Electron pair spectrometer to study the meson modification

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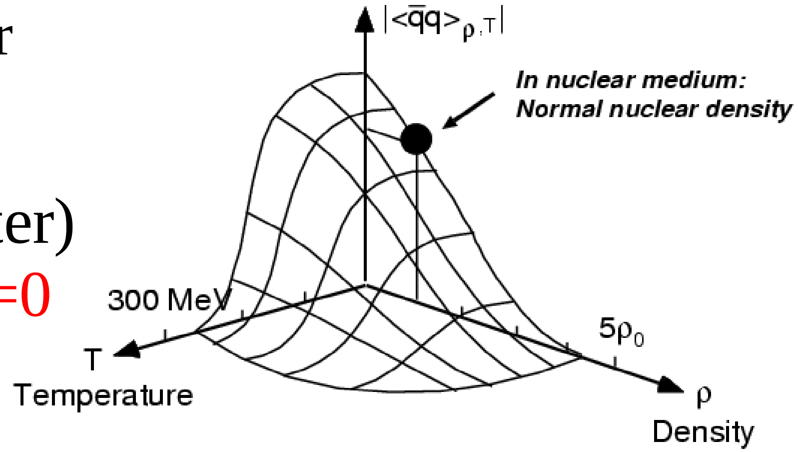
- Physics : Chiral symmetry in nuclear matter
- Recent results of KEK-PS E325 : $\rho/\omega/\phi \to e^+e^-$
- Proposed Experiment & Spectrometer at J-PARC
- Detector R&D status

Chiral symmetry restoration in nuclear matter

- Spontaneous CS braking is the origin of hadron mass
- confine-deconfinement phase transition is related with chiral transition
- In hot/dense matter, chiral symmetry is expected to restore
  - hadron modification is expected in such matter
    - HI collision
  - quark-antiquark condensate (order parameter) ~2/3 even at the normal nuclear density, T=0
    - p+A reaction

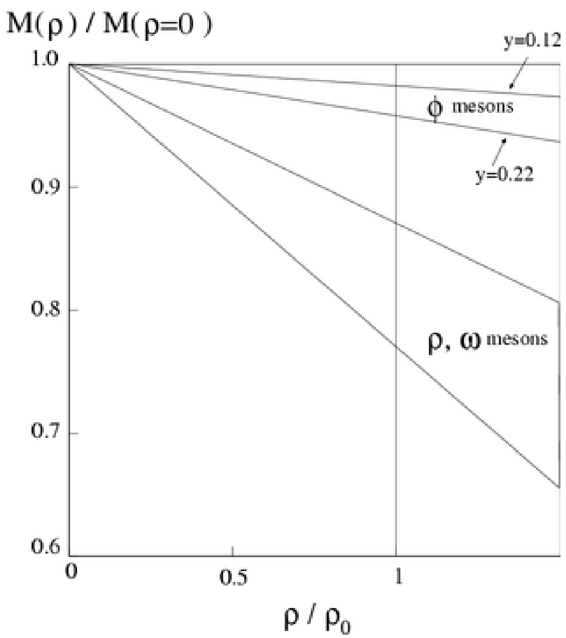


- Many theoretical predictions of vector meson (mass/width) modification in dense medium, related (or not related) with CS
  - Brown & Rho ('91) : $m^*(\rho)/m_0 \sim f_\pi^*/f_\pi \sim 0.8$ at $\rho=\rho_0$
  - Hatsuda &Lee ('92) , Klingle, Keiser &Weise ('97), Muroya, Nakamura & Nonaka('03), etc.

Hatsuda and Lee, 92,95

mass decreasing
~16% for ρ/ω
~2-4% for ϕ
at the normal nuclear density

(Lee also predicted
the momentum dependence
of mass decreasing)

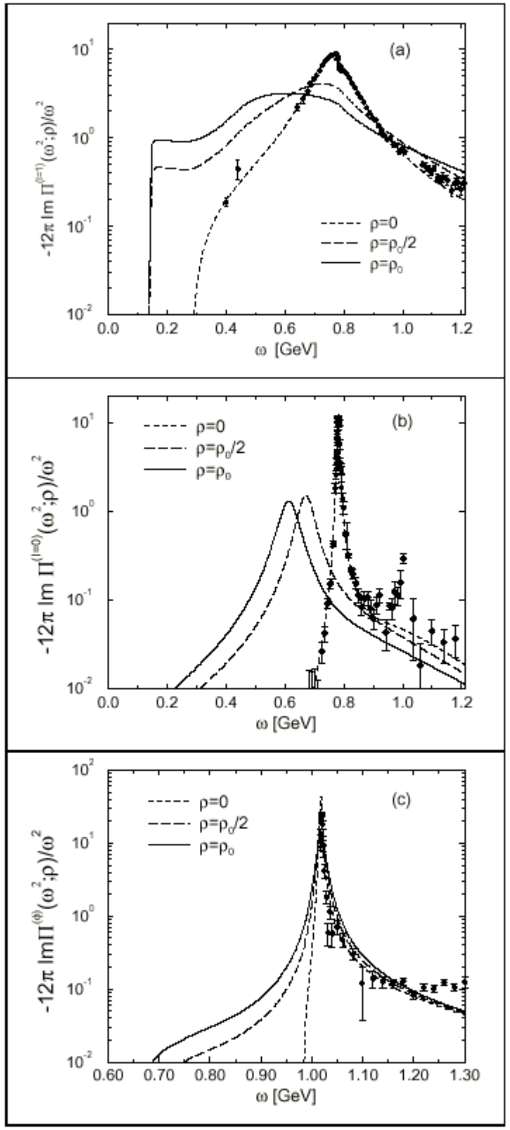


Klingle,Keiser,Weise, 97

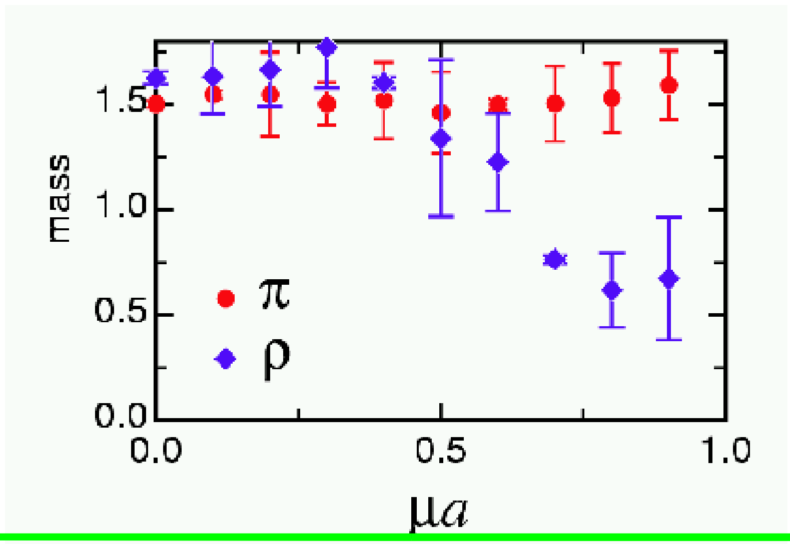
ρ

ω

ϕ



Muroya, Nakamura, Nonaka, 03



Vector meson measurements

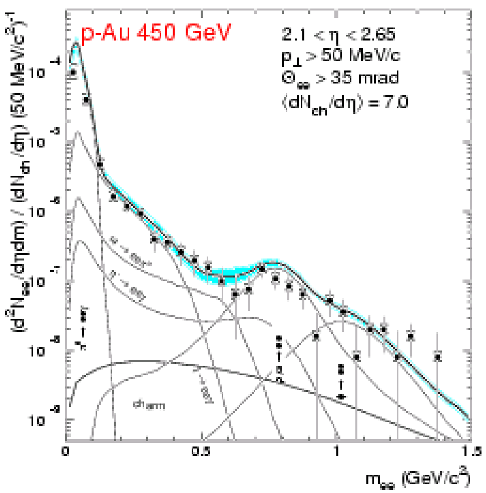
- Leptonic decay channel
  - HELIOS (ee, μμ) 450GeV p+Be / 200GeV A+A
  - CERES (ee) 450GeV p+Be/Au / 40-200GeV A+A
  - E325 (ee,KK) 12GeV p+C/Cu
  - PHENIX (ee,KK) p+p/Au+Au
  - NA60 (μμ) 400GeV p+A/158GeV A+A
  - HADES (ee) 4.5GeV p+A/ 1-2GeV A+A
  - *J-PARC* (ee) 30/50GeV p+A / ~20GeV A+A
  - *CBM (GSI)* (ee) 8~40GeV A+A
- Hadronic decay channel
  - TAGX (ππ) ~1 GeV γ+A
  - STAR (ππ,KK) p+p/Au+Au
  - LEPS (KK) ~2 GeV γ+A

