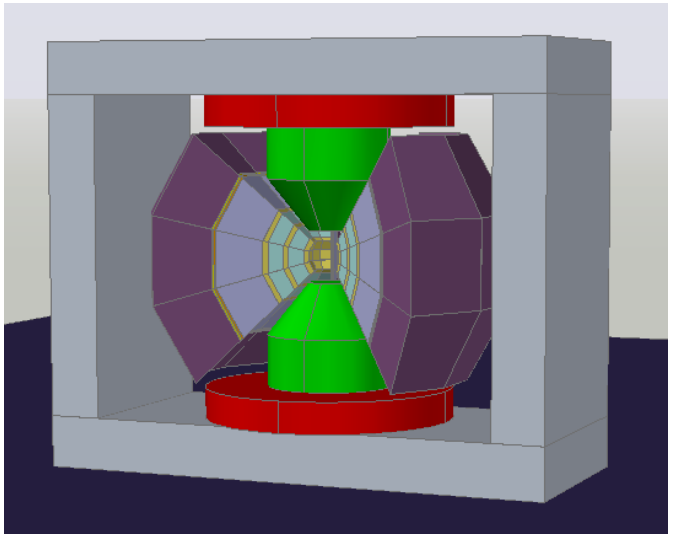
Project C01 and J-PARC E16 spectrometer

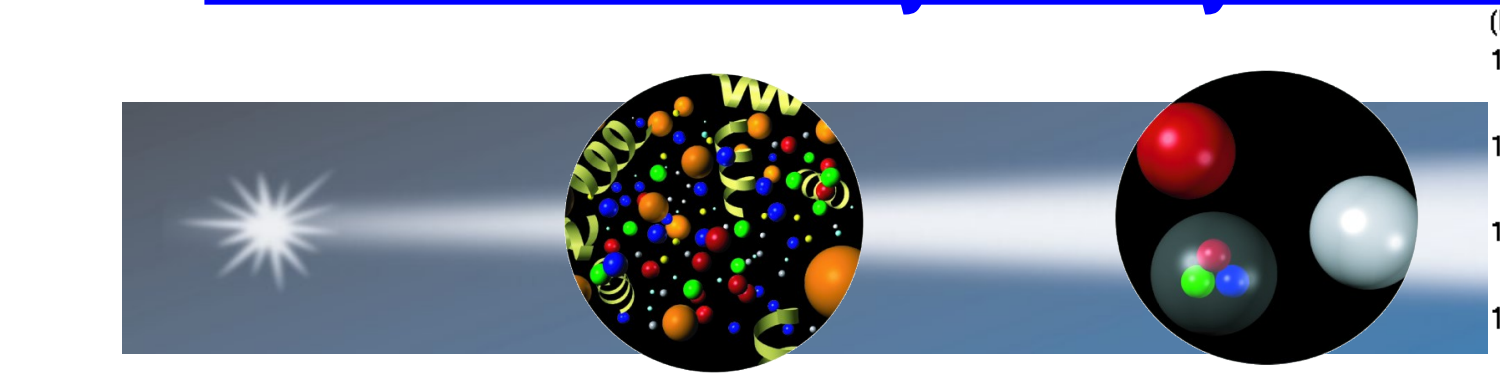
Satoshi Yokkaichi
(RIKEN Nishina Center)

C01 : Experimental study on the origin of mass due to the breaking of Chiral symmetry

- J-PARC E16 experiment
  - systematic study of mass modification of phi meson
- R&D : Progress in JFY 2009-10
- Outlook

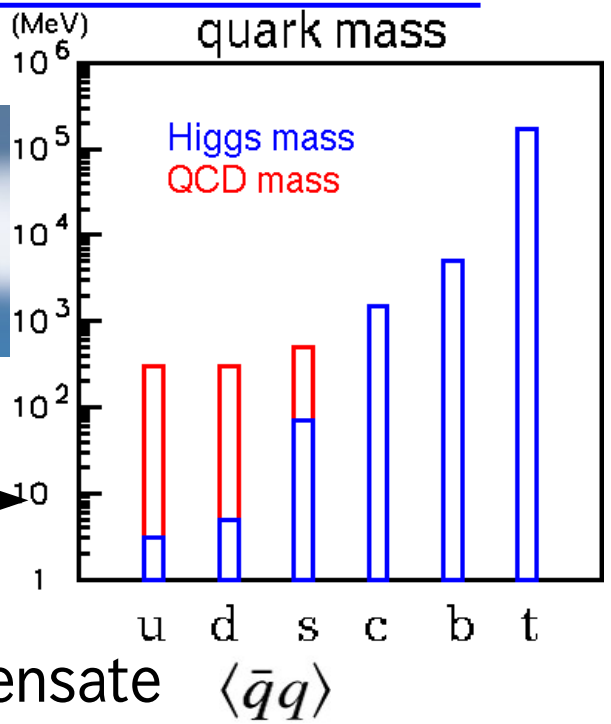


Mass and chiral symmetry in nuclear matter

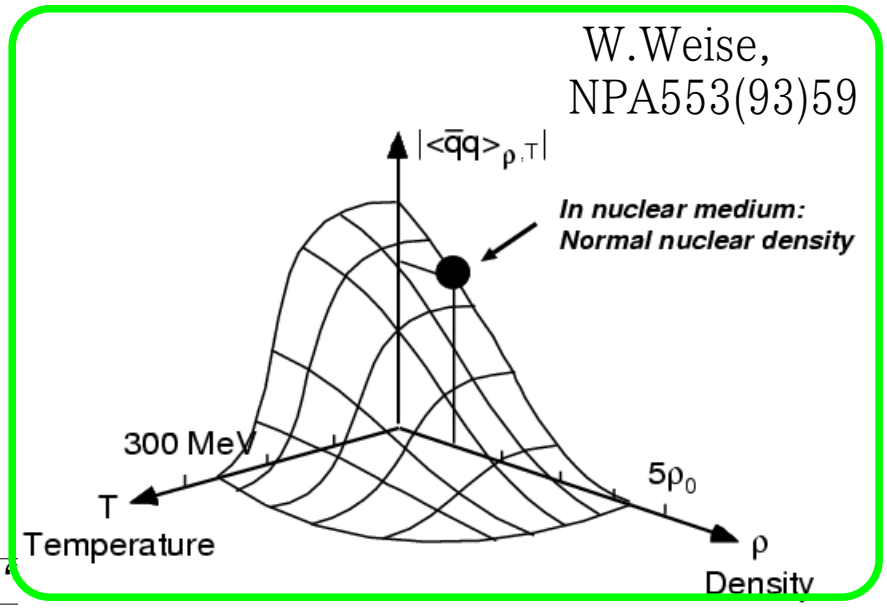


big bang 10psec 0.1msec

quark mass 0MeV 3MeV from Higgs 300MeV from chiral condensate $\langle\bar{q}q\rangle$



- Origin of hadron mass : spontaneous breaking of chiral symmetry
- In hot/dense matter, chiral symmetry is expected to be restored
  - hadron modification is also expected
  - many theoretical predictions, related CS restoration (or not); meson mass decreasing, width broadening, and so on.



Vector meson measurements in the world

dilepton mesurement

- 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
- NA60 (μμ) 400GeV p+A/158GeV In+In
- PHENIX (ee,KK) p+p/Au+Au
- HADES (ee) 4.5GeV p+A/ 1-2GeV A+A
- CLAS (ee) 1~2 GeV γ+A
- *J-PARC* (ee) 30/50GeV p+A/ ~20GeV A+A
- *CBM/FAIR* (ee) 20~30GeV A+A

as of 2006/June

- TAGX (ππ) ~1 GeV γ+A
- STAR (ππ,KK) p+p/Au+Au
- LEPS (KK) 1.5~2.4 GeV γ+A
- CBELSA ($\pi^0\gamma$) 0.64-2.53 GeV γ + p/C/Nb

already state 'modified'
running/in analysis
future plan

Vector meson measurements in the world

dilepton measurement

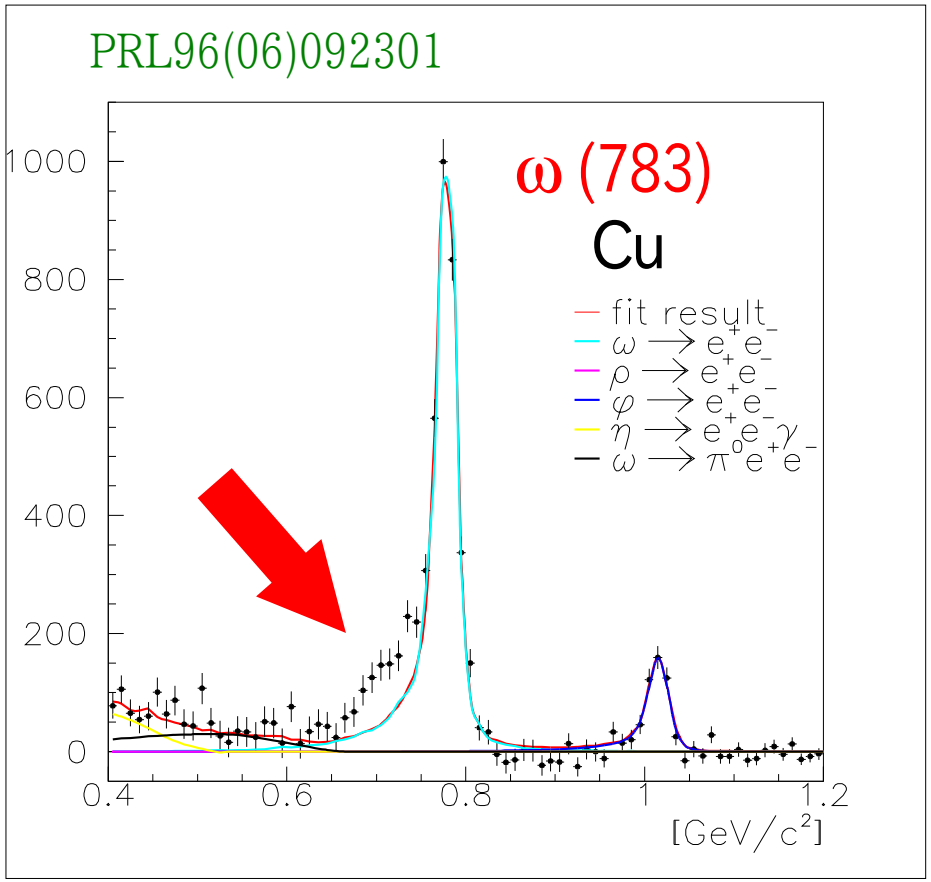
- HELIOS/3 (ee, μμ) 450GeV p+Be / 200GeV A+A
- DLS (ee) 1 GeV A+A
- CERES (ee) 450GeV p+Be/Au / 40-200GeV A+A
- E325 (ee,KK) 12GeV p+C/Cu
- NA60 (μμ) 400GeV p+A/158GeV In+In
- PHENIX (ee,KK) p+p/Au+Au
- HADES (*) (ee) 4.5GeV p+A/ 1-2GeV A+A
- CLAS-G7 (*) (ee) 1~2 GeV γ+A
- *J-PARC E16* (ee) 30/50GeV p+A / ~20GeV A+A ?
- *CBM/FAIR* (ee) 20~30GeV A+A

