poly – Carbon

pure C – ceramics => polish
ρ= 1.5 [g/cm^3]
E - Mod = 35 [GPa]
stiffness = 260 - 210 [MPa]
direct Al + MgF_2 coating

•Radiation length

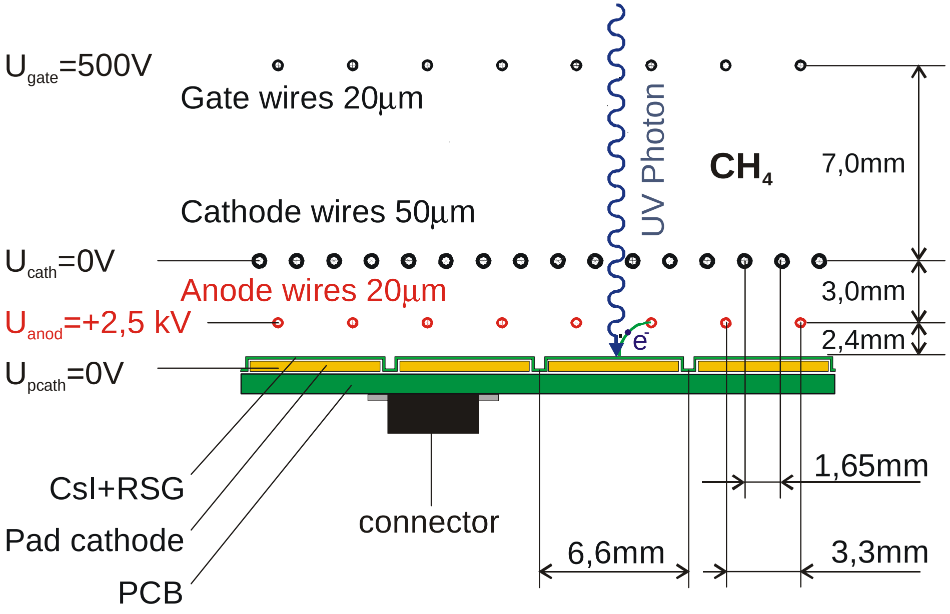
- –C_4F_{10}: 1.5%
- –Windows: 0.2%
- –Mirror panels: 0.73%
- –Mirror support: off acceptance
- –Total: 2.43%

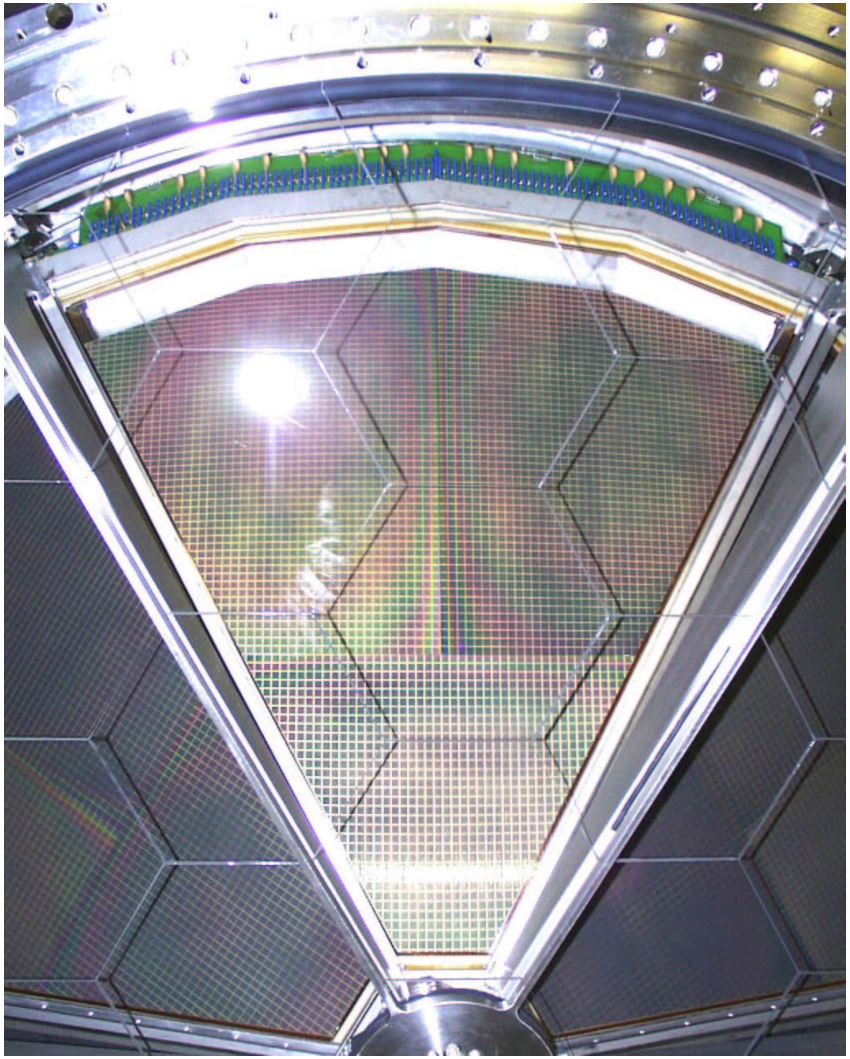
•Ring center deviation with reference to track: $\Delta\phi < 0.2°$

RICE

HADES Photon Detector

- 6 sector shaped MWPCs with 2.4 mm gap
- $5*10^4 <$ gain $< 1*10^5$ @ 2450V
- 28272 pads, GASSIPLX readout
- solid CsI photon converter on special substrate material (RSG)