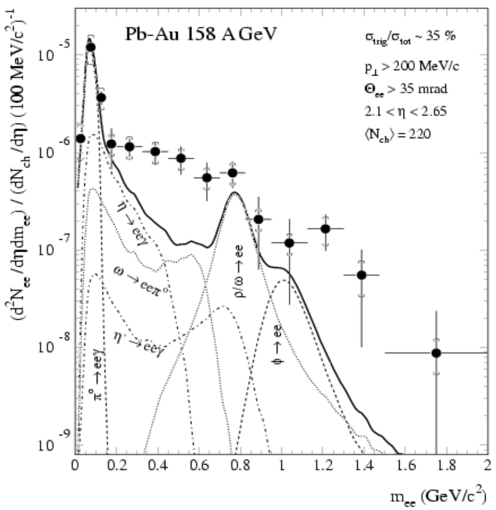
red : state modification
blue : not state/in analysis
green: future project

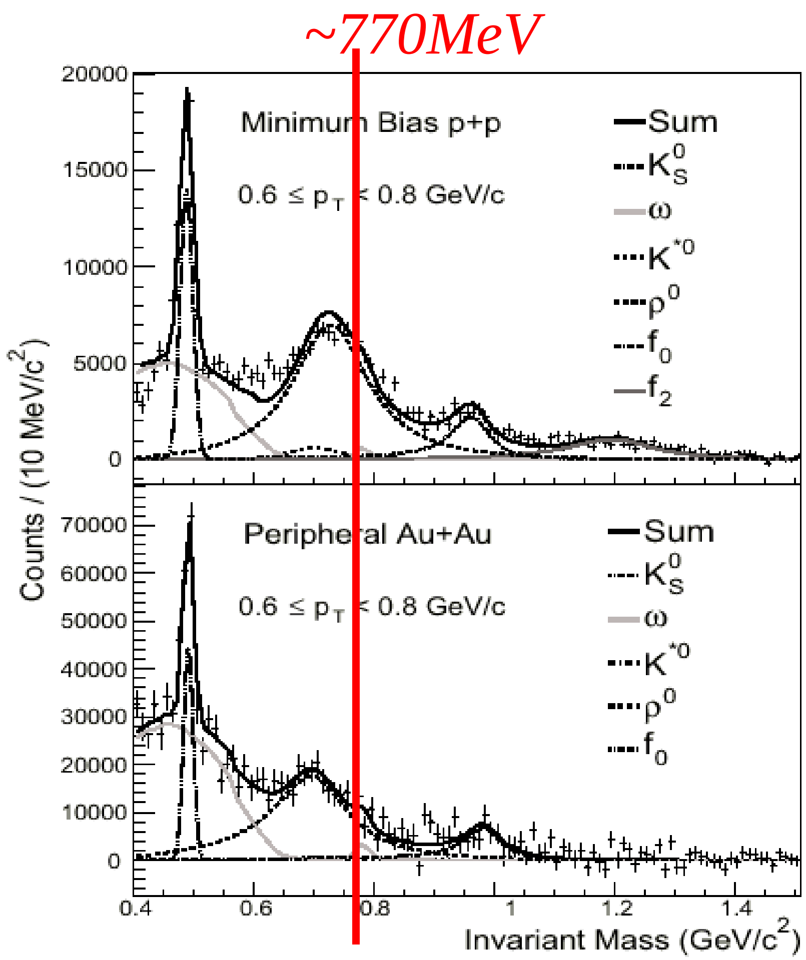
Vector meson measurements in HI collisions

- CERES :
  - anomaly in A+A, not in p+A
  - relative abundance is determined by their statistical model

- STAR : 'shift' in p+p & A+A peripheral (nucl-ex/0307023)
  - relative abundance is free parameter/ shape is BWxPS

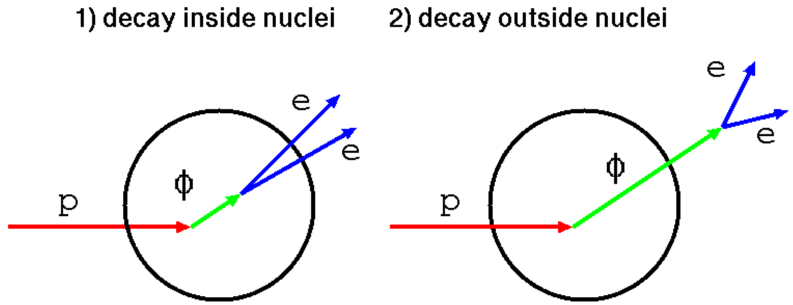


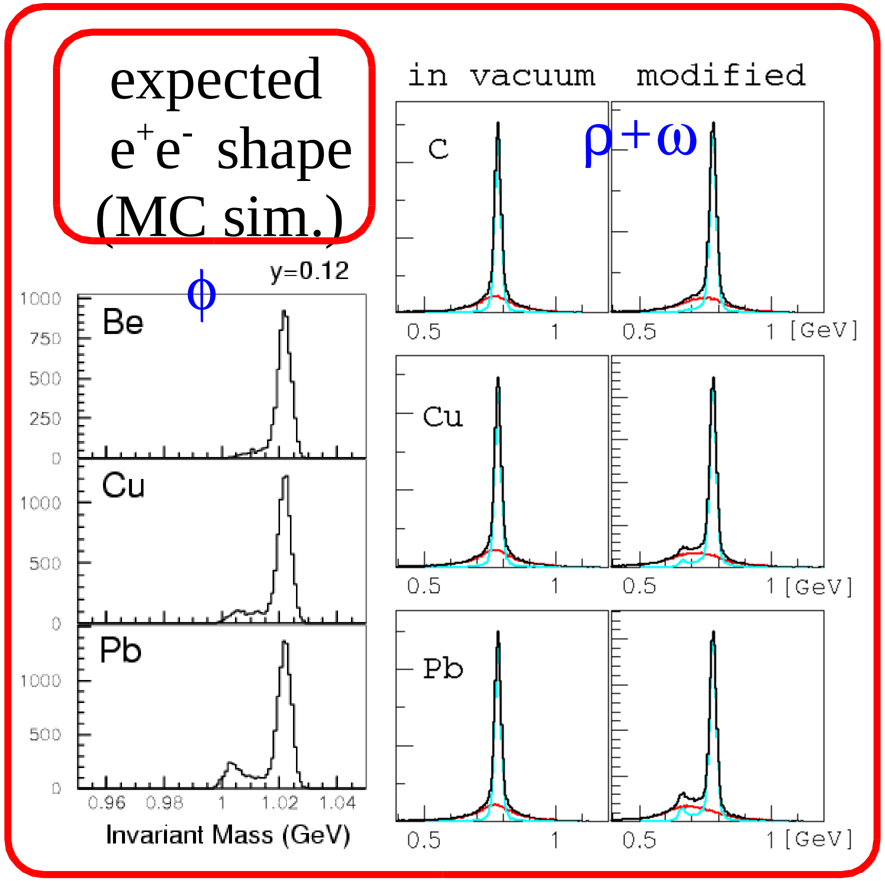




Expected signal in p+A -> e^+e^- channel

- smaller FSI in e^+e^- decay channel
- double peak or tail-like structure
  - second peak is made by inside-nucleus decay (modified meson)
  - larger nuclei / slowly moving mesons are expected to have larger 'peak(tail)'
- comparison of ρ and ϕ
  - ρ (770) & ω(783) :
    - larger production cross section
    - larger decay prob. inside nuclei
    - cannot distinguish ρ & ω in e^+e^-
  - ϕ (1020) : narrow width
    - smaller decay prob. inside nuclei
    - smaller production cross section





Experiment KEK-PS E325

- 12GeV p+A -> ρ/ω/φ +X (ρ/ω/φ ->e^+e^- , φ->K^+K^-)
- Experimental key issues:
  - Very thin target to suppress the conversion electron background (typ. 0.1% interaction/0.2% radiation length of C)
  - To compensate the thin target, high intensity proton beam to collect high statistics (typ. 10^9 ppp -> 10^6Hz interaction)
  - Large acceptance spectrometer to detect slowly moving mesons, which have larger probability decaying inside nuclei (1<βγ<3)

Collaboration

J. Chiba, H. En'yo, Y. Fukao, H. Funahashi, H. Hamagaki, M. Ieiri, M. Ishino, H. Kanda, M. Kitaguchi, S. Mihara, K. Miwa, T. Miyashita,T. Murakami, T. Nakura, M. Naruki, M. Nomachi, K.Ozawa, F. Sakuma, O. Sasaki, H.D.Sato, M.Sekimoto, T.Tabaru, K.H. Tanaka, M.Togawa, S. Yamada, S.Yokkaichi, Y.Yoshimura
(Kyoto Univ. , RIKEN, KEK, CNS-U.Tokyo, ICEPP-U.Tokyo, Tohoku-Univ.)