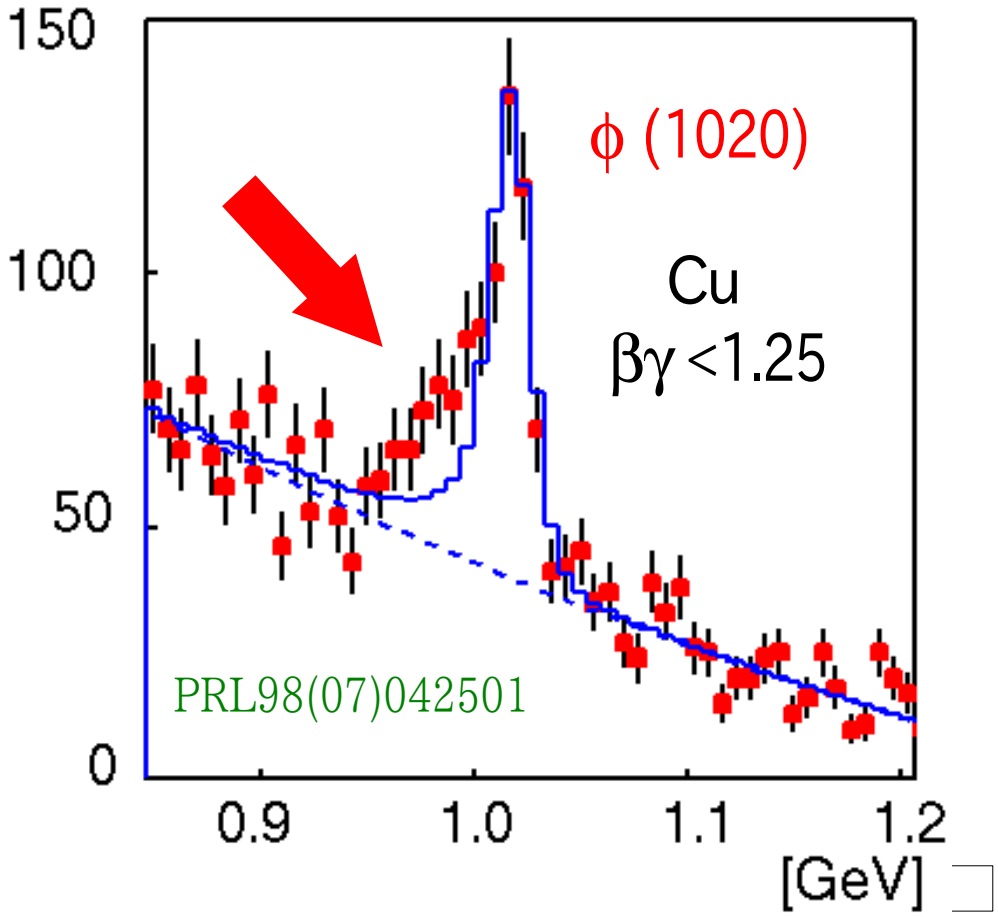
- TAGX (ππ) ~1 GeV γ+A
- STAR (ππ,KK) p+p/Au+Au
- LEPS (KK) 1.5~2.4 GeV γ+A
- CBELSA/TAPS(*) ($\pi^0\gamma$) 0.64-2.53 GeV γ + p/Nb

published/ 'modified'
published/ 'unmodified'
running/in analysis
future plan
as of 2010/Dec

E325 observed the meson modifications

- in the e^+e^- channel
- below the ω and ϕ, statistically significant excesses over the known hadronic sources including experimental effects





Mass modification?

- mass modification of vector mesons in nuclear matter exist (E325/CLAS-G7/(TAPS) at the lower energy, NA60/CERES/PHENIX in HI collision)
  - interpretations are not converged
    - mass dropping and/or width broadening?
    - interpretation model dependence ?
      - space-time evolution of the (T, ρ) of matter in the real world
  - physics
    - hadronic many-body effect? chiral symmetry restoration?
- Next step in the invariant-mass approach
  - $\phi \longrightarrow e^+e^-$: less uncertain than the ρ/ω case
    - ρ's broad and complicated shape, ρ–ω interference, ρ/ω ratio, etc.
  - systematic study of the mass modification
    - matter-size dependence: larger/smaller nuclei, impact parameter
    - momentum dependence : never measured
  - check the interpretation models

J-PARC E16 experiment

Systematic study of the modification of vector meson spectra in nuclei to approach the chiral symmetry restoration

Collaboration

RIKEN S.Yokkaichi, H. En'yo, F. Sakuma, K. Aoki, J. Kanaya
U-Tokyo K. Ozawa, K. Utsunomiya, Y.S. Watanabe, Y.Komatsu, S.Masumoto, A.Takagi, K. Kanno
CNS, U-Tokyo H. Hamagaki Hiroshima-U K. Shigaki
KEK A.Kiyomichi, M. Naruki, R. Muto, S. Sawada, M. Sekimoto

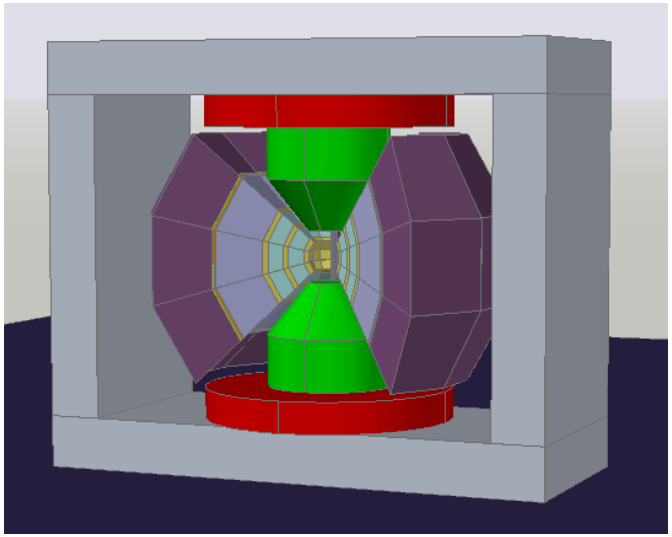
Proposal http://ribf.riken.jp/~yokkaich/paper/jparc-proposal-0604.pdf

Scientific approval : 2007/3
... Detector R&D is on going (already supported)
... production is dependent on budget status
... beamline is also : budget requested by KEK/J-PARC
Goal of construction : end of JFY2012

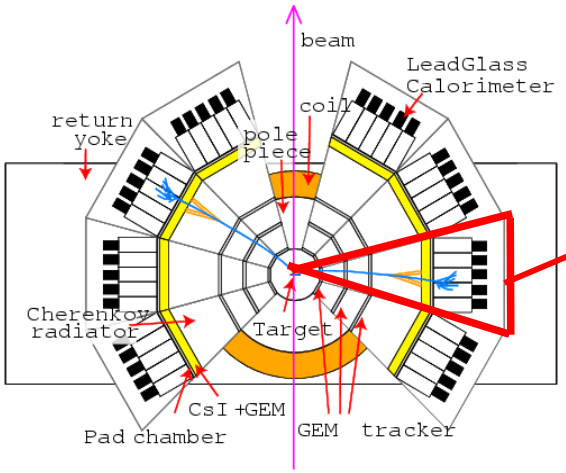
Collect high statistics for the systematic study

- 30(50)GeV p+H/C/Cu/Pb $\rightarrow \phi$ (and ρ/ω) +A in e^+e^- decay channel
- For the statistics 100 times as large as E325, new spectrometer is required.
  - To cover larger acceptance : x~ 5
  - Higher energy beam (12 $\rightarrow$ 30/50 GeV) : x ~2 of production
  - Higher intensity beam ($10^9 \rightarrow 10^{10}$ /spill (1sec)) : x 10 ($\rightarrow$ ~ 10MHz interaction on targets)