1. photon detector out of active area
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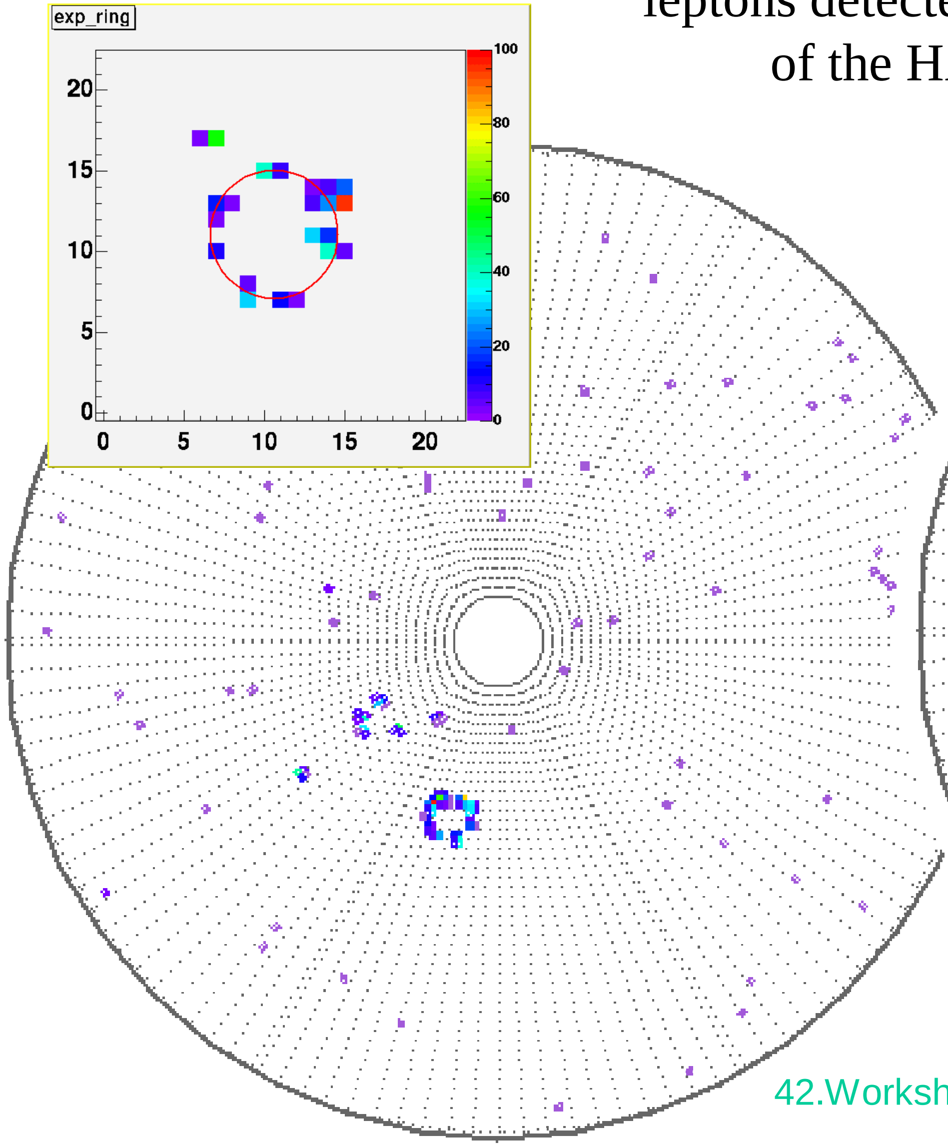
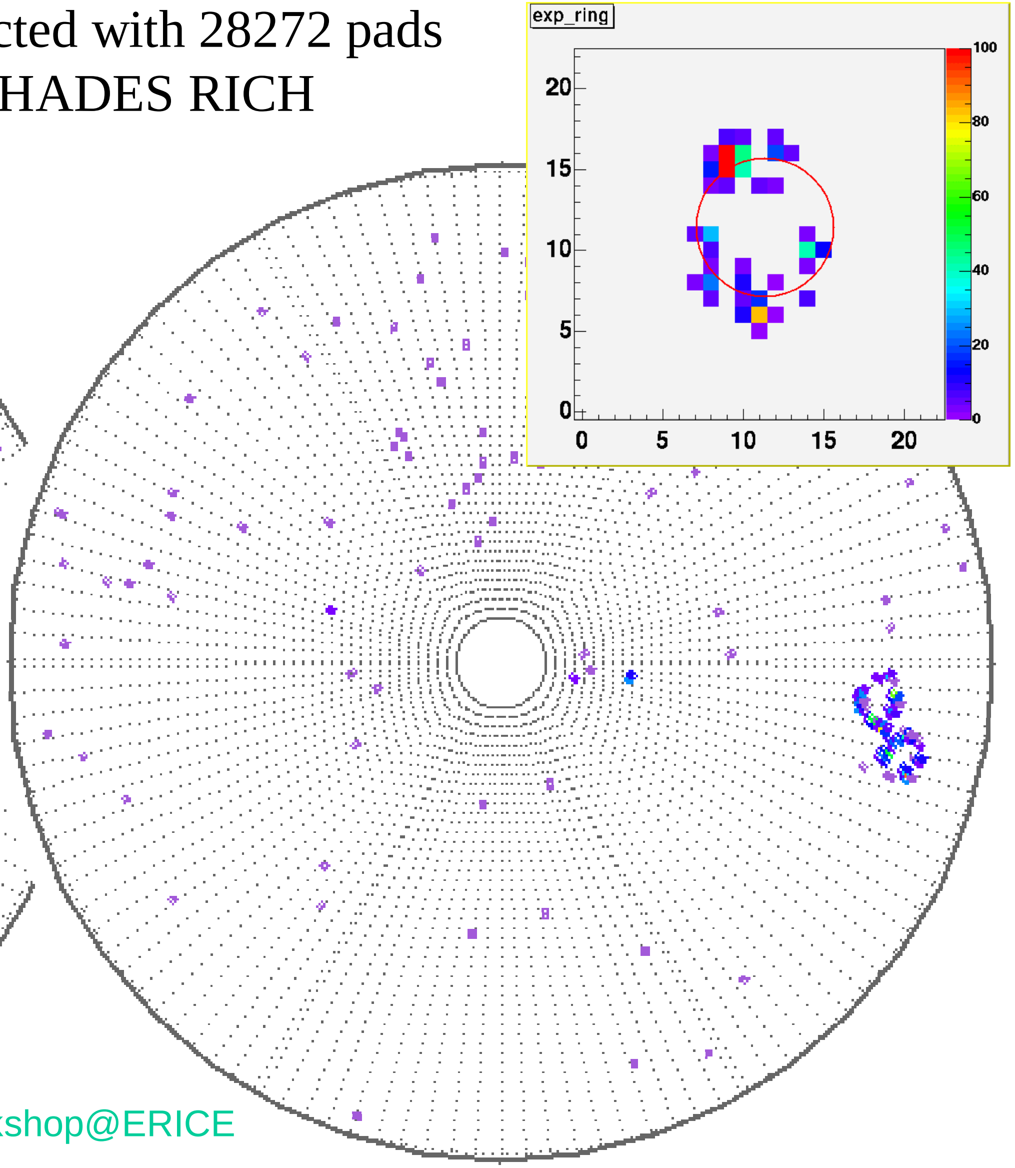
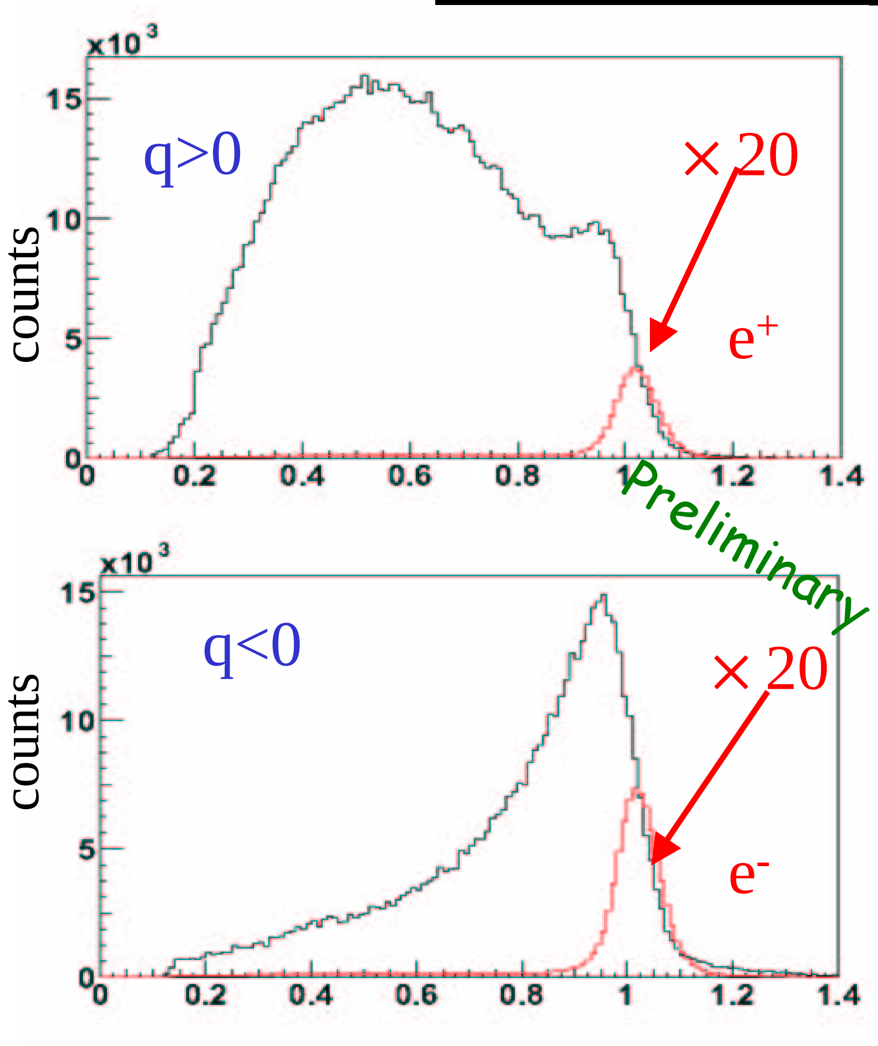
A clear Signature