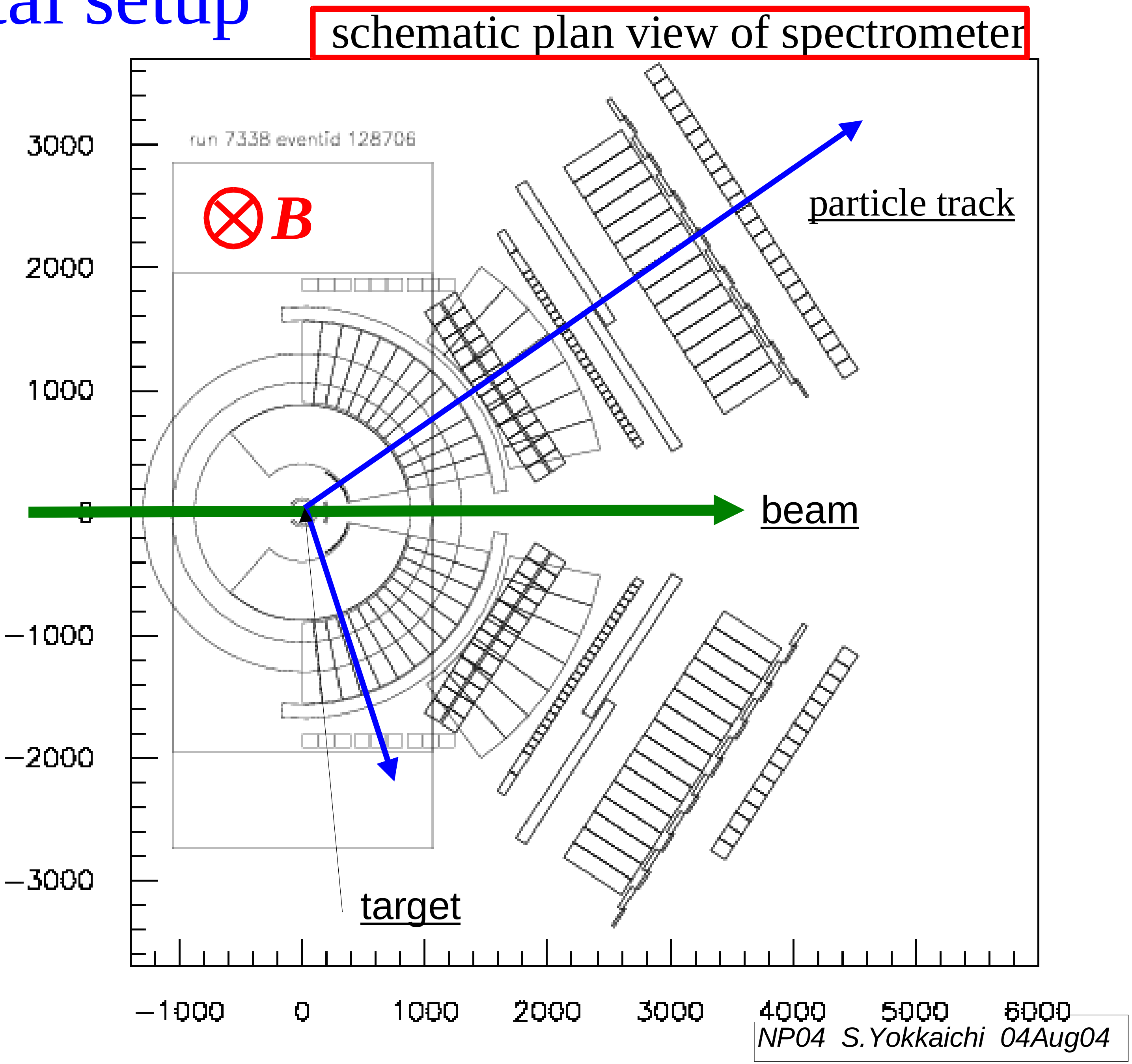
(Cont'd)

- History of E325
  - 1996 const. start
  - '97 data taking start
  - '98 first ee data
    - PRL86(01)5019
  - 99,00,01,02....
    - x100 statistics
      - presented today
  - '02 completed
  - spectrometer paper
    - NIM A516(04)390

E325 spectrometer
located at KEK-PS EP1-B primary beam line

Experimental setup

- Spectrometer Magnet
  - 0.71T at the center
  - 0.81Tm in integral
- Targets
  - at the center of the Magnet
  - C & Cu are used typically
  - very thin: ~0.1% interaction length
- Primary proton beam
  - 12.9 GeV/c
  - ~1x10^9 in 2sec duration, 4sec cycle