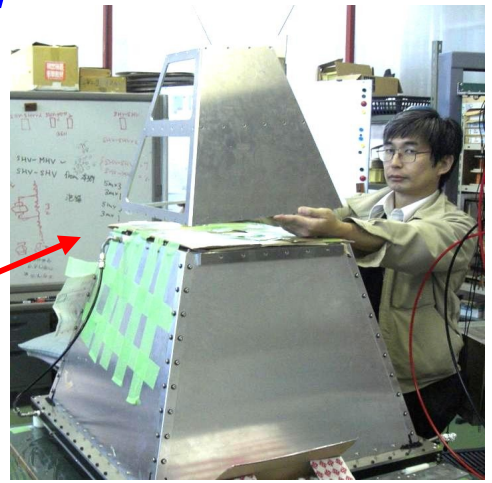
Proposed Spectrometer



Plan View

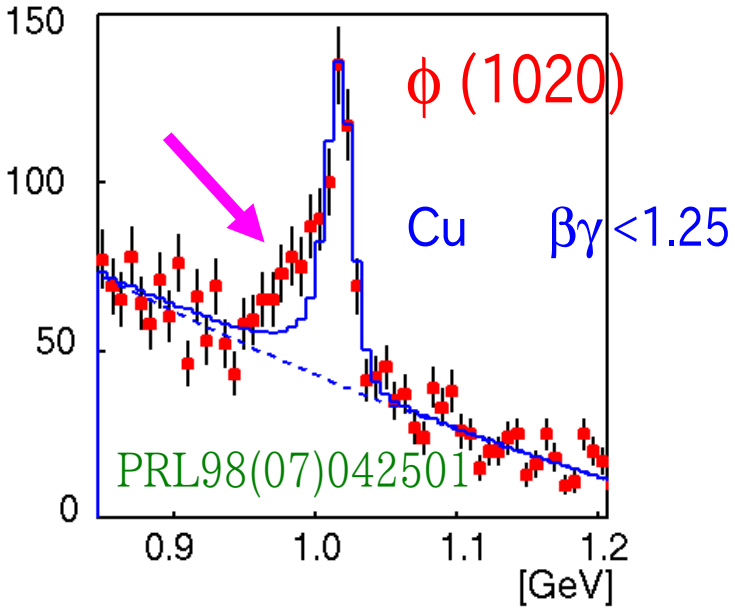


Prototype Module

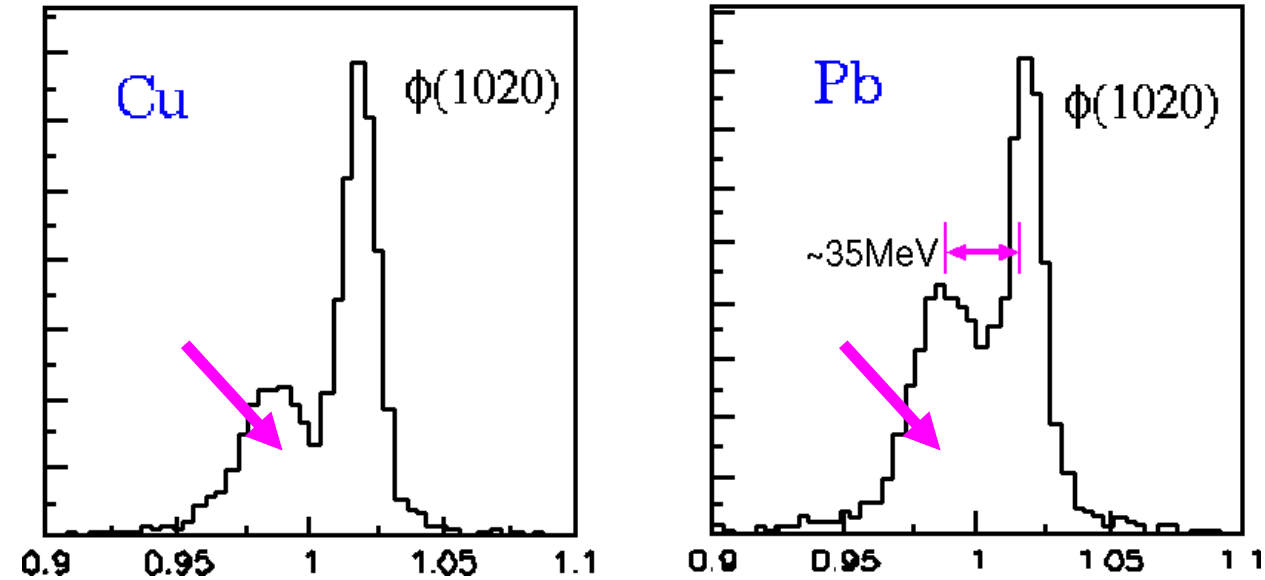


mass resolution requirement

- mass resolution should be kept less than ~10MeV
- Very ideal case : very slow mesons w/ best mass resolution:



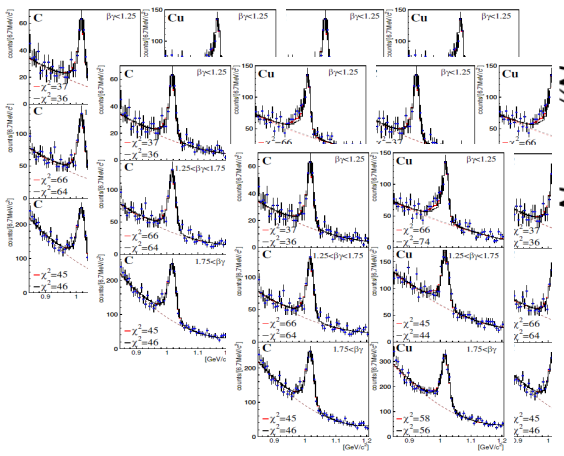
βγ<0.5, σ=5 MeV

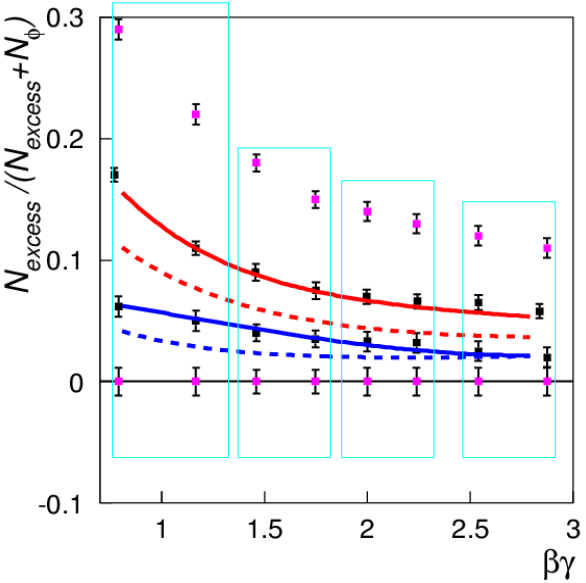


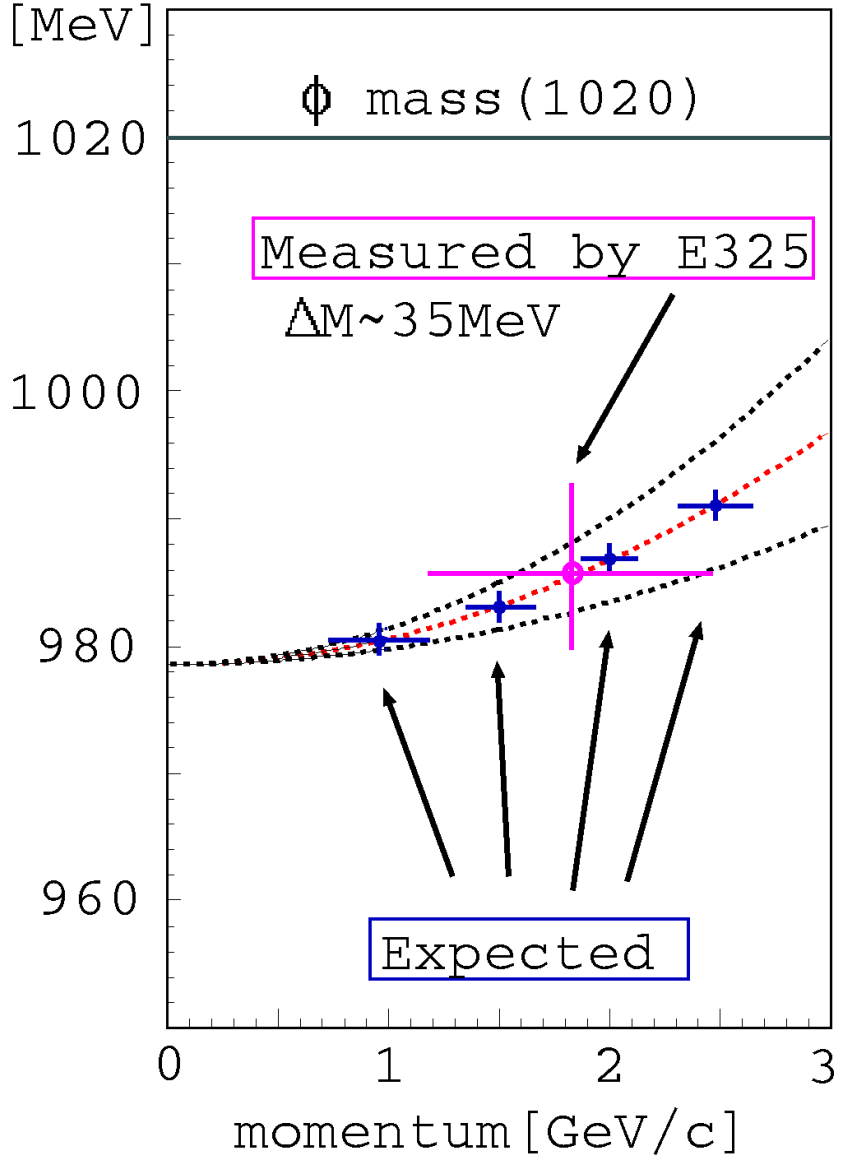
(model calc.)

dispersion relation (mass VS momentum)

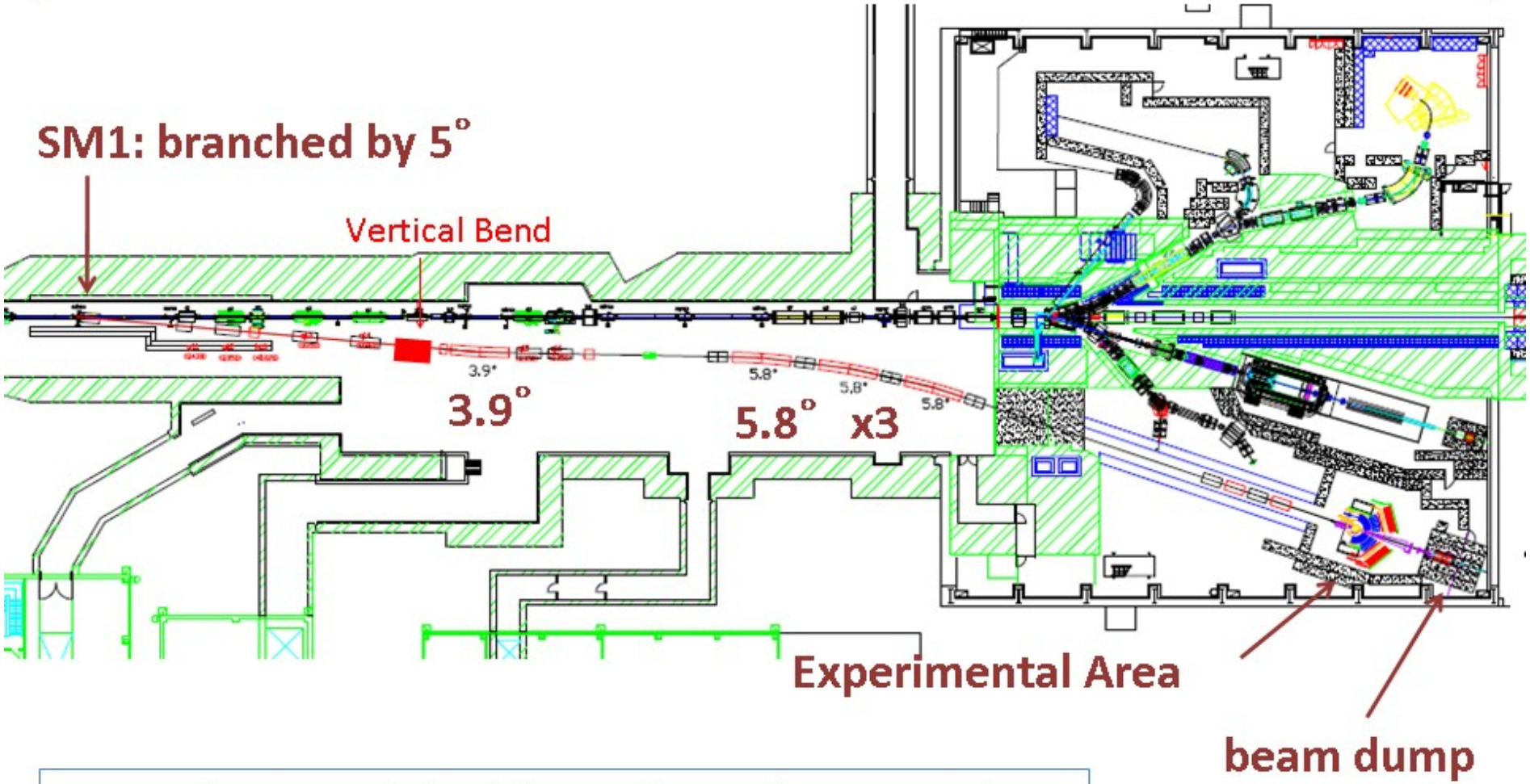
- prediction for ϕ by S.H.Lee(p<1GeV/c)
- current E325 analysis neglects the dispersion (limited by the statistics)
- fit with common shift parameter $k_1(p)$, to all nuclear targets in each momentum bin