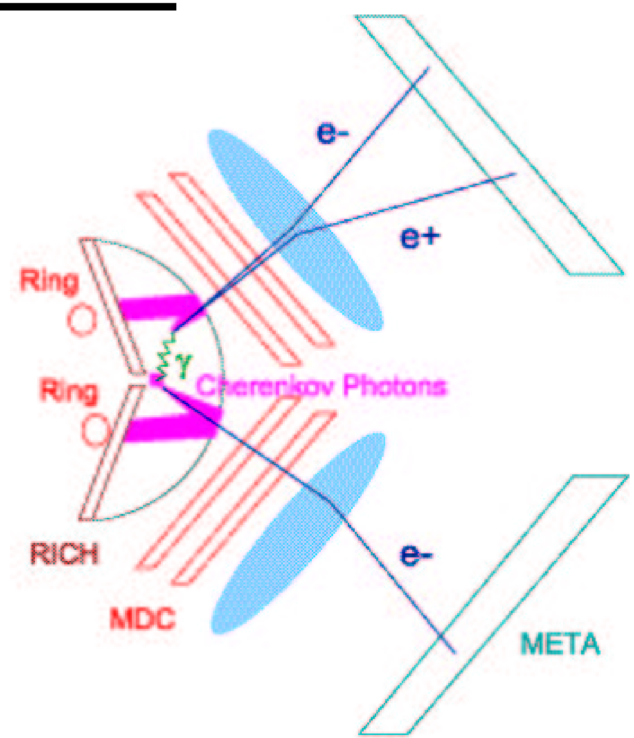
leptons detected with 28272 pads
of the HADES RICH





Lepton ID RICH-TOF-Track





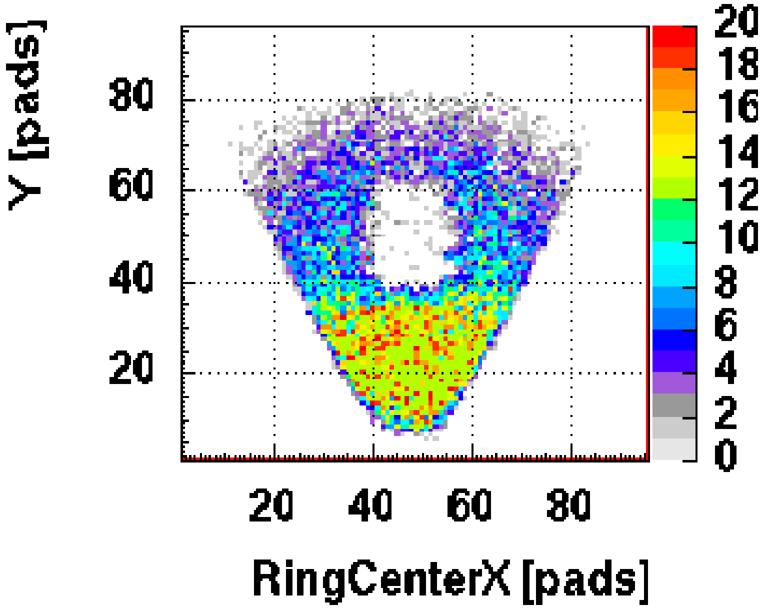
Hadron supression
~ 10^4 without momentum cut

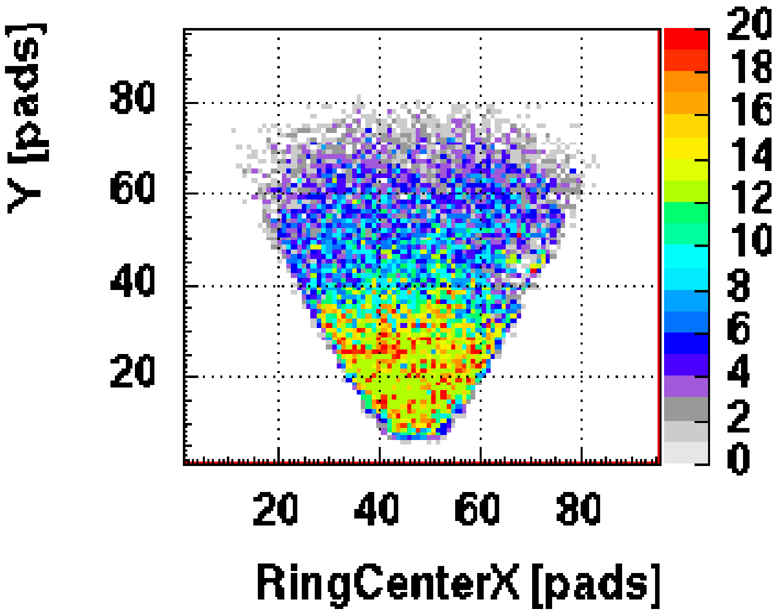
Electron single track identification :

- ✓ Ring-Track matching $|\Delta\theta|<1.7^0 \sin\theta$ $|\Delta\phi|<1.8^0$
- ✓ conditions on TOF (3σ) + PreShower
- ✓ conditions on Track matching

Prove by Accident

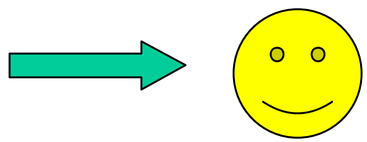
lepton density in the RICH: Nov01



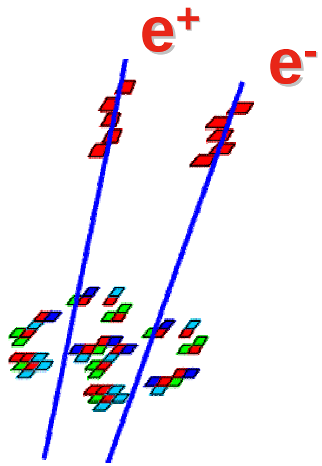


Logbook entry Dec 01

"After testing we saw two ports of sect 4 changed. So we changed back sect 4 port 4 and 6 to correct position …. "

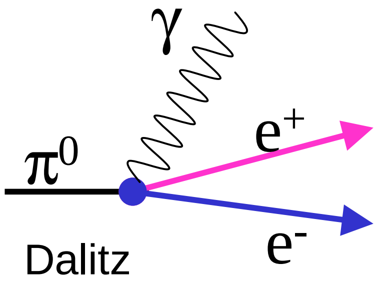


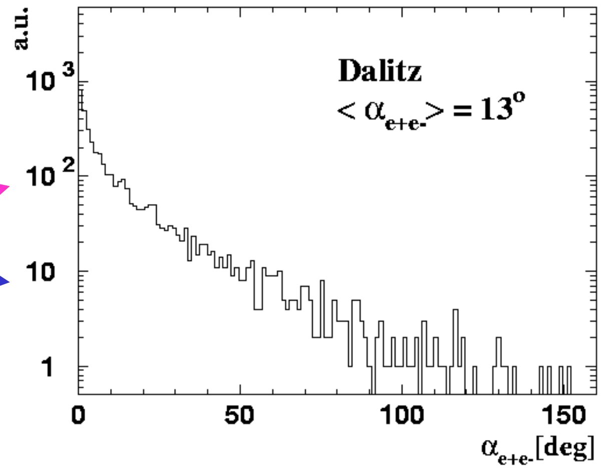
Lepton Pairs

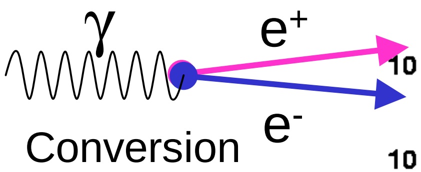


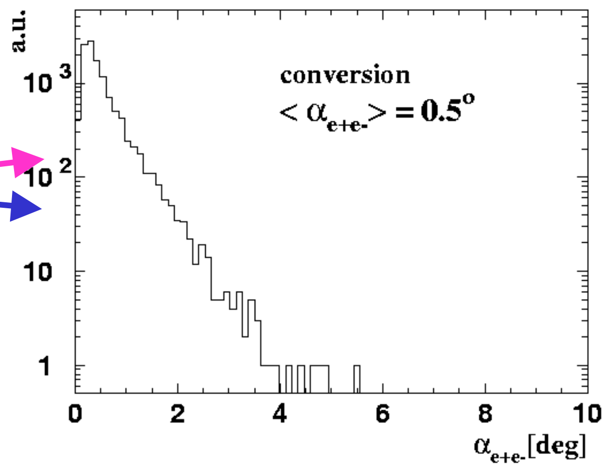
Invariant masses
Opening angle distributions
(simple) Combinatorial background