Experimental setup - Detectors

Electron ID counters

Gas Cherenkov &

Lead Glass EMC

total 3x10^{-4} π rejection

with 78% e efficiency

in two-stage operation

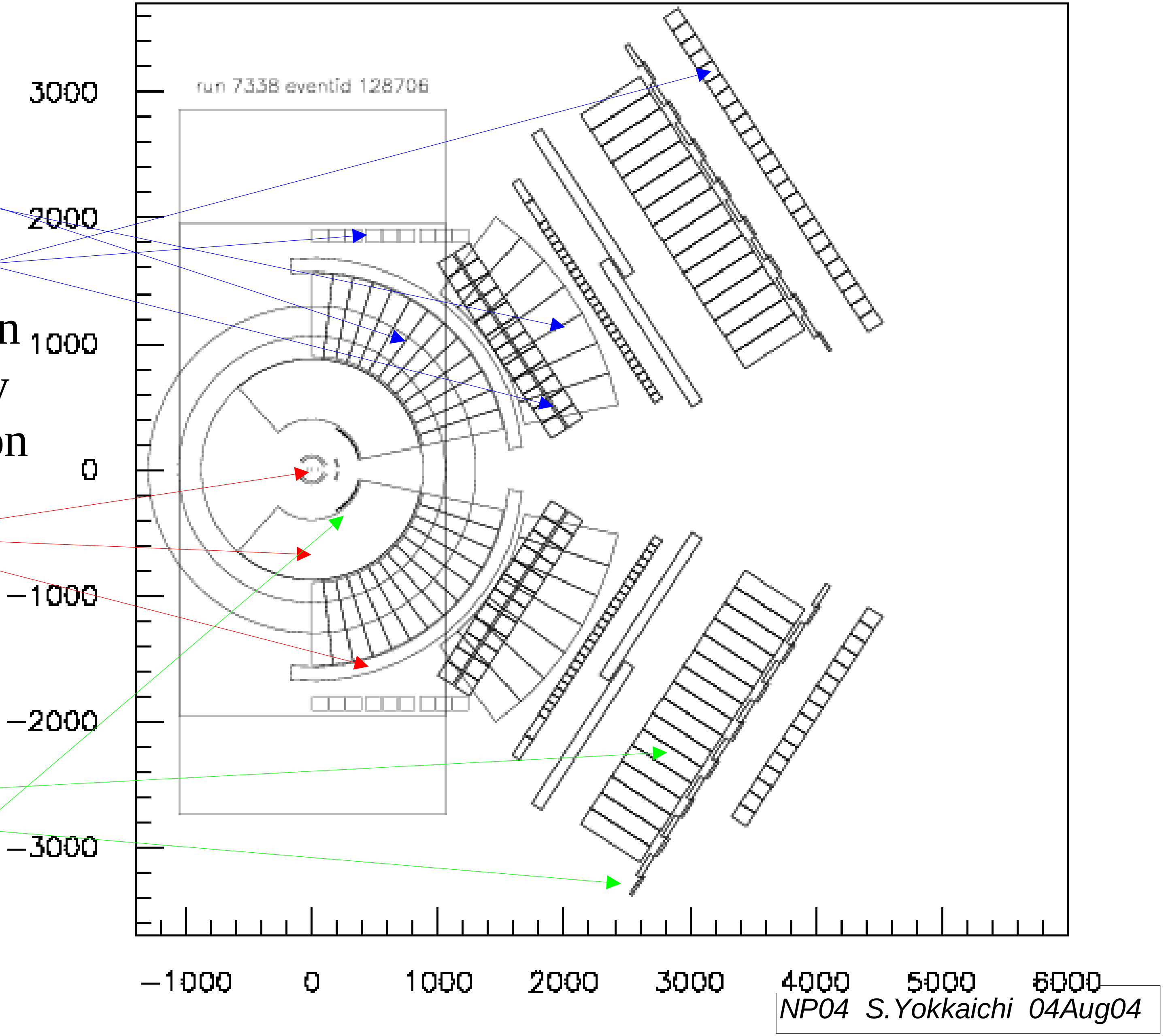
Tracker

Three Drift Chambers

Kaon ID counters

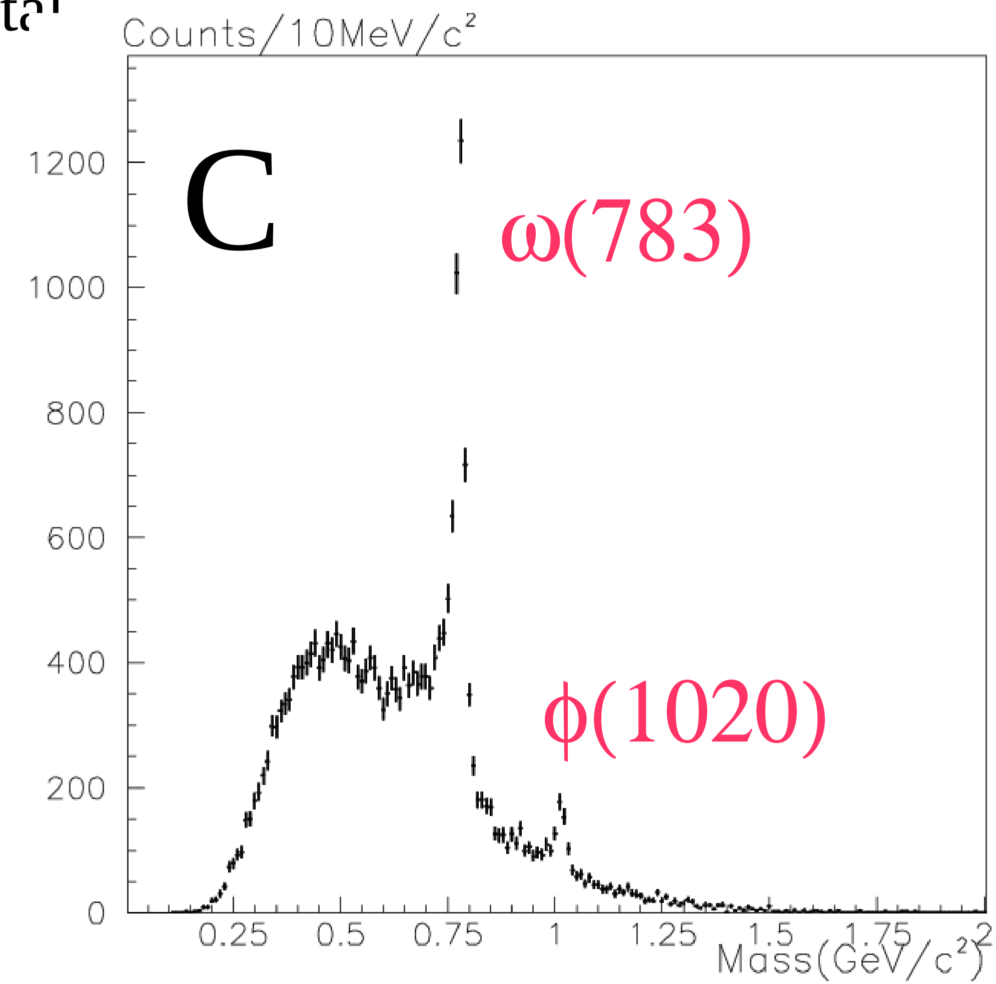
Aerogel Cherenkov

& TOF



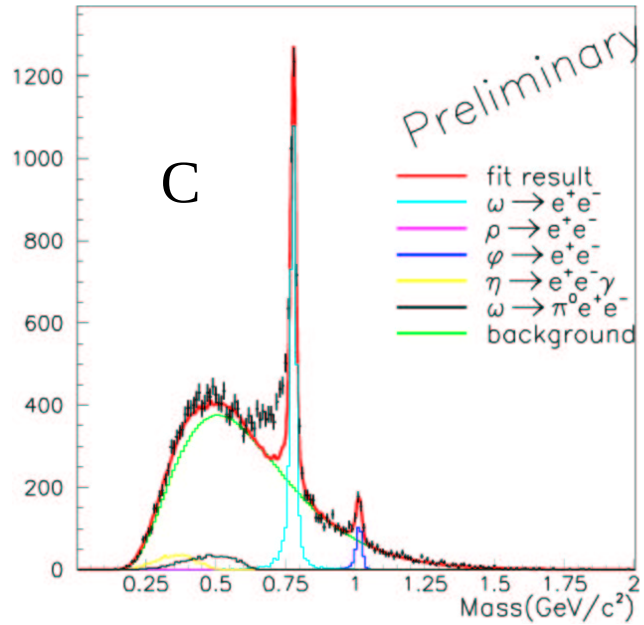
Observed e^+e^- invariant mass spectra

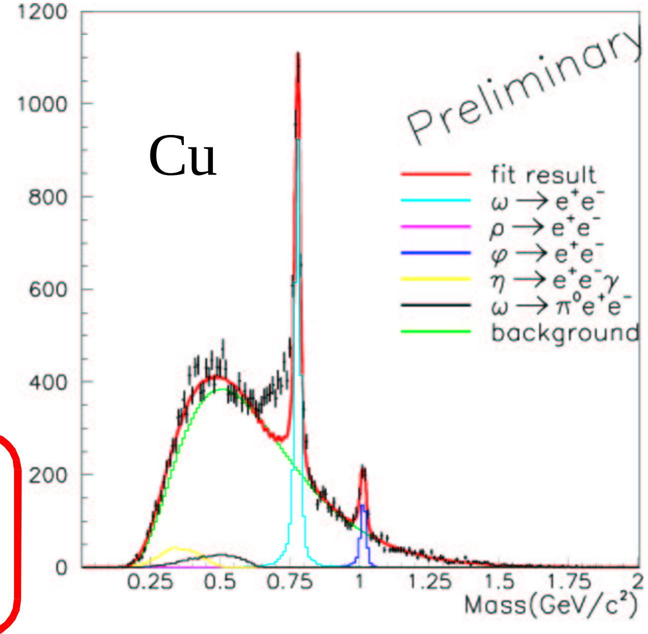
- from 2002 run data (~70% of total data)
- C & Cu target
- clear resonance peaks
- m<0.2 GeV is suppressed by detector acceptance
- acceptance uncorrected



Fitting with known sources

- Hadronic sources of e^+e^-:
  - $\rho/\omega/\phi \to e^+e^-$, $\omega \to \pi^0 e^+e^-$, $\eta \to \gamma\, e^+e^-$
  - Breit-Wigner shape (no modification is assumed)
  - Geant4 detector simulation (energy loss of e^+/e^- in detector, acceptance, etc.)
- Combinatorial background : event mixing method
- Relative abundance of these components are determined by the fitting