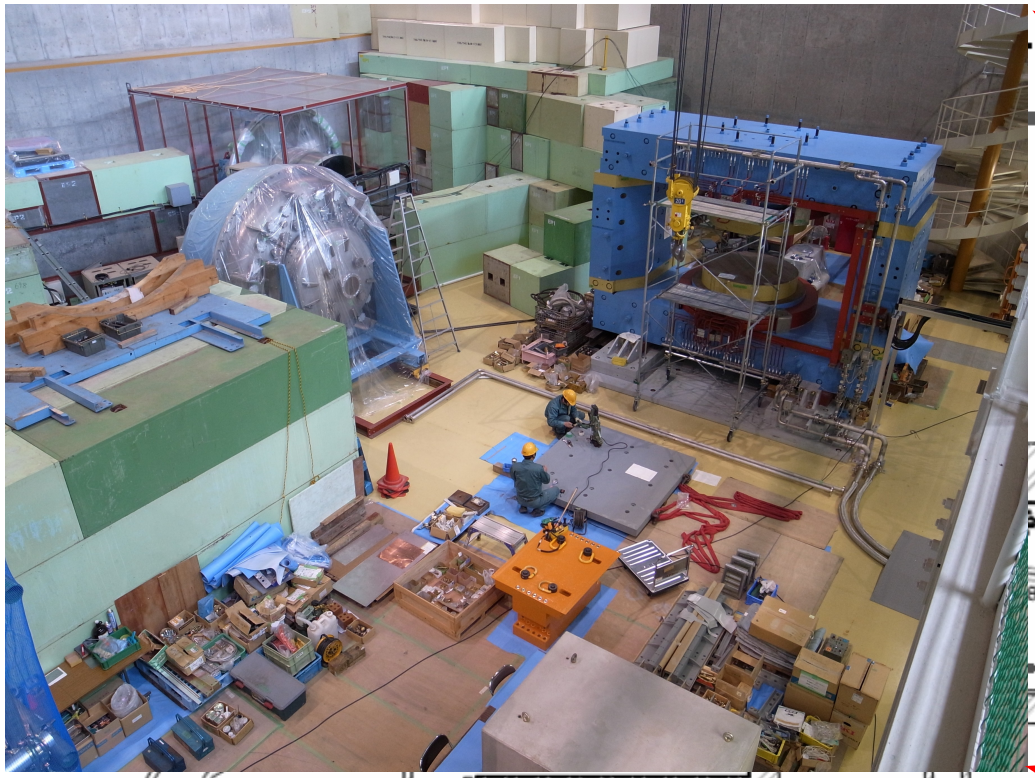


Location of E16 : High-momentum beam line

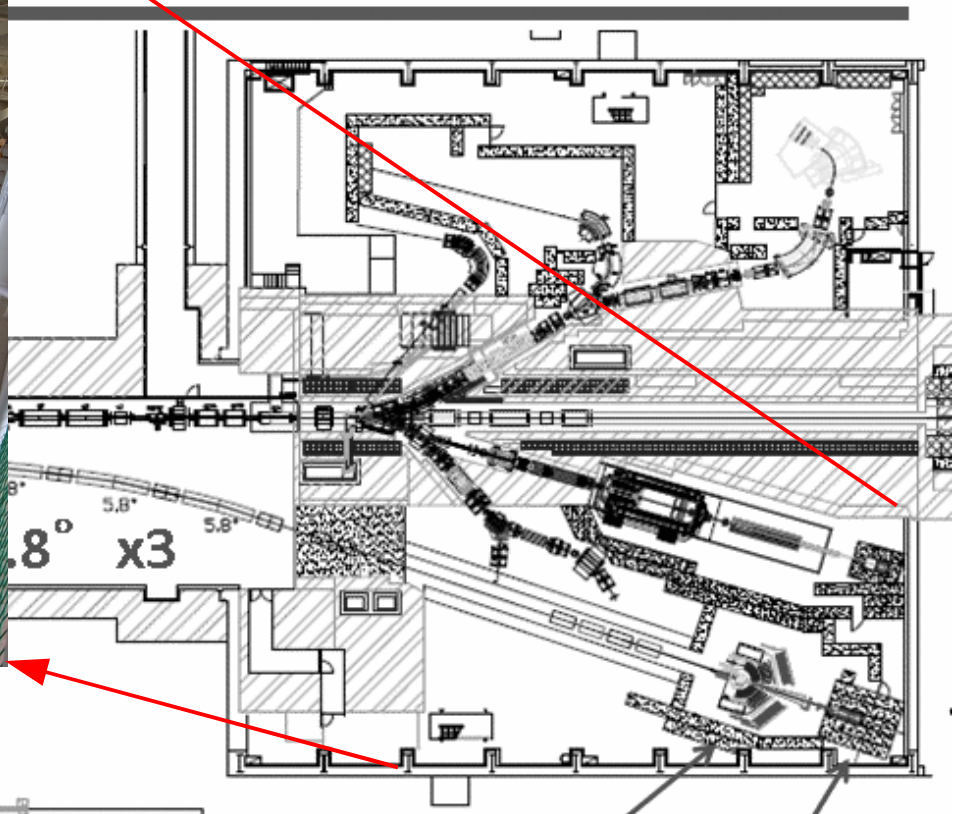


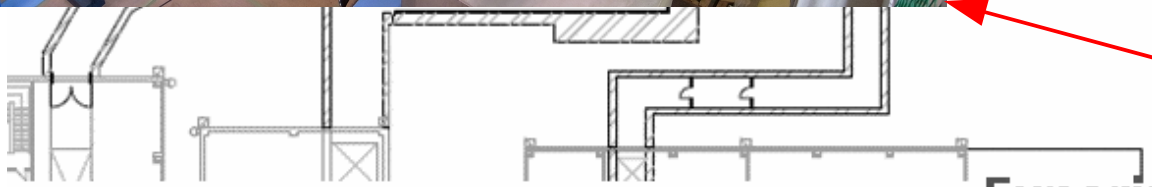
Beam dump and shields are for 10^{10} protons/s

by R. Muto



momentum beam line

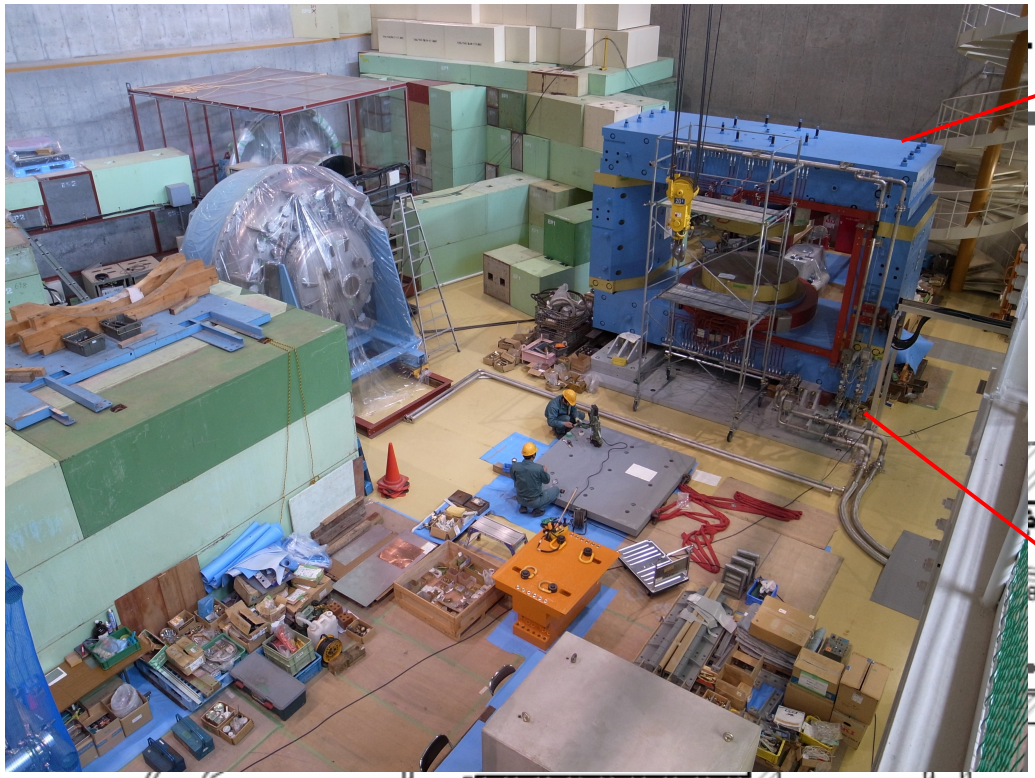




Experimental Area

beam dump

Beam dump and shields are for 10^{10} protons/s



Already the spectrometer magnet has been moved to Hadron Hall. (as of 2010/4)

Beamline construction budget is being requested.