Dominant Dilepton Sources

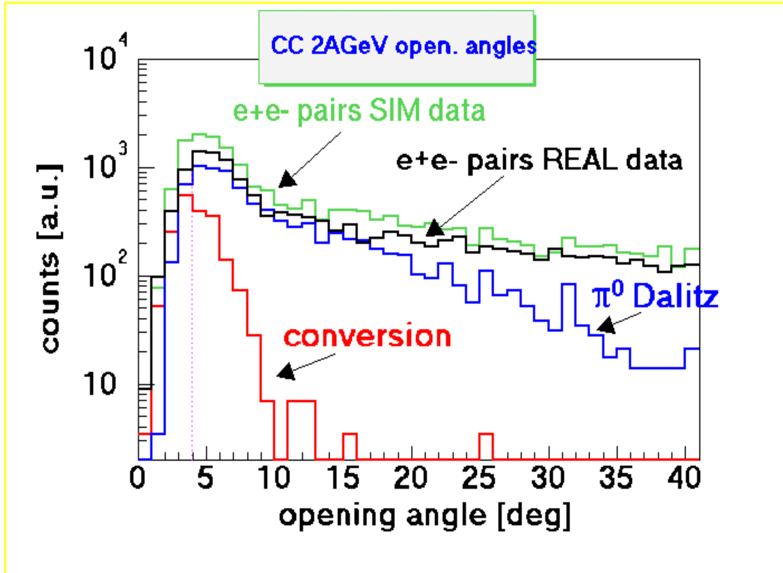




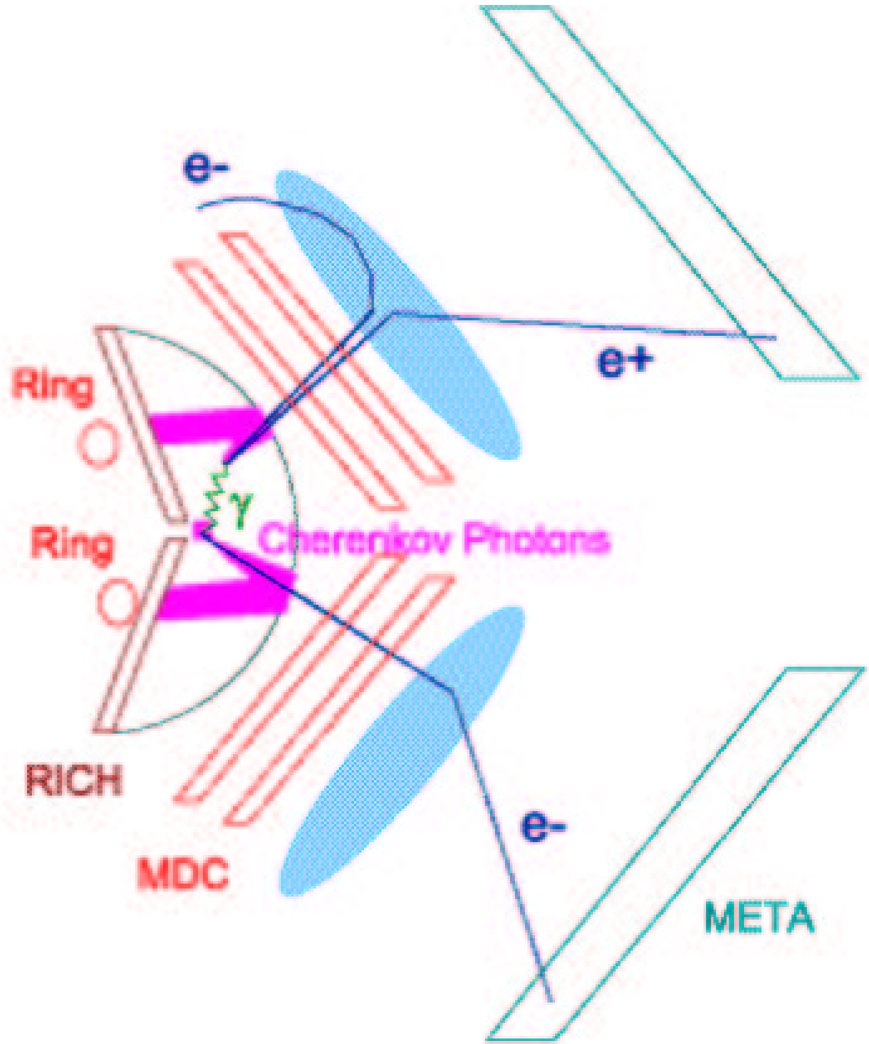


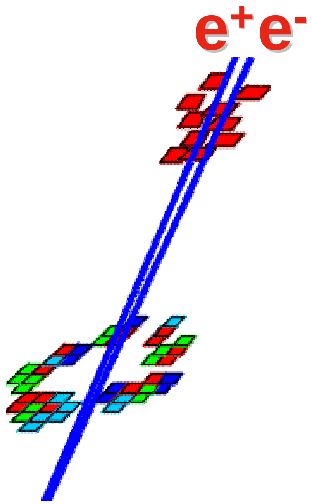


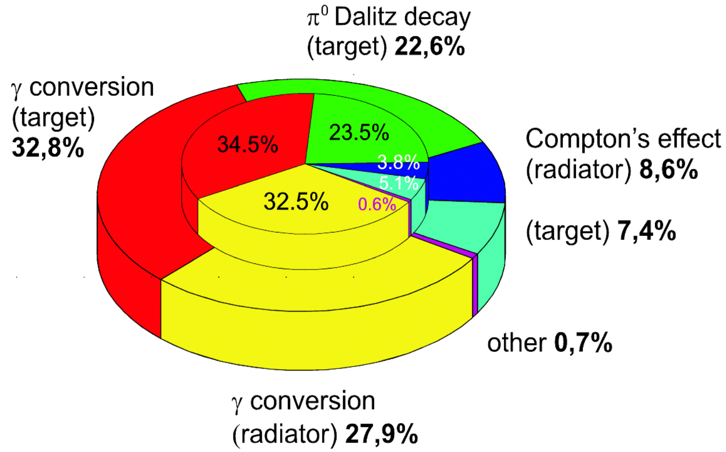
e+e- pairs,
opening angle before B-field