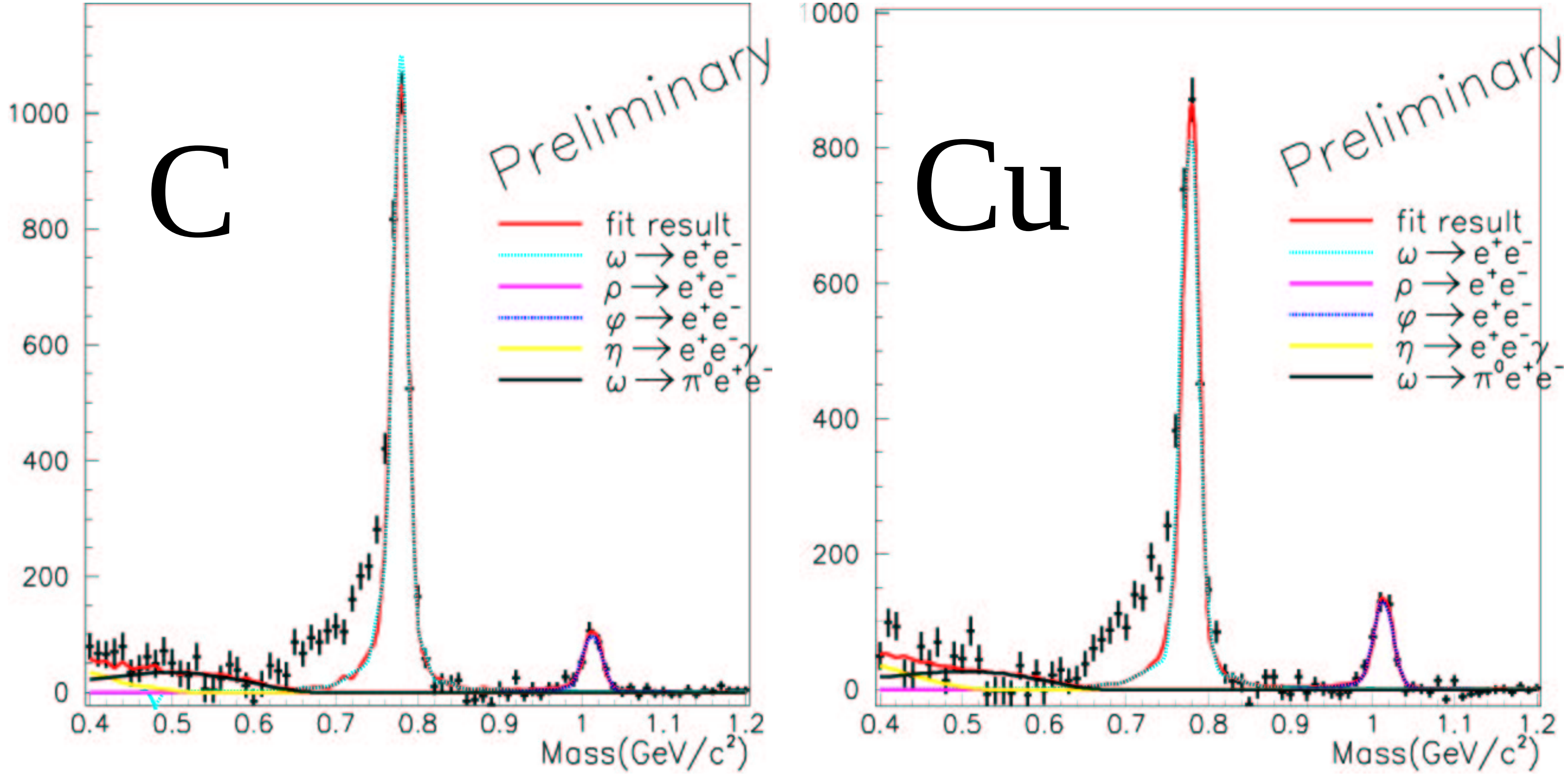




- excess at the low-mass side of ω (0.6~0.75 GeV)
- ρ–meson component seems to be vanished !

E325 e^+e^- spectra (BKG subtracted)

ρ/ω=0.0+-0.01(stat.)+-0.2(sys.) , 0.0+-0.05(stat.)+-0.5(sys.)

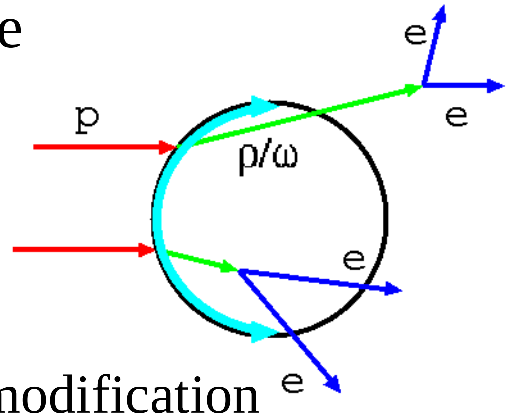


- However, ρ/ω ~1 in former experiment (p+p, 1974) .... suggests the excess is from modified ρ mesons

Discussion: Toy model including modification

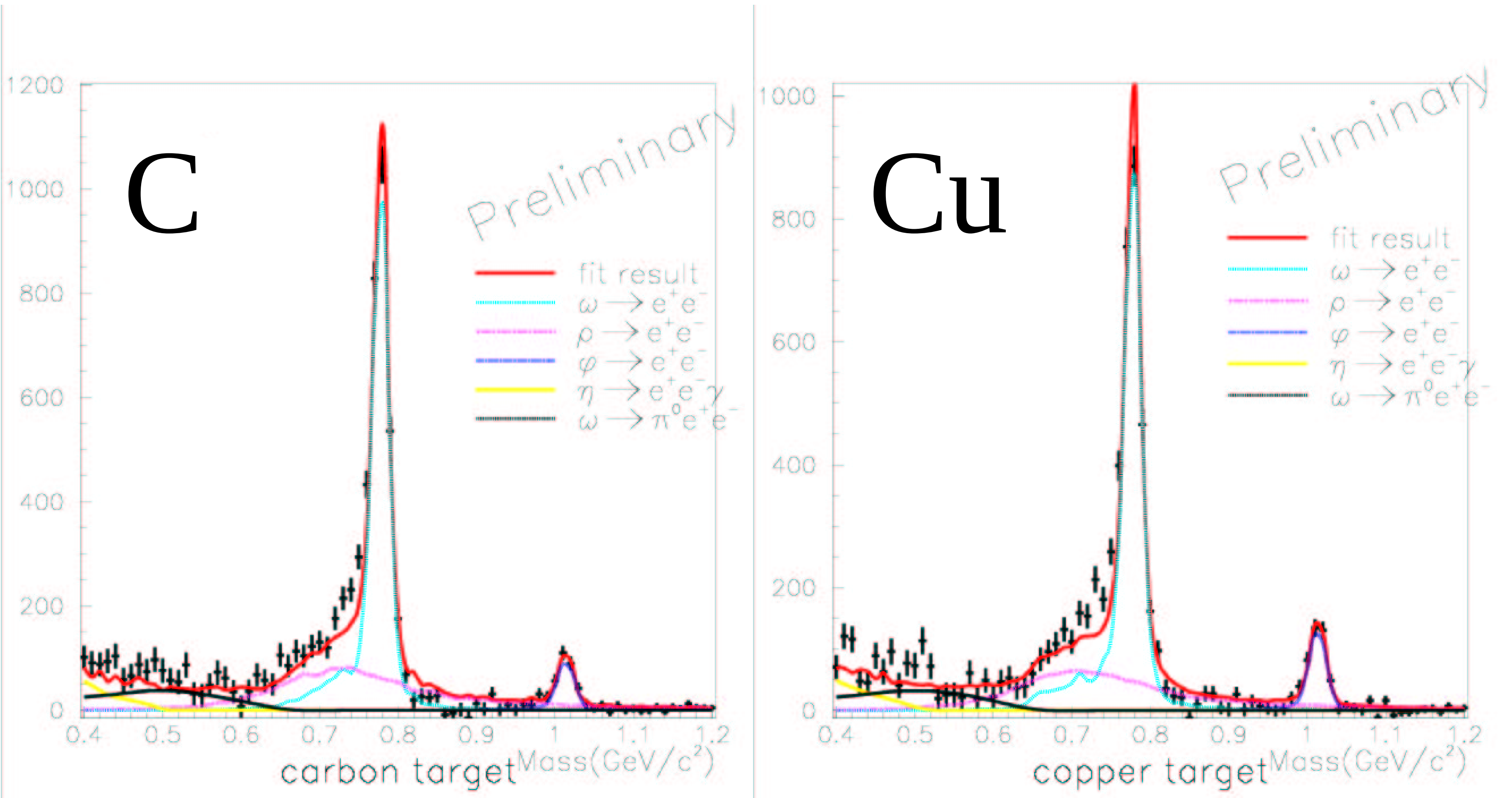
- Assumptions to include the nuclear size effect in the fitting shape
  - meson fly through the nucleus, decay with modified mass if the decay point is inside nuclei
    - meson production point : incident surface of nuclei
    - meson momentum : measured distribution in our experiment
    - nuclear density distribution : Woods-Saxon type
  -
    - modification as : $m^*/m_0 = 1 - 0.16\ \rho^*/\rho_0$

      (Hatsuda & Lee, '92,'95)
    - (width modification & momentum dependence of modification are not taken into account)