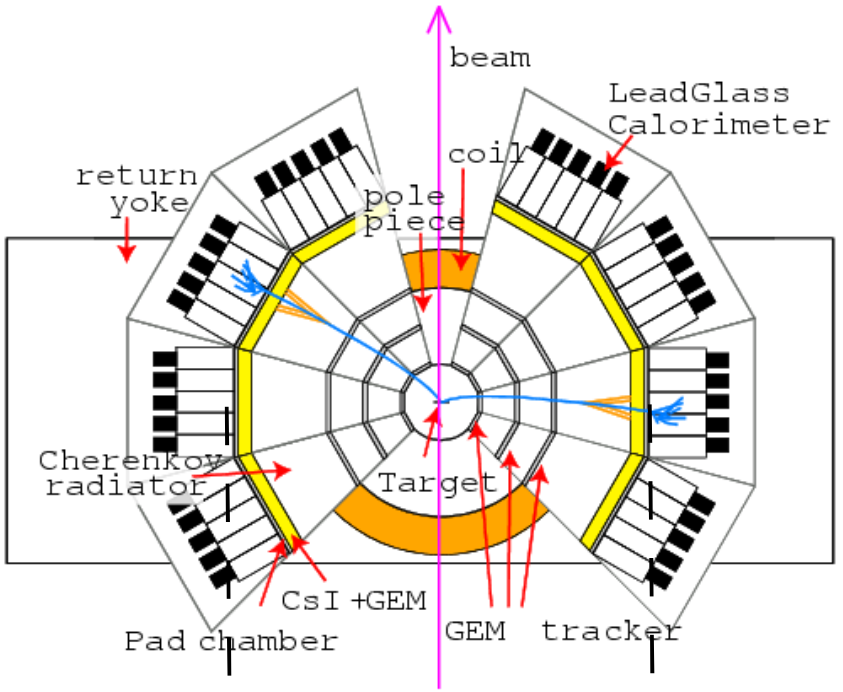
(failed to obtain the JFY2011 budget)

R&D for the actual beam line is underway.

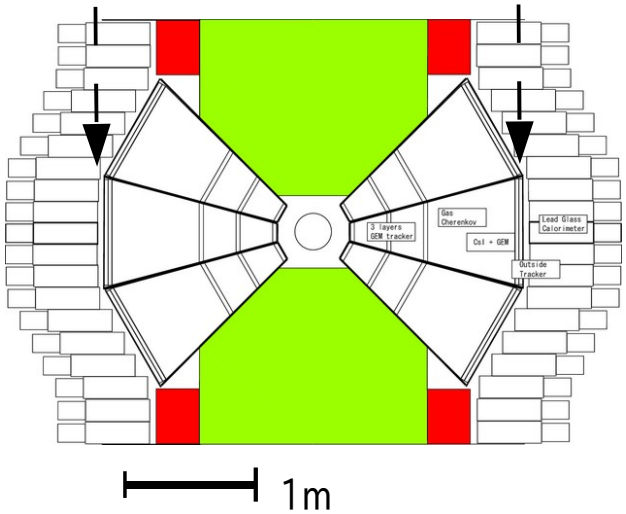
Proposed spectrometer

- Spectrometer Magnet : reuse E325 's
  - remodeling the pole / repairing the coil
  - stronger field for compact detector size
- GEM(Gas electron multiplier) Tracker
    - cope with high rate (5kHz/mm^2)
- Two-stage Electron ID (~10^{-4} π rejection)
  - Hadron Blind Detector (Gas Cherenkov)
    - GEM+CsI photocathode
    - hexagonal pad readout (~36mm ϕ)
  - Leadglass EMC: reuse of TOPAZ
- ~70K Readout Channels (in 26 segments)
  - cf. E325: 3.6K, PHENIX:~300K (w/o VTX)
- Cost : ~$5M (including ~$2M electronics)
  - cf. E325: $2M not including electronics

Plan view

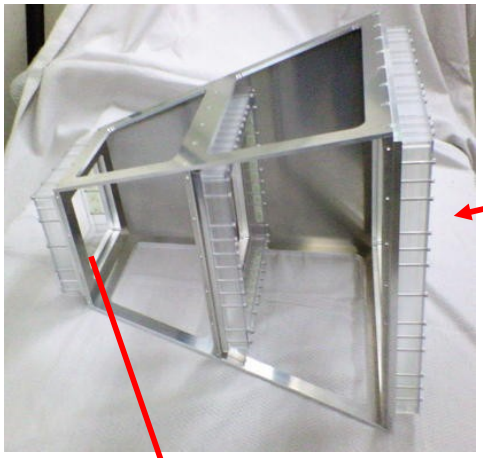


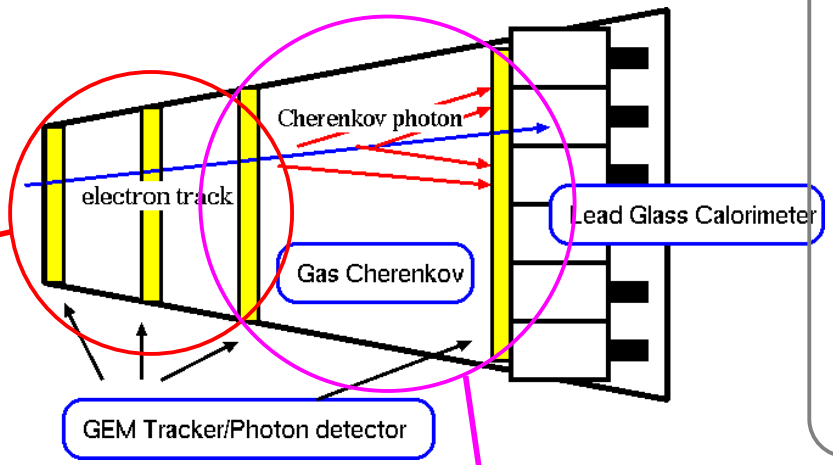
Beam view



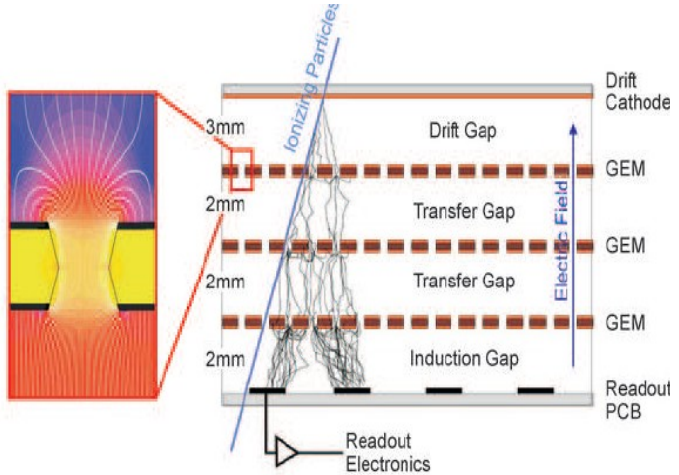
Detector R&D

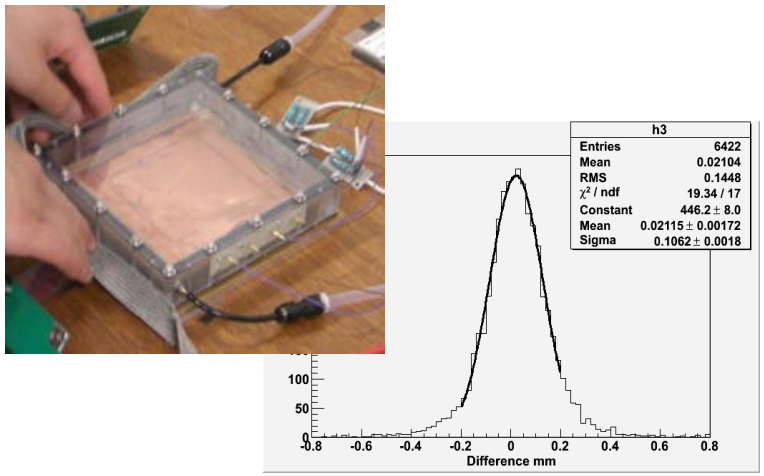
Beam test results of the Prototype Detector Module