Combinatorial background

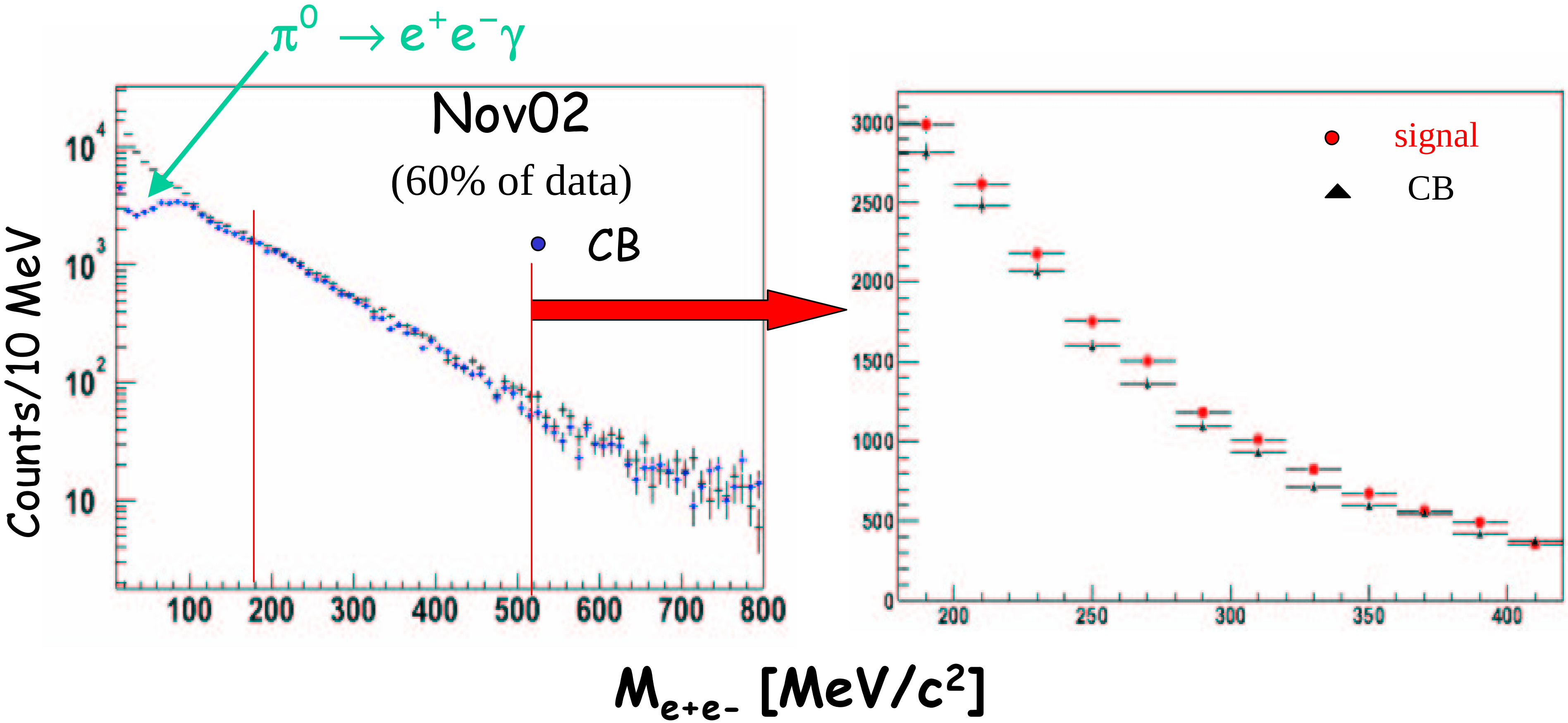






electrons

Pairs from C+C @2 AGeV

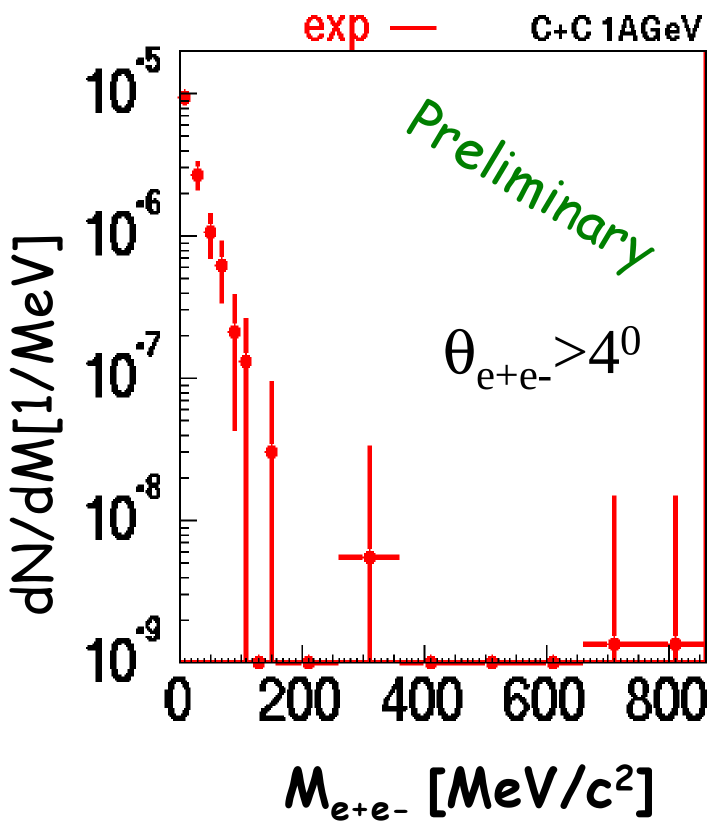


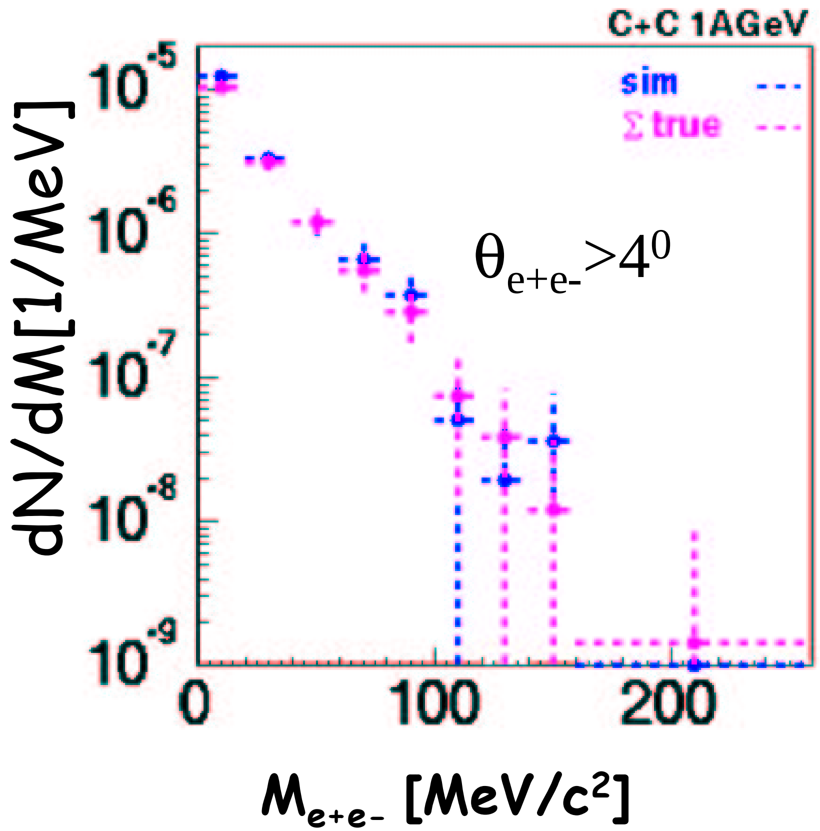
✓ CB combinatorial background

$N_{CB} = 2\sqrt{N_{++}N_{--}}$ (from same event)

10 x more statistics on tape

Nov01 1AGeV





- CB subtracted but not acceptance corrected
- Normalized by number of LVL1 triggers

- reconstruction of signal Σtrue:

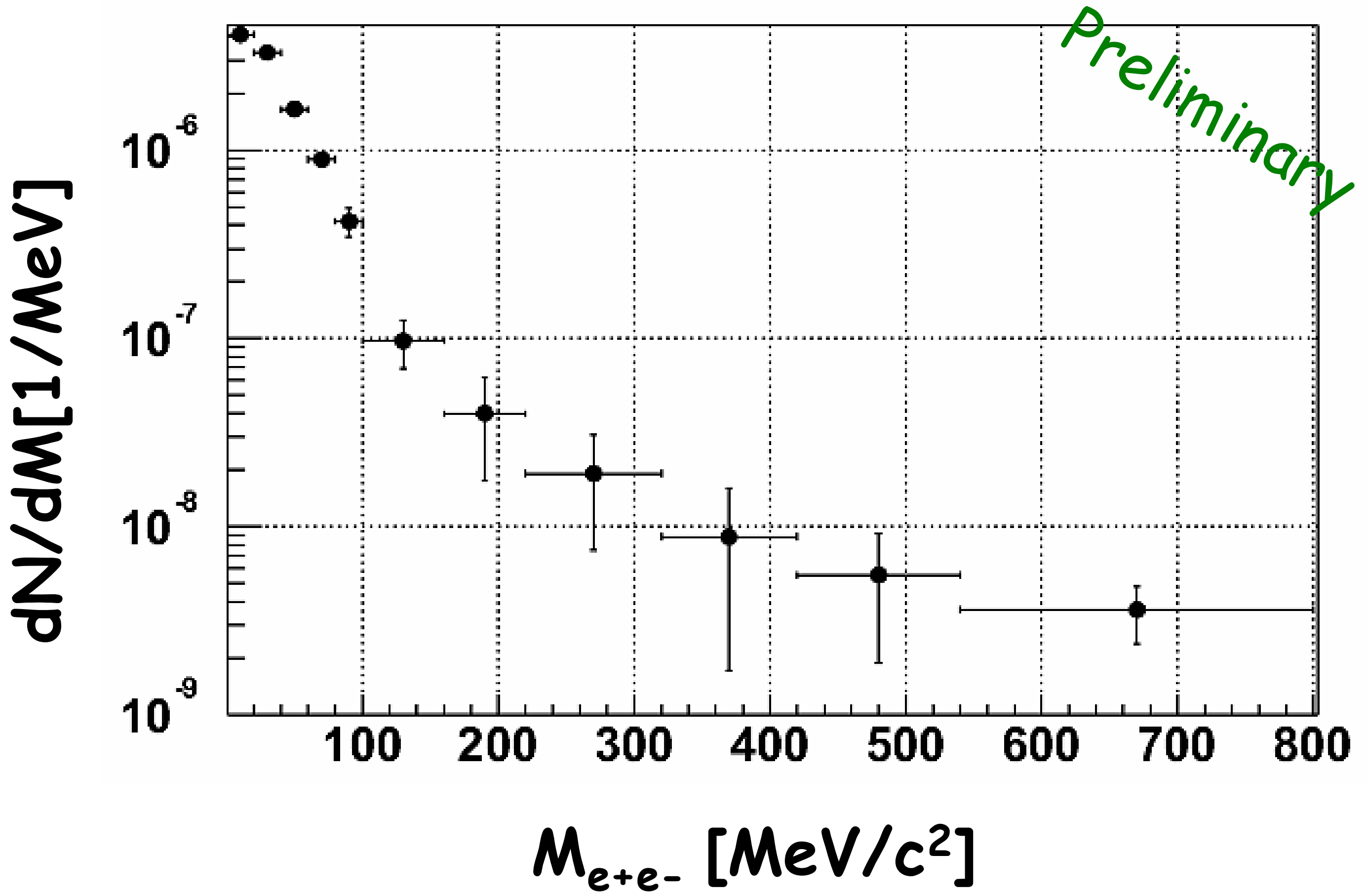
60% $\pi^0 \to e^+e^-\gamma$

30% conversion ($\gamma \to e^+e^-$)

($M_{e+e-} < 20$ MeV/c^2)

Nov01 C+C 2AGeV

$\theta_{e+e-} > 4^0$



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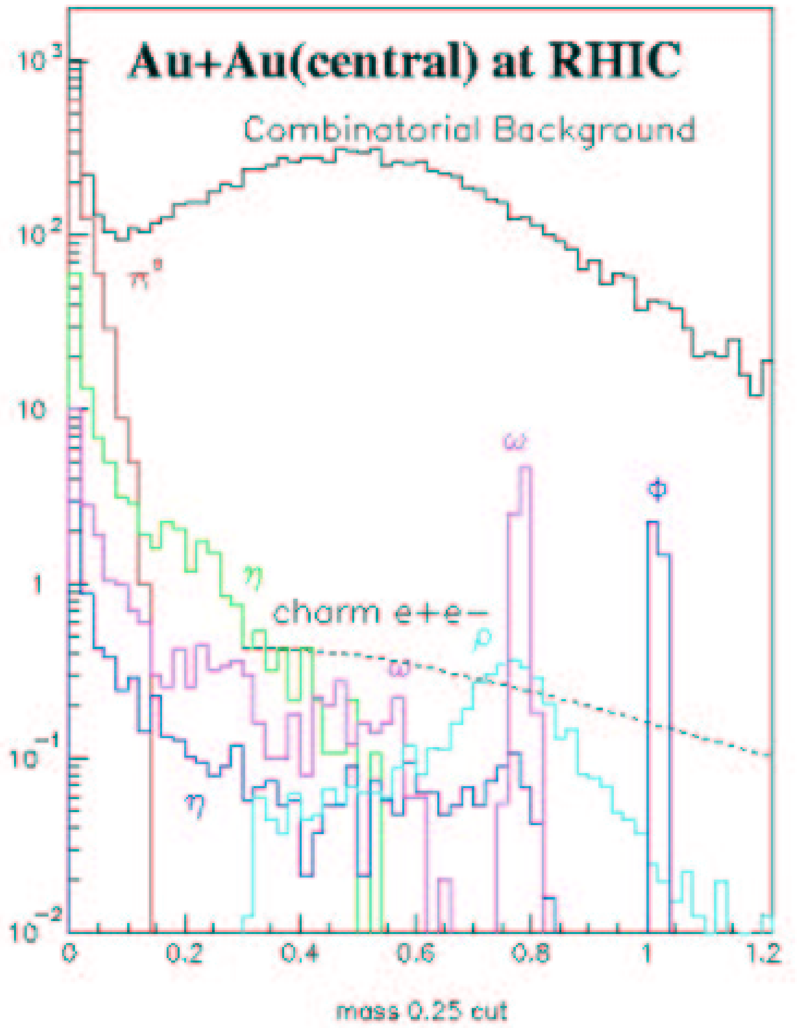
PHENIX combinatorial Background