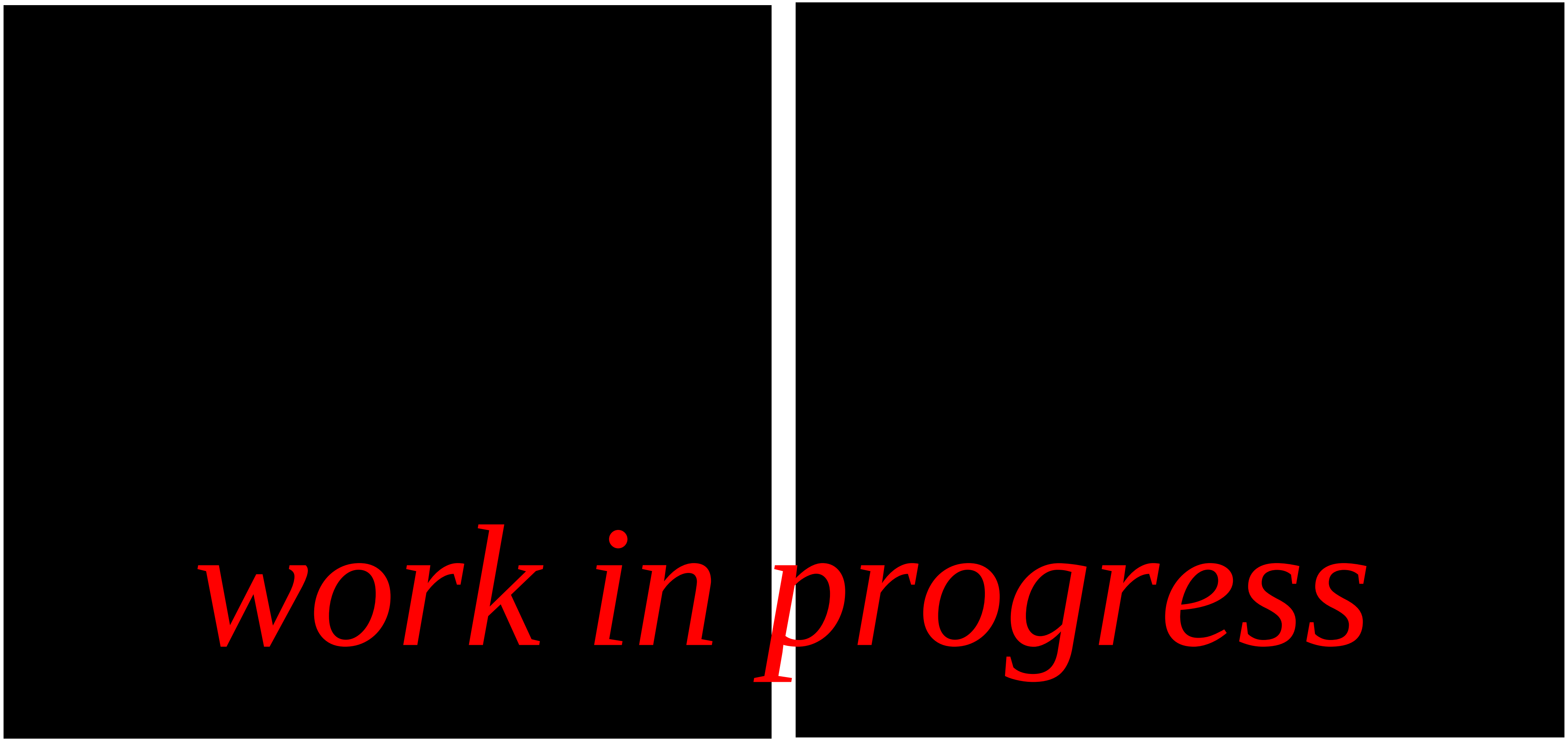
- ρ/ω ratio is fixed to unity as measured in former exp.

Fitting results by the toy model



- the tendency of the data are reproduced qualitatively by the model

E325 e^+e^- spectra of ϕ meson (BKG not subtracted)



- Clear peak is already seen, over 1000 of ϕ s for each target, in 2001/02 all statistics
- careful and precise analysis is on going

Proposed Experiment at J-PARC

Proposed Experiment at J-PARC

- Same concept as E325
  - thin target / primary beam (10^9 ~10^{10} ppp)/ slowly moving mesons
- Main goal : collect 10^4 ~10^5 ϕ -> ee for each target in 100 shifts
  - 10-100 times as large as E325
    - velocity dependence of 'modified' component
    - new nuclear targets : proton (CH_2 -C subtract), Pb
  - narrow width -> sensitive to modification
  - free from ω–ρ interference
- ω, ρ and J/ψ can be collected at the same time
  - higher statistics of ω, ρ than E325 with differ A targets
  - 100-1000 J/ψ are expected in 50GeV operation
- Normal nuclear density (p+A)
  - but also high matter density (A+A, ~20GeV/u) in the future

examine the modification from various view points

Spectrometer : two options

A) Reuse of E325 spectrometer

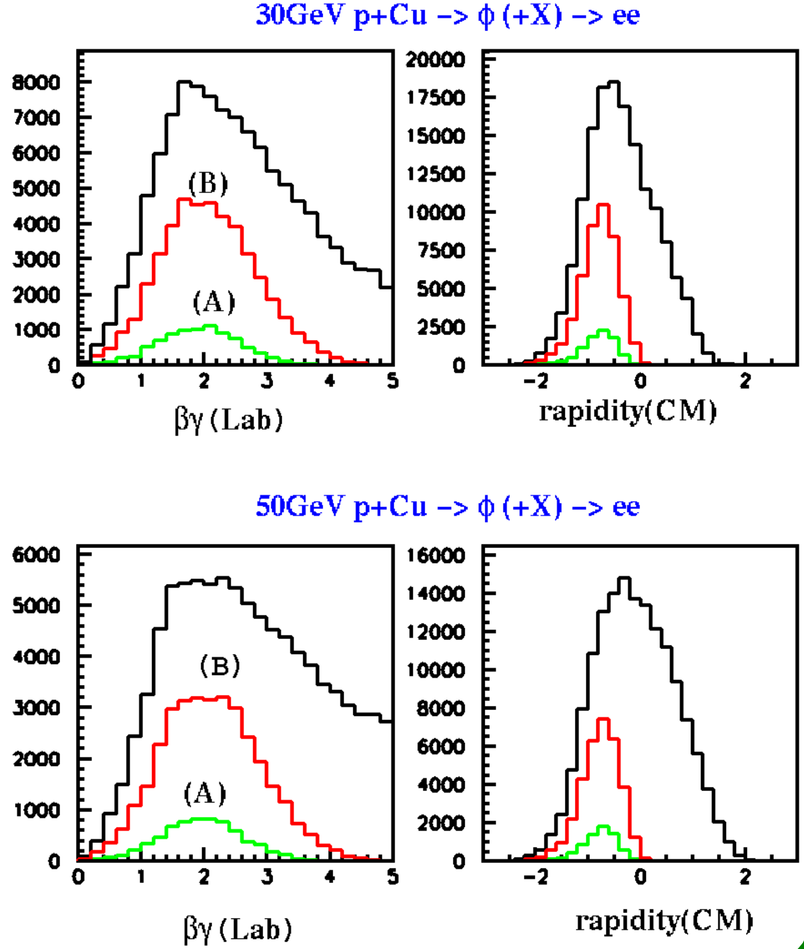
or

B) Newly constructed larger acceptance spectrometer

using Gas Electron Multiplier (GEM) as a Cherenkov photon sensor and/or tracker

spectrometer acceptance

$\phi \to ee$



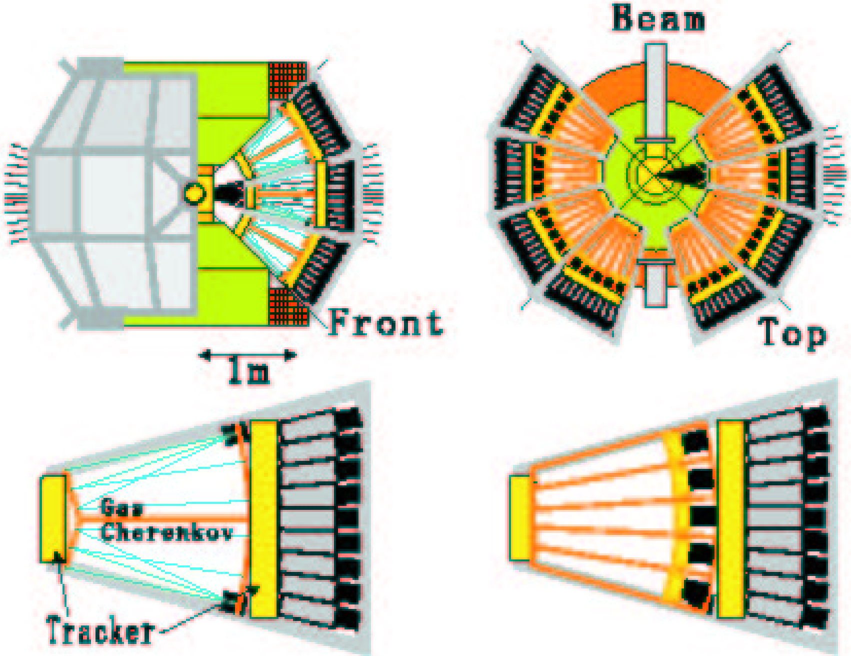
expected ϕ yield for two options(using JAM)

		12 GeV	30 GeV	50 GeV
beam energy		12 GeV	30 GeV	50 GeV
ϕ production CS (p+Cu)		1.0 mb	3.0 mb	5.1 mb
detector acceptance	case A	8.8%	6.0%	4.5%
	case B	45%	31%	23%
normalized yield by E325	case A	1	2.0	2.6
	case B	5.1	10.0	12.7