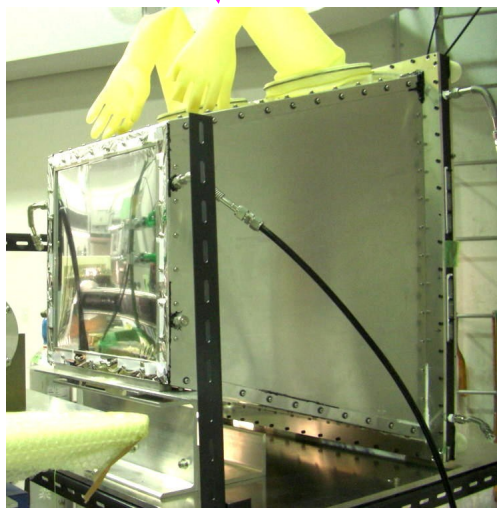




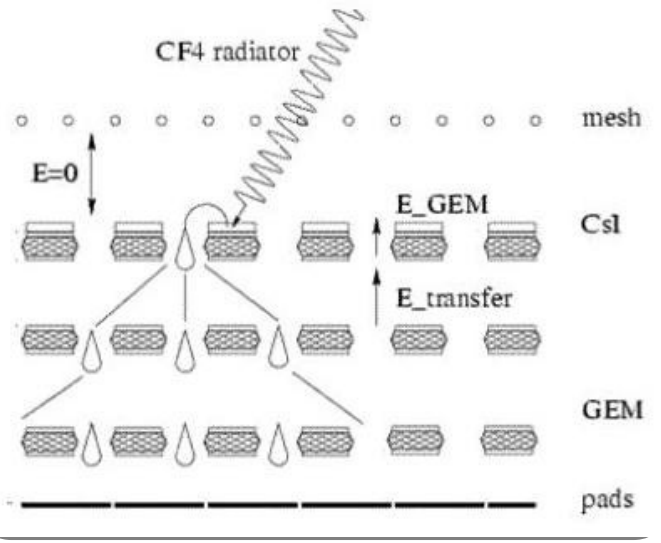
GEM & GEM chamber schematics







HBD(Hadron Blind Gas Cherenkov Detector)schematics

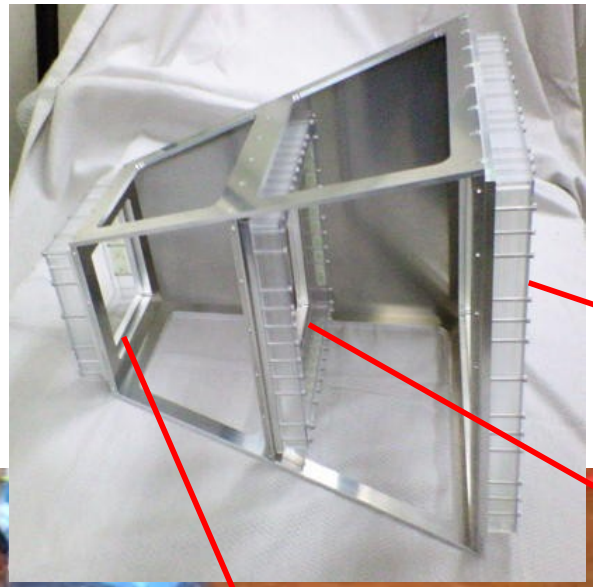


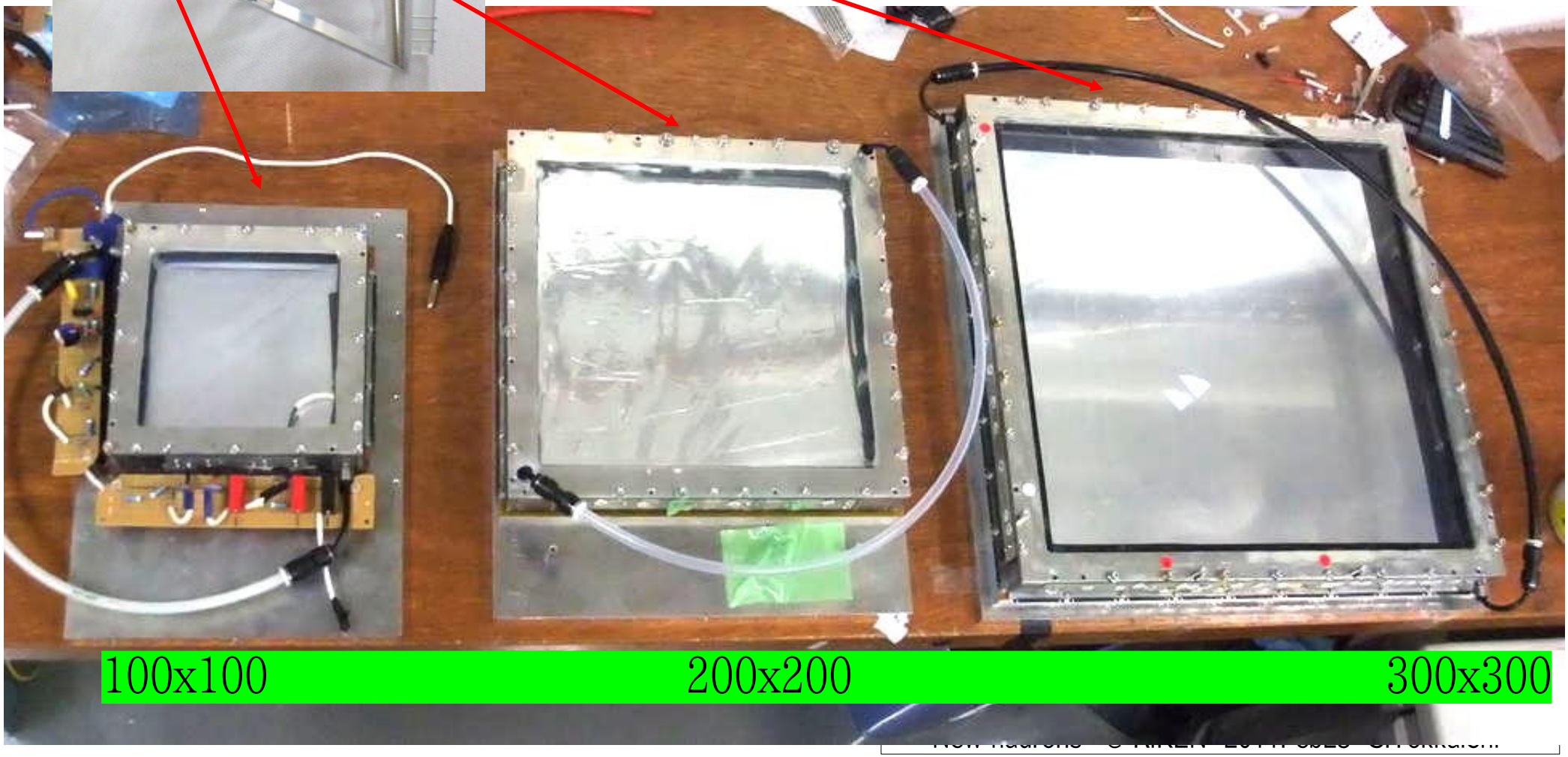
GEM Chamber :
required position resolution (~100μm) is achieved

Hadron Blind Detector :
UV Cherenkov photons from the electron beam are detected by CsI-GEM in CF4

Achievements in beam tests

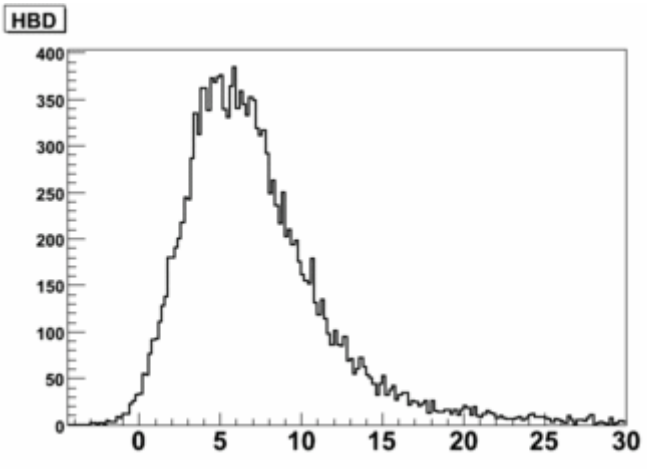
- GEM Tracker
  - Goal : position resolution 100μm
  - GEM(PI 50um) by Raytech.Co.
    - 100mmx100mm, 200mm x 200mm, 300mm x300mm
  - R/O double sided strip PCB (PI 25um) by Raytech.Co
  - position resolution (using ArCO2/350um pitch strip) for angled tracks
    - 100μm (for 0deg/15deg) – 140 μm(30deg) in 100mm x 100mm GEM
    - larger GEMs were also checked in the beam test

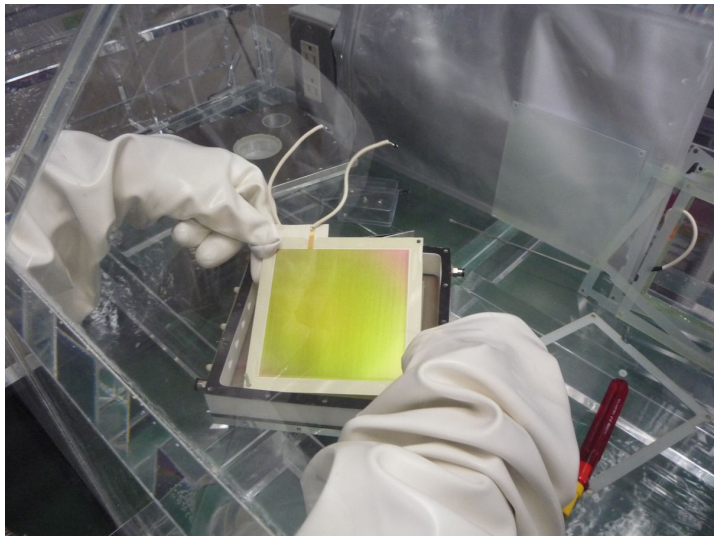


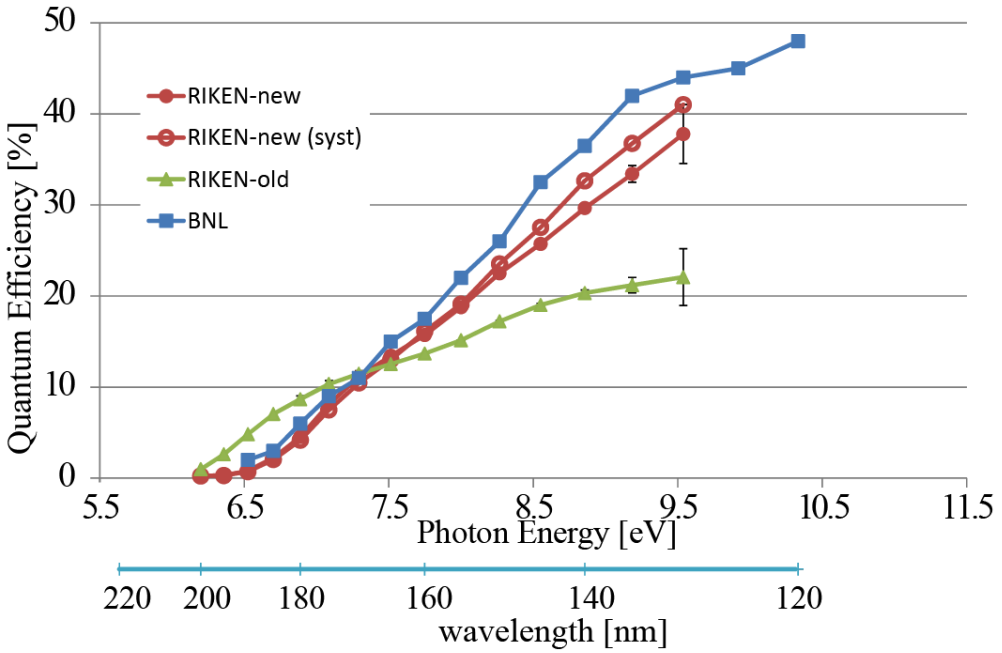

100x100
200x200
300x300

Achievements in beam tests and Labs

- HBD(Gas Cherenkov)
  - developed thanks to Weizmann/Stony Brook
  - GEM(LCP 100um: higher gain) by Scienergy.Co.
  - CsI evaporation by Hamamatsu
  - 5-6 photoelectrons detected (cf. PHENIX ~20 p.e.)
    - Improvement of gas purity and CsI q.eff. is required
  - QE improved at RIKEN : beam test in 2011/3