'Single' e-tracks/evt in the two central arms: **1.2 tracks/evt**

♦ Signal to Background:
S/B = 1 / 250

♦ **Goal: improve S/B by at least two orders of magnitude**

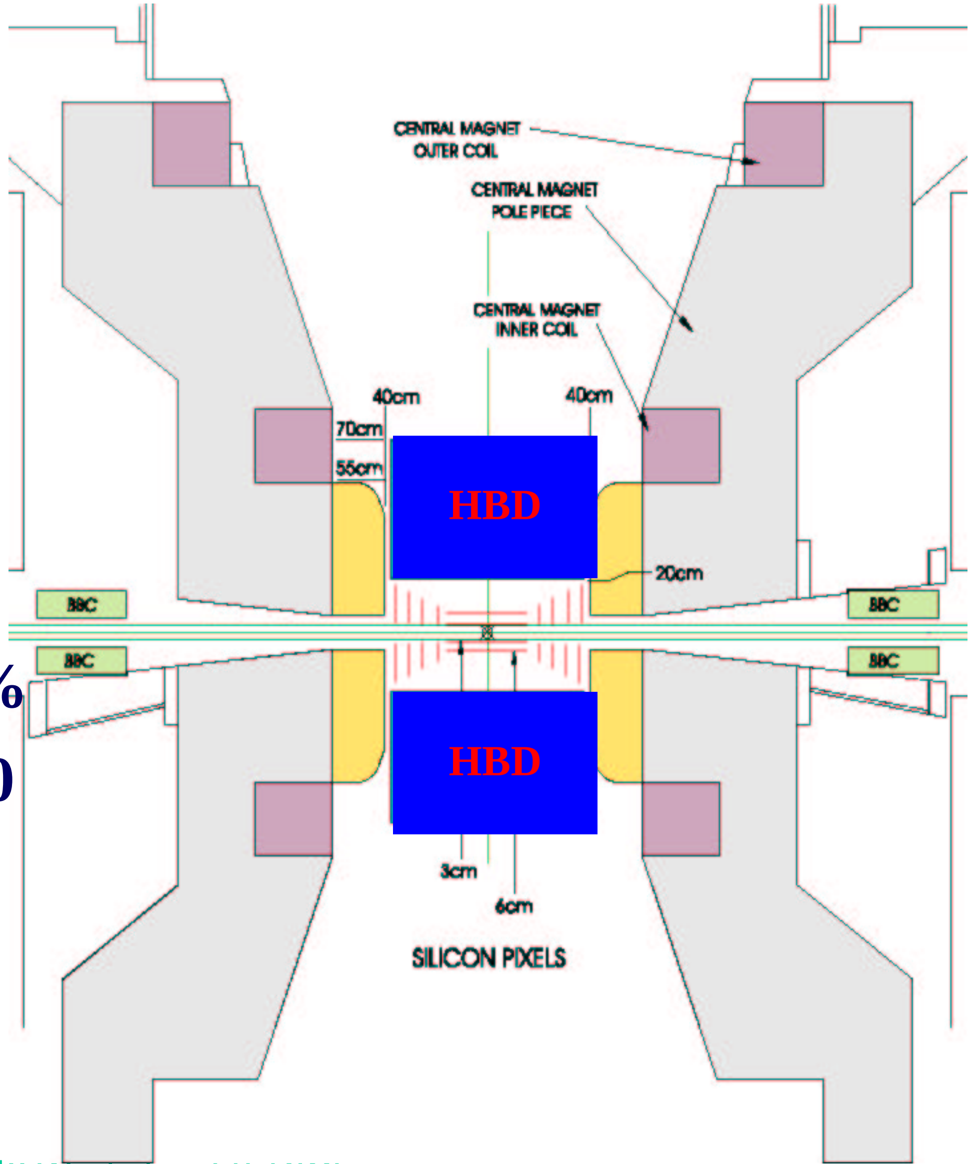
⇒ **Must reject single tracks at least to the 90% level**

HBD in PHENIX

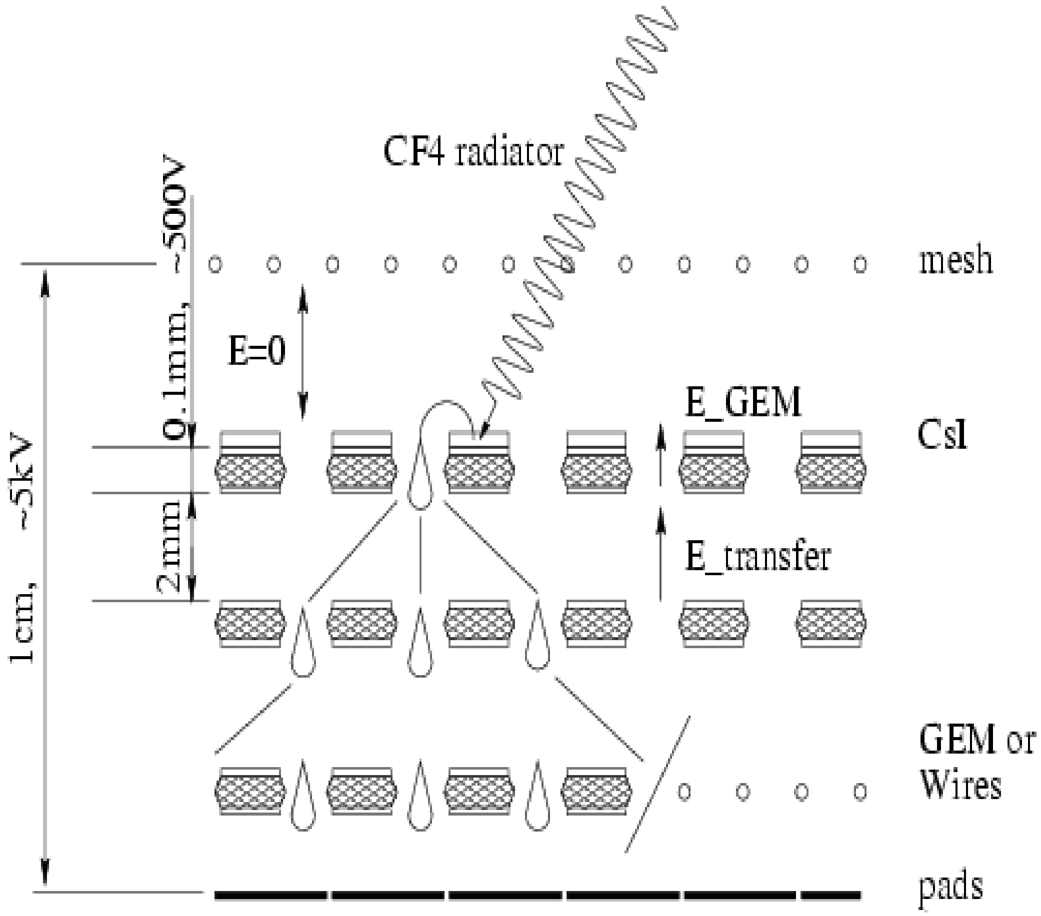
- Compensate magnetic field with inner coil (B=0 for r ≤ 50-60cm)

- Compact HBD in the inner region
  Specifications

  * Electron efficiency ≥ 90%
  * Modest π rejection ~ 200
  * Double hit recognition ≥ 90%



HBD



Concept:

- **Windowless Cherenkov detector**
- **Radiator and detector gas: CF_4**

⟹ **Large bandwidth and N_{pe} (40!)**

•Transmissive CsI photocathode

⟹ **No photon feedback**

•Proximity focus → blob (R ~1.8cm)

⟹ **Low granularity**

•Detector element: multi - GEM

⟹ **High gain**

1. photon detector out of active area
2. low material budget
3. low signal occupancy
4. clear signature
5. good position resolution
6. online hadron suppression

Technological Limits

- Radiation length @PHENIX
  - CO_2: 0.41%
  - Windows: 0.2%
  - Mirror panels: 0.53%
  - Mirror support: 1.0%
  - Total: 2.14%

- Radiation length@HADES
  - C_4F_{10}: 1.5%
  - Windows: 0.2%
  - Mirror panels: 0.73%
  - Mirror support: off acceptance
  - Total: 2.43%

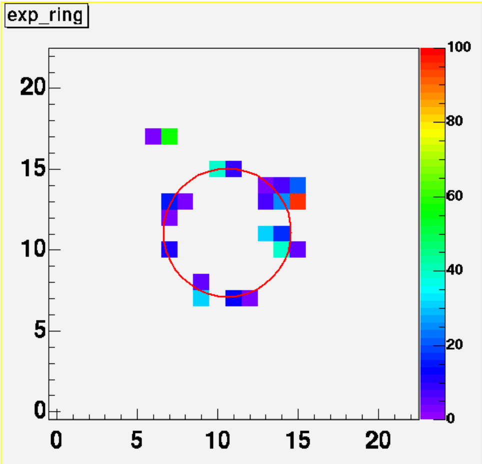
- Photon detector:
  - gaseous detectors (details on Tuesday)
  - vacuum based detectors (details on Friday)
  - solid state detectors (details on Friday)