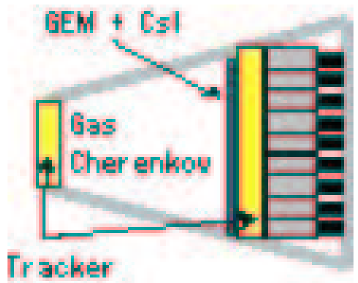
Further, for 10 times higher intensity beam (10^{10})
(i.e. high interaction rate : 10MHz)
to collect higher statistics (100 times of E325 $=10^5$ ϕ), (B) is needed

Proposed new spectrometer

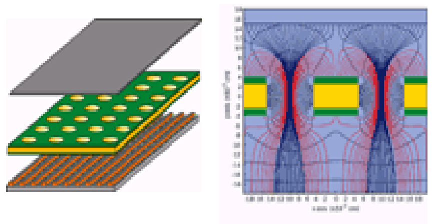
- Tracking Device
  - Drift Chamber
  - GEM(Gas electron multiplier)
    - strip readout
- Two-stage Electron ID
  - Gas Cherenkov
    - PMT+2 mirrors
    - GEM+CsI photocathode
      - pad readout
  - Leadglass EMC
- ~30K Readout Channels (in 20 units)
  - E325: 3.6K, PHENIX:~300K
- Cost : ~$5M (including $2M electronics)



Schematic view of spectrometer



GEM segment



GEM

Challenges in Detector R&D

- Environment with high intensity beam : (10^9 ~10^{10} ppp)

  high interaction rate (1-10MHz)

  beam halo is origin of trigger background/saturation of forward detector

  spot size : ~1mm

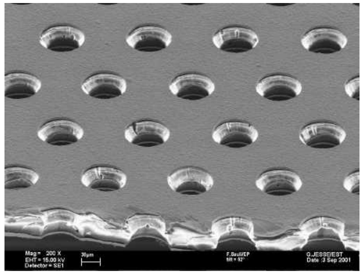
- Tracking detector should cope with high intensity beam/high int. rate
  - Drift Chamber
  - GEM and strip read out for tracking detector
    - No drop of gain up to particle flux of ~10KHz/mm^2 (E325 highest is 0.5KHz/mm^2)

- High performance electron ID counter : π rejection ~10^{-4}
  - Leadglass EMC recycled from TRISTAN : < 10^{-1}
  - Gas Cherenkov : ~10^{-3}
  - advantages of GC with GEM-CsI photocathode and pad readout (HBD: *hadron blind detector*)
    - No mirror and No segment. ->No photon loss with reflection at mirrors
    - Less materials.
    - Flexible trigger configuration with pad readout.

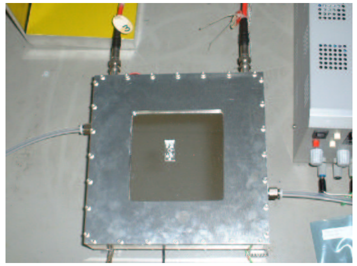
Detector R&D status

GEM R&D at CNS,U-Tokyo

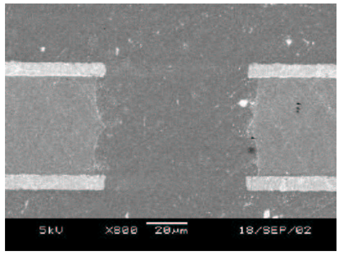
- GEM foils and CsI photo cathode
  - Originally, made in CERN. Recently, Fuchigami Micro co. and 3M produce GEM foils.
  - R&D program is on going at CNS, Weitzman, and BNL.
    - mainly for the PHENIX upgrade program.
  - Check the feasibility
    - Basic parameters (Gain, Quantum Eff. and so on)
    - long term stability
- Results from CNS
  - Produce GEM foils
    - Collaborate with Fuchigami co.
    - Use plasma-etching method.
    - Compare gain with CERN's foils.
  - We have established the scheme for making foils.
    - Checking for gain stability should be done soon.
  - Produce GEM foils with CsI cathode
    - Collaborate with Hamamatsu co.



GEM (CERN)



Test bench



GEM (CNS)

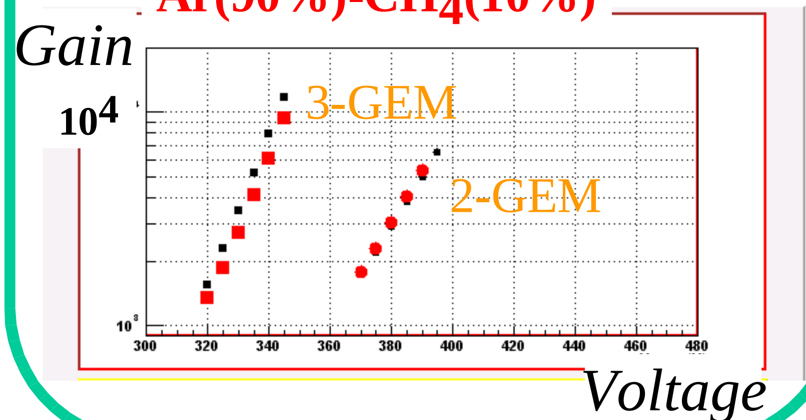
ϕ: 70 μm

Pitch: 140 μm

Kapton: 50 μm

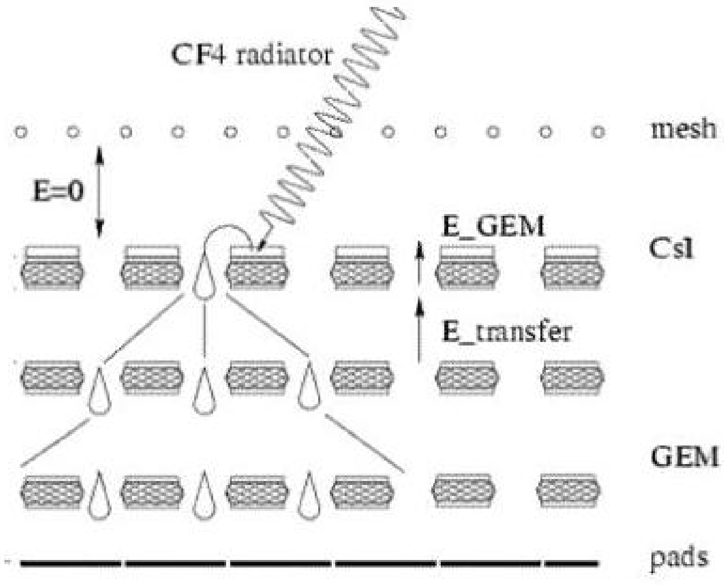
Cu: 5 μm

Ar(90%)-CH_4(10%)

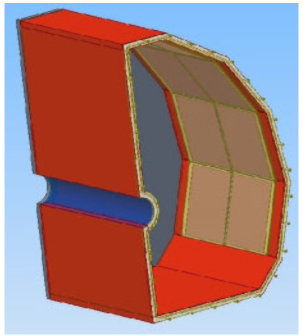


HBD (Hadron Blind Detector)

- HBD : Thr. type Gas Cherenkov Counter
  - CsI photocathode : UV photon sensitive
  - Triple GEM with pad readout
    - low granularity/low gain
  - Ionized electrons are collected by mesh
    - photoelectrons are amplified by 3 stages
    - ionized electrons are amp. by only last 2 stages
    - -> can detect only particles with cherenkov photon.
- Joint development with Weitzman Institute
  - originally for PHENIX upgrade
  - GEM with CsI
    - made in CERN and also in Japan are tested
- beam test was done in this May at KEK



Concept of HBD

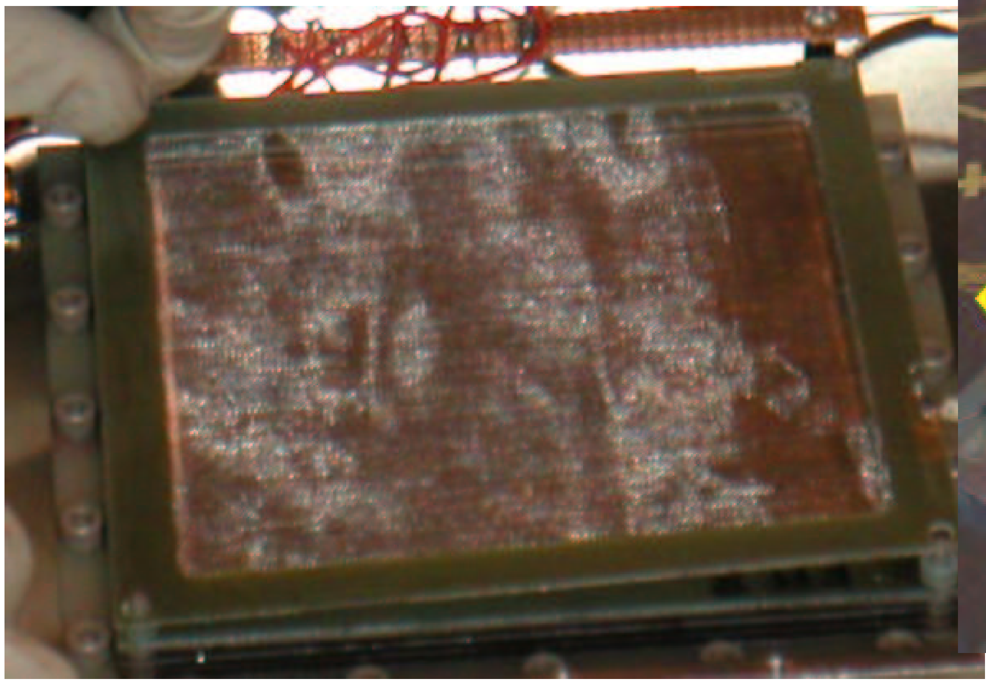


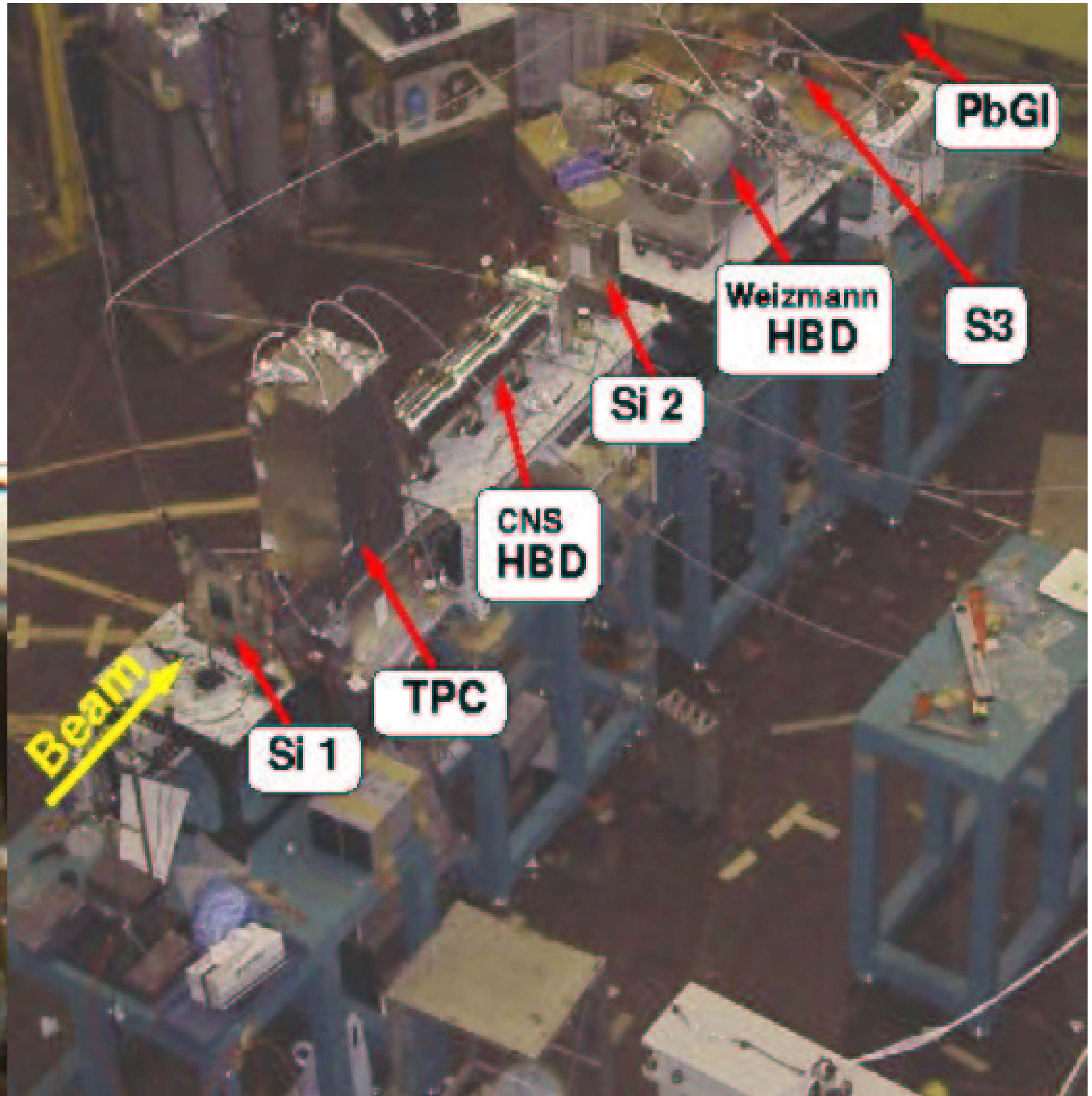
Proposed structure for PHENIX HBD

Beam test at KEK (2004/May)

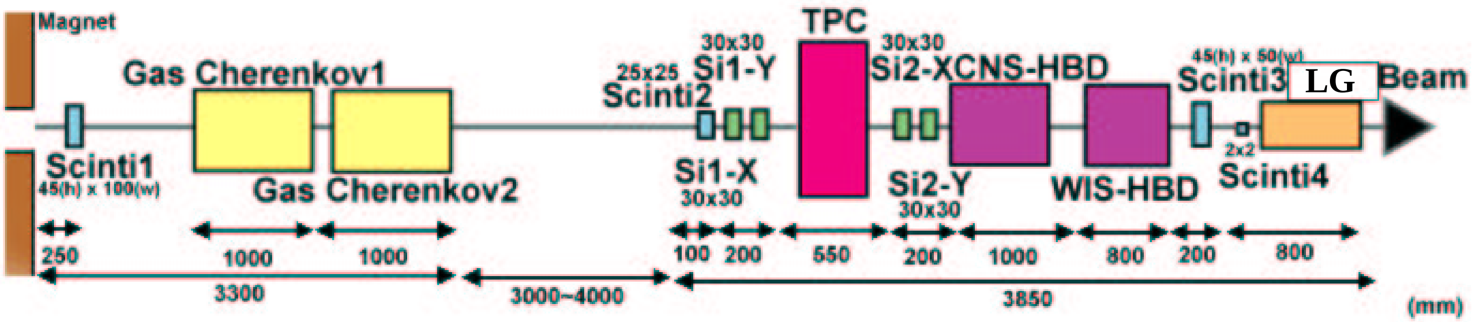
setup at KEK-PS π2 beam line

GEM(CNS)

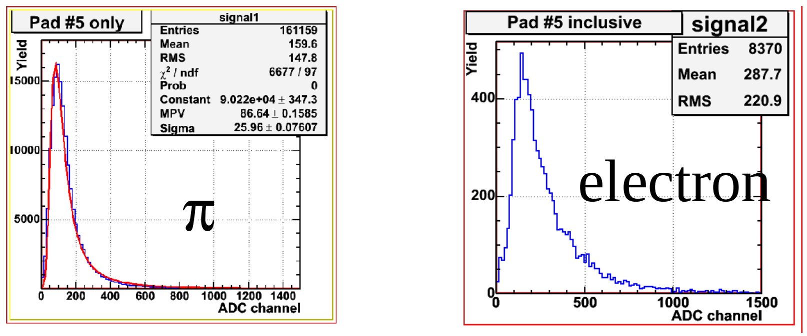




Beam Test at KEK



- detector response for π and electron are tested
- Two detectors
  - Weitzman
  - CNS



Response of Weitzman detector

- ADC spectrum for π is very consistent with Energy loss in Gas.
- Electron produces more (photo-)electron than π.
  - However, it is smaller than expectation. Still, we're investigating this problem.

Further analysis is underway. Please see K.Ozawa's talk in JPS.

Summary

- Measure the vector meson modification in nuclear matter to investigate the chiral symmetry in QCD
- E325- type experiment at J-PARC
  - use primary proton beam ($1x10^9$ ~$1x10^{10}$ /sec) on thin targets (~0.1% int.length) to reduce electron background
  - especially collect 10^4 ~10^5 $\phi \to e^+e^-$ in p+A reaction in 100shift(1month)
    - (10-100 times as large as E325's statistics)
  - Using old E325 spectrometer, 2-3 times larger statistics than E325 with 30~50GeV proton beam
- New spectrometer using new technology (GEM tracker/HBD)
  - better mass resolution : ~5 MeV/c^2
  - larger acceptance -> 10 times larger statistics.
  - higher rate capability -> more 10 times stat. using higher intensity beam
- Test Detector with new technology is being developed. Beam test was done and also planned in next year.