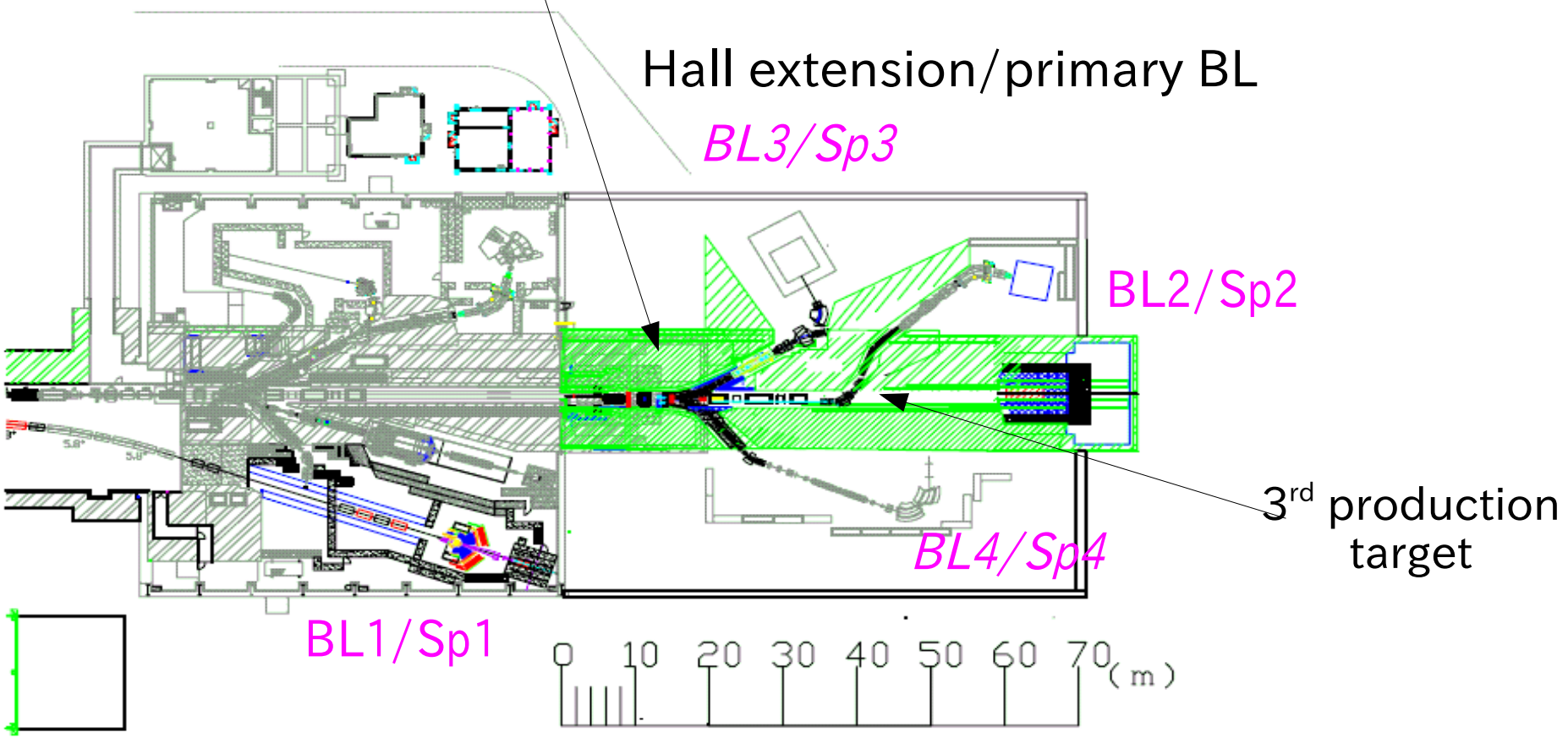


JFY2011

- Two new PD
- Spectrometer Magnet
- EMC(Lead glass)
  - recycled from TOPAZ LG : check at KEK
  - beam test of the prototype module
- GEM Tracker
  - decide R/O board architecture :strip pitch, and so on
  - under the magnetic field
  - use the R/O circuit
- HBD
  - beam test of the production type : using large volume/large GEM

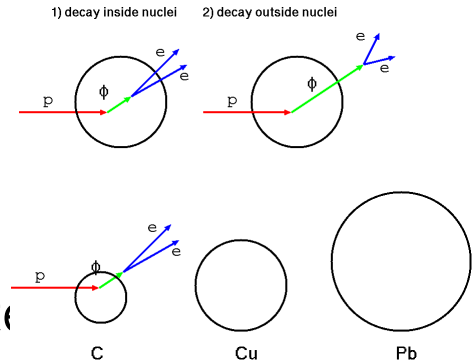
J-PARC Hadron Hall extension
(* RIKEN-proposal for the SCJ master plan)

BL1: High-p RIKEN
BL2: p-bar RIKEN
BL3: K (low p) RCNP
BL4: dispersion matching RCNP



Summary :J-PARC E16

- Main goal : collect ~1-2 x 10^5 $\phi \rightarrow e^+e^-$ for each target in 5 weeks
  using 30 (or 50) GeV p +A (C/CH_2/Cu/Pb) reactions
  - statistics : ~100 times as large as E325
  - **systematic study of the modification**
    - velocity & nuclear size (0~10 fm) dependence
      - proton/Pb targets / collision geometry (impact parameter)
    - momentum dependence (dispersion relation)
  - mass resolution : < 10 MeV (E325 : 10.7 MeV for ϕ)
    - double peak structure with σ ~ 5 MeV, selecting $\beta\gamma < 0.5$ (vely slow)



- Confirm the modification observed in E325, and provide new information about the mass of hadrons
- Detector R&D is underway : Goal is the end of JFY2012

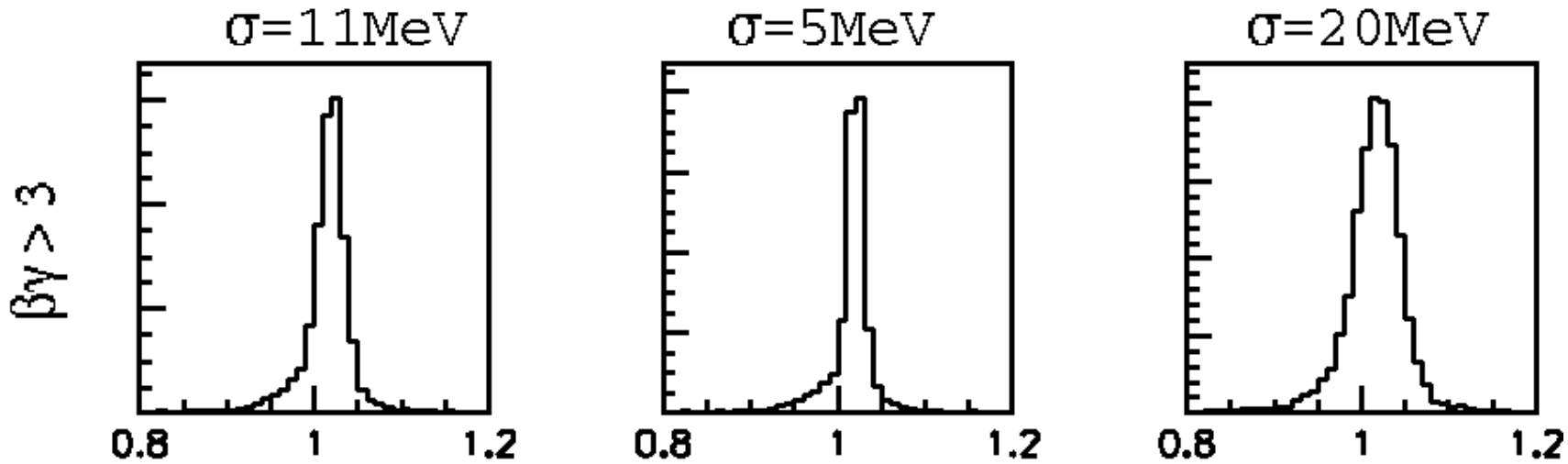
Backup slides...

-

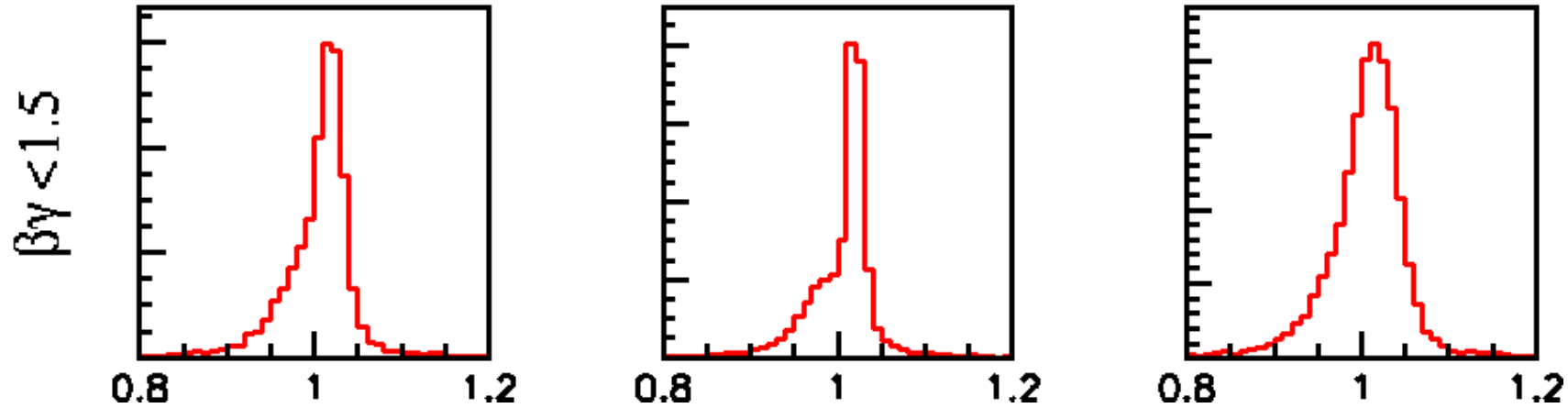
mass resolution requirement

- mass resolution should be kept less than ~10MeV

Fast



Slow

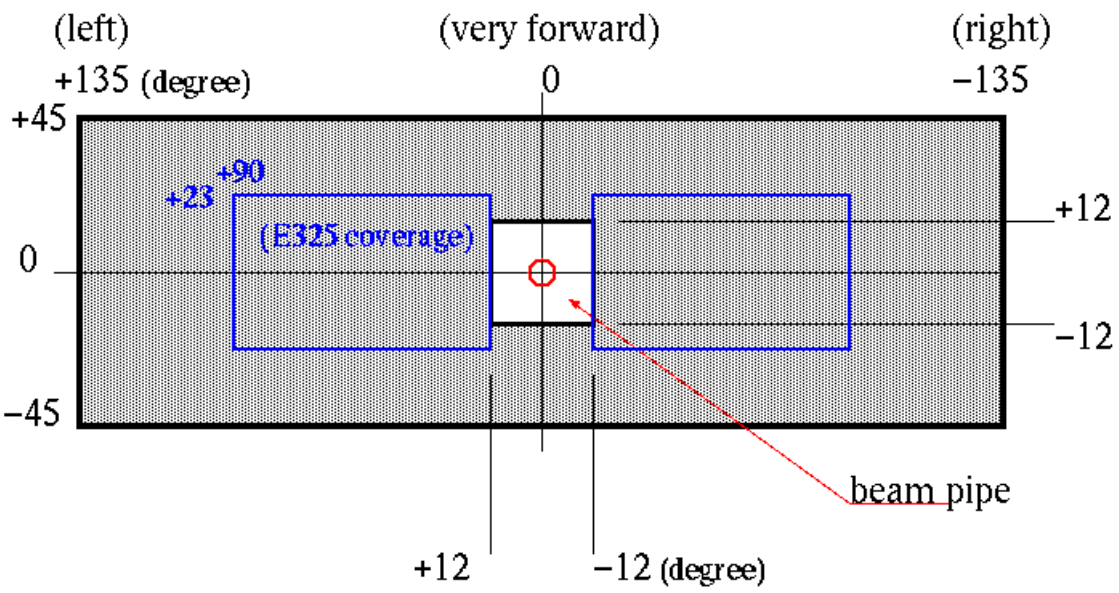


(model calc. for the Cu target)

To collect high statistics

- For the statistics 100 times as large as E325, new spectrometer is required.
  - To cover larger acceptance : x˜ 5
  - Higher energy beam (12 → 30/50 GeV) : x ˜2 of production
  - Higher intensity beam (10^9 →10^{10} /spill (1sec)) : x 10 (→ ~10MHz interaction on targets)

Geometrical (horizontal & vertical) coverage of the spectrometer



Target configuration

nuclei	interaction length(%)	radiation length(%)	thickness [μm]
C	0.05	0.1	200
CH_2	0.05	0.1	400
Cu	0.05	0.5	80
Pb	0.01	0.3	20

Vector meson mass spectra in dense matter

Bronwn-Rho scaling
PRL 66(91)2720, etc

$$m_\rho^*/m_\rho \sim (\langle\bar{q}q\rangle^*/\langle\bar{q}q\rangle)^{1/2}$$

effective Lagrangian (chiral SU(3)+VMD)

Klingle,Kaiser,Weise,
NPA 624(97)527

QCD sum rule
Hatsuda and Lee, PRC 46(92)R34, PRC 52(95)3364

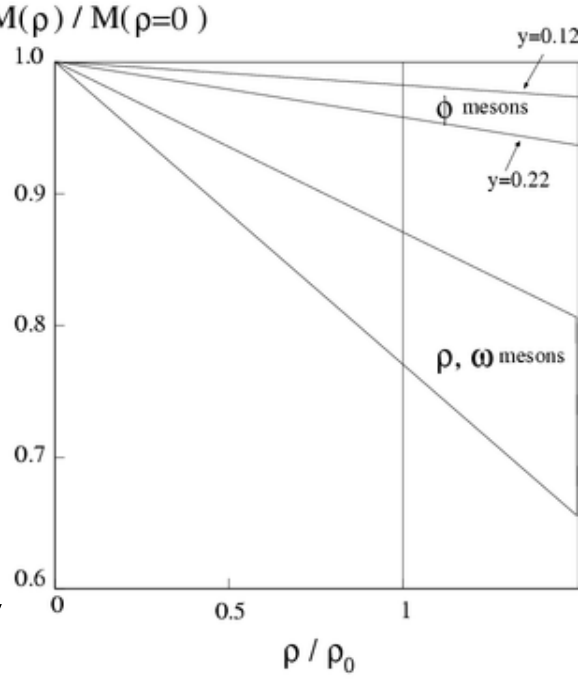
linear dependence on der

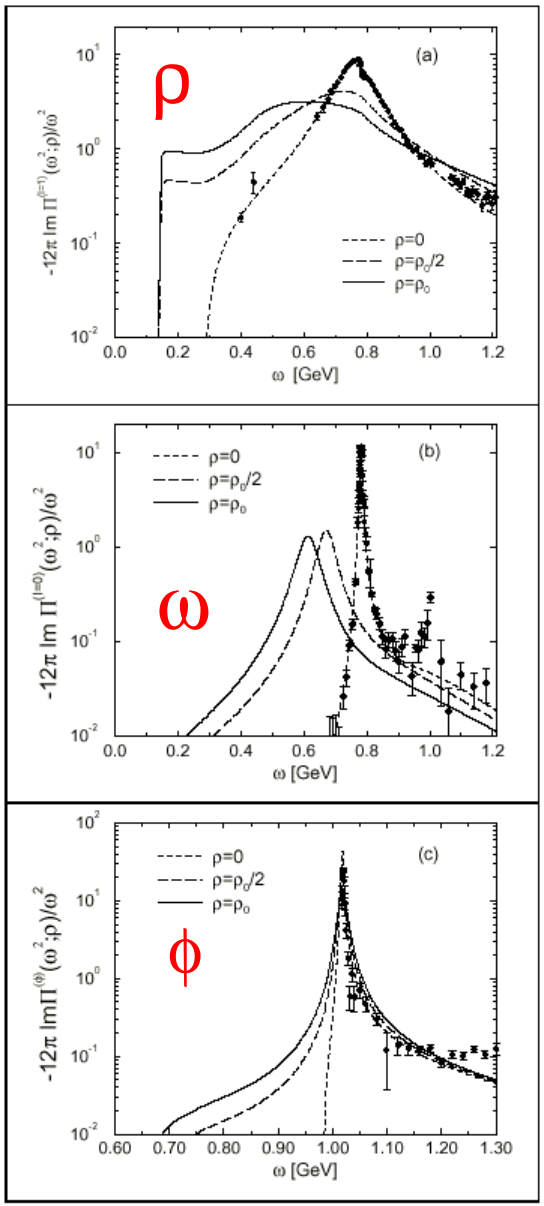
$m^*/m_0 = 1 - k\ \rho/\rho_0$

mass 'dropping'

- 16(±6)% for ρ/ω
- 0.15(±0.05)*y
  =2~4% for ϕ

for y=0.22
at the normal nuclear density

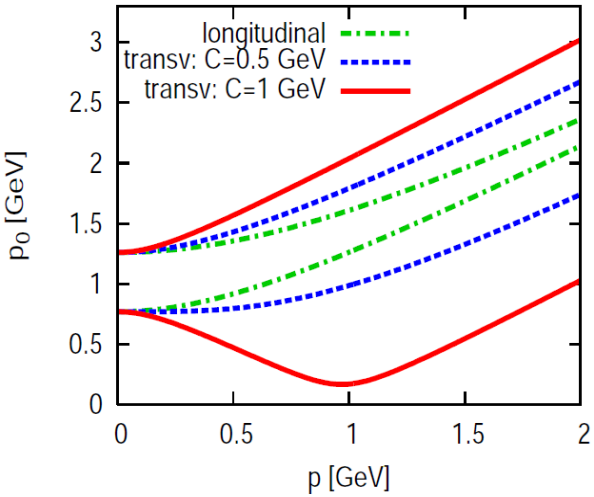




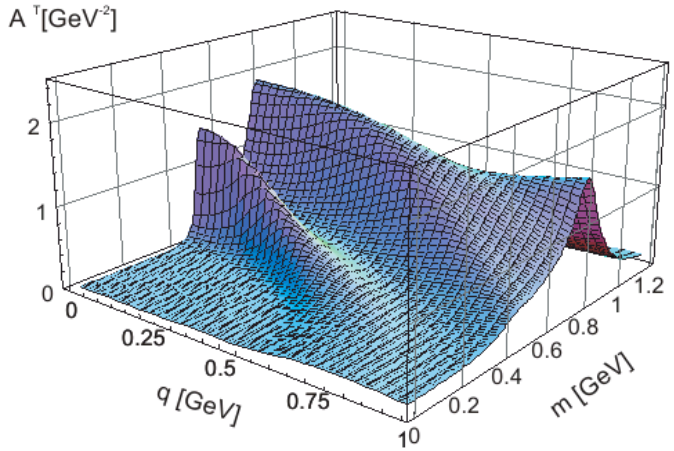
dispersion (mass VS momentum) in dense matter

- S.H.Lee (PRC57(98)927)
  - $m^*/m_0 = 1 - k\,\rho/\rho_0$
  - ρ/ω : $k=0.16\pm0.06+(0.023\pm0.007)(p/0.5)^2$
  - ϕ : $k=0.15(\pm0.05)*y - (0.0005\pm0.0002)(p/0.5)^2$
    - for p<1GeV/c

- Harada & Sasaki (PRC80(09)054912)

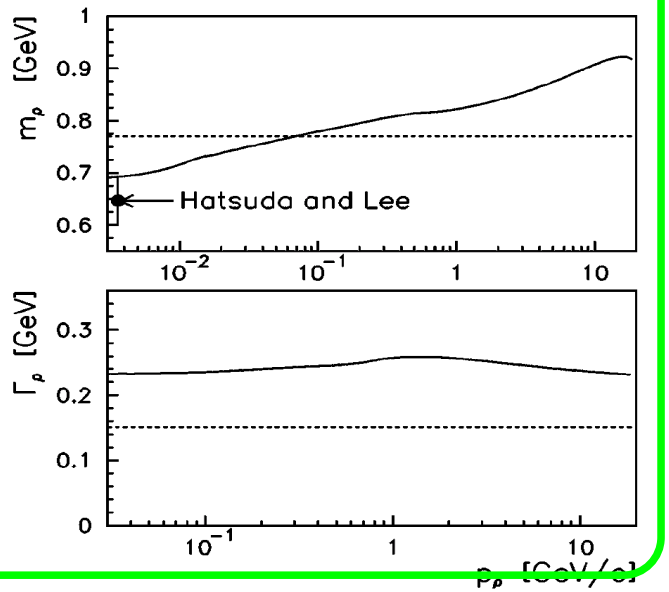


- Post & Mosel (NPA699(02)169)



- Kondratyuk et al. (PRC58(98)1078)

ρ



"New hadron

Experiment KEK-PS E325

- 12GeV p+A $\rightarrow$ $\rho/\omega/\phi$ +X ($\rho/\omega/\phi \rightarrow e^+e^-$, $\phi \rightarrow K^+K^-$)
- 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 $\rightarrow$ 10^6Hz interaction)
  - Large acceptance spectrometer to detect slowly moving mesons, which have larger probability decaying inside nuclei ($1<\beta\gamma<3$)

Collaboration

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(Kyoto Univ. , RIKEN, KEK, CNS-U.Tokyo, ICEPP-U.Tokyo, Tohoku-Univ.)

History of E325

- 1993 proposed
- 1994 R&D start
- 1996 construction start
- '97 data taking start
- '98 first ee data
  - PRL86(01)5019 ρ/ω (ee)
- 99,00,01,02....
  - x100 statistics
  - PRL96(06)092301 ρ/ω (ee)
  - PRC74(06)025201 α (ee)
  - PRL98(07)042501 φ (ee)
  - PRL98(07)152302 φ (KK),α
- '02 completed
- spectrometer paper
  - NIM A457(01)581
  - NIM A516(04)390

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