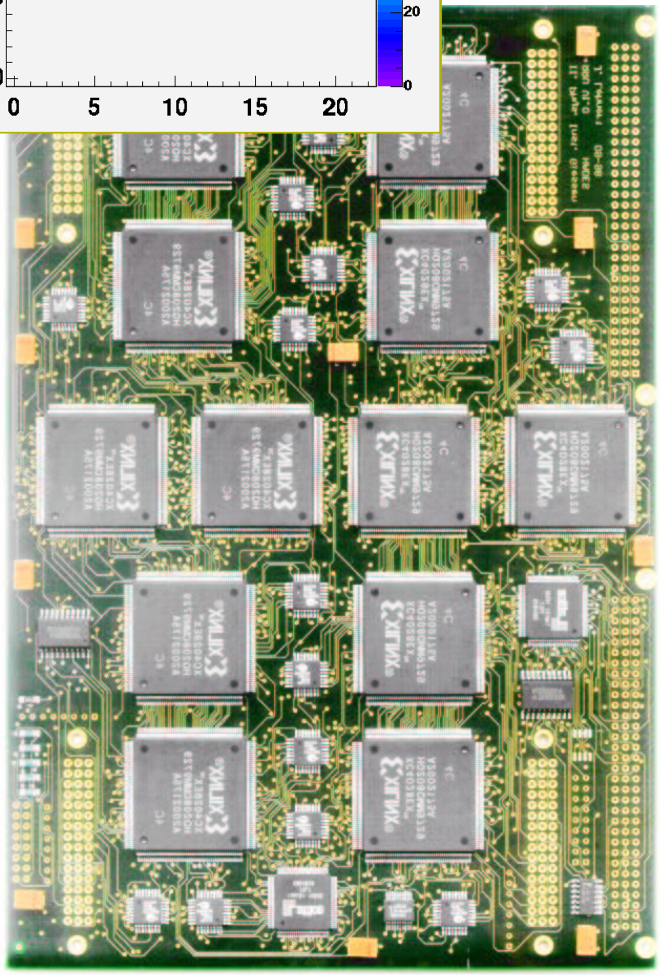
efficiency,
ageing,
field dependence,
S/B ...

Though the detectors are hadron blind there is still a lot of data produced!

⇨ calculate Θ, Φ ,quality...

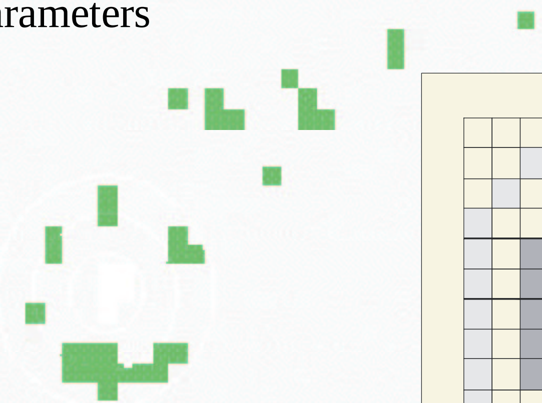
⇨ trigger decision in real time



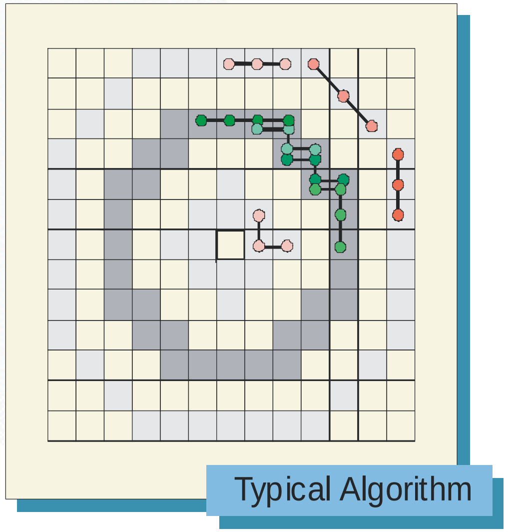


Online Ring Recognition

- Ring recognition algorithm (fixed radius)
  - Ring radius (+) inner and outer veto regions (-)
  - Threshold on positive and negative quality parameters



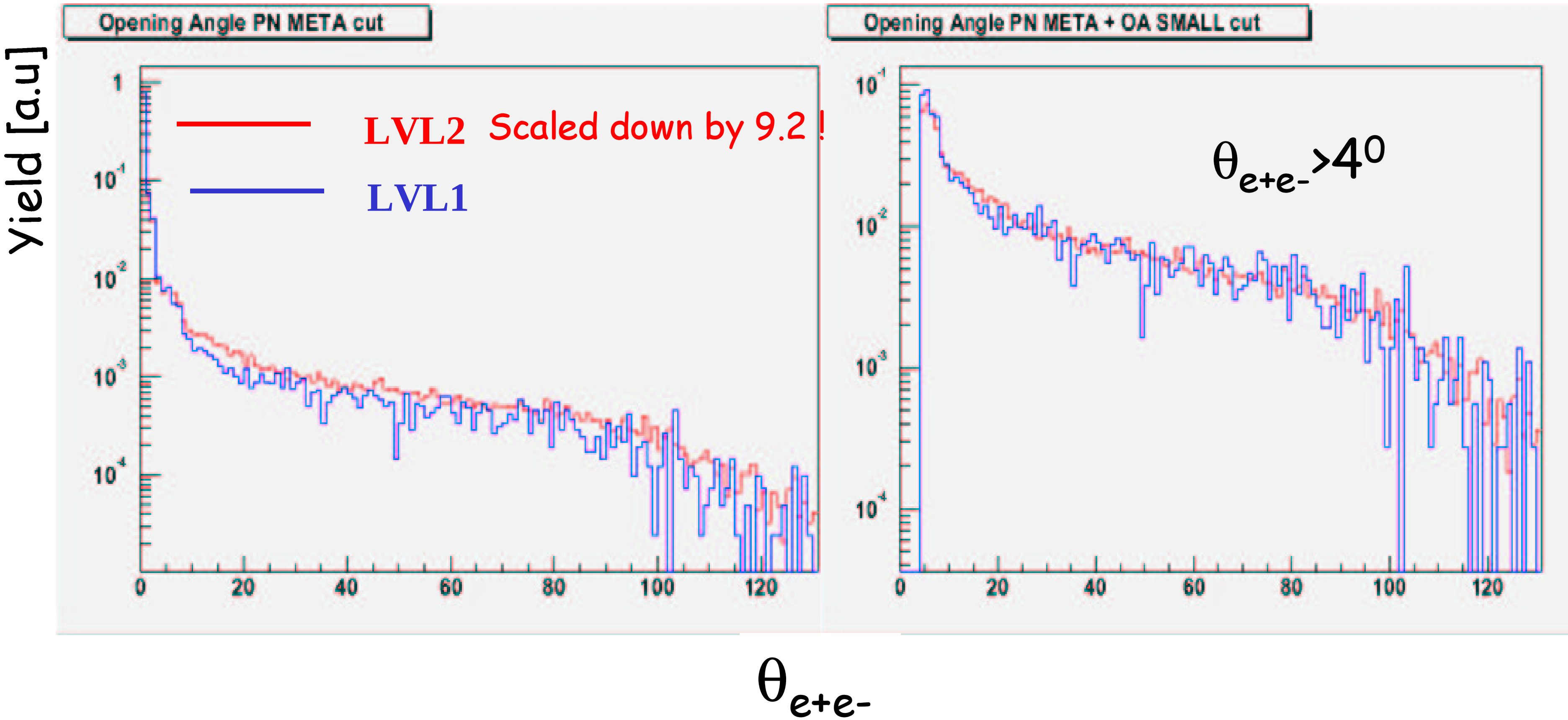
J. Lehnert, (Giessen)



Reference of qualitative and quantitative detector response needed

Comparison of dilepton distributions LVL1/LVL2

- unlike sign pairs opening angle distributions
- minimum bias event reduction Factor 9.2



Summary

RHIC	For Au-Au	For p-p
Beam Energy	100-30 GeV/u	250-30 GeV
Luminosity	2×10^{26} cm^{-2}sec^{-1}	[1.4×10^{31} cm^{-2}sec^{-1}]*

Potential for net increase of 40x in average luminosity for Au Au

RHIC luminosity upgrade White Paper available

The message:

- rare probes will become more important.
- RICH technology is well under control.
- hopefully there will be a solution for RICH inside B-field soon: