

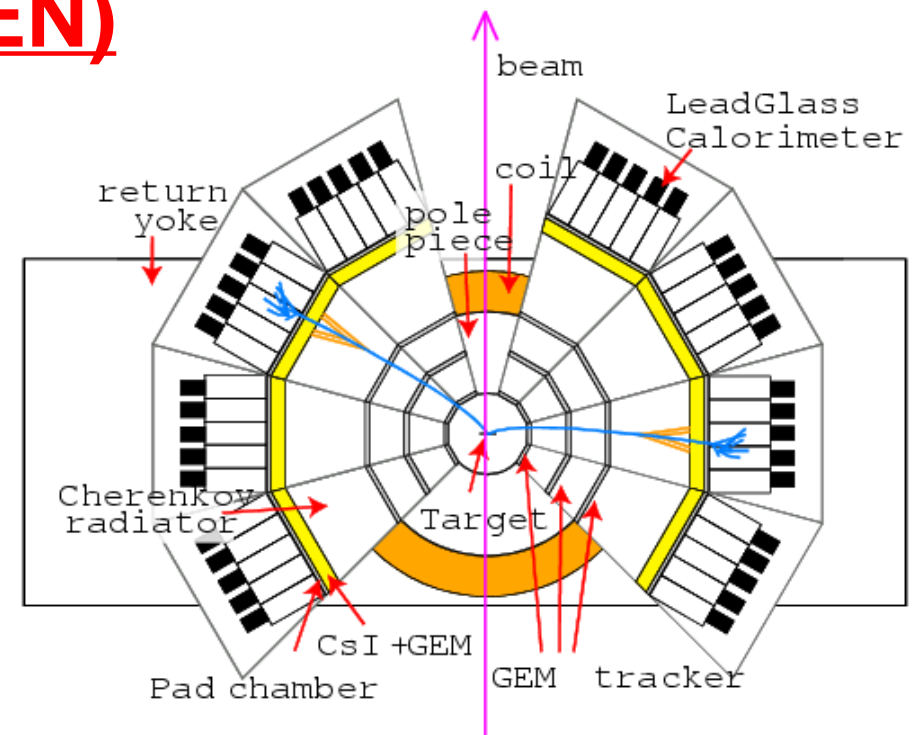
Low mass dielectron measurement at J-PARC

---J-PARC E16 experiment---

Satoshi Yokkaichi (RIKEN)

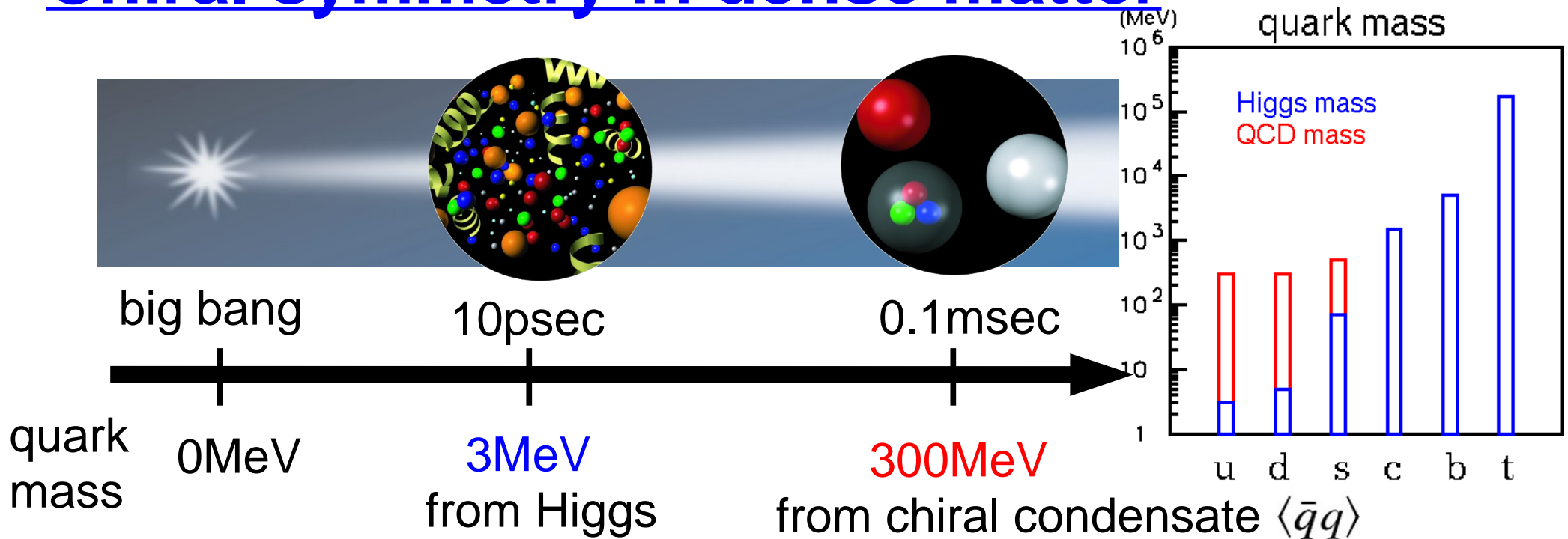
Collaboration

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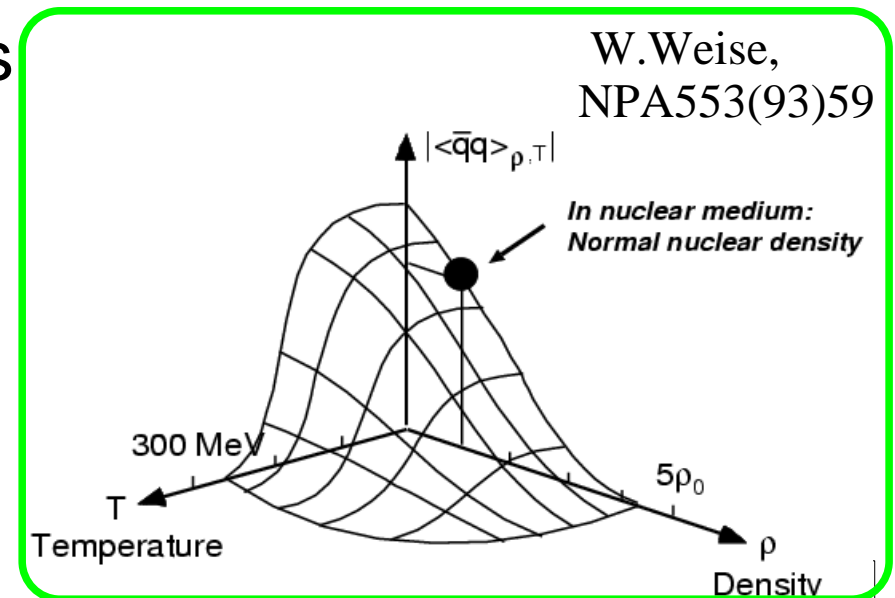


Proposal revised version 1 (2006 June 7) is located on :
<http://ribf.riken.jp/~yokkaich/paper/jparc-proposal-0604.pdf>

Chiral symmetry in dense matter



- 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...



Hatsuda and Lee, PRC46(92)R34, PRC52(95)3364

linear dependence on density

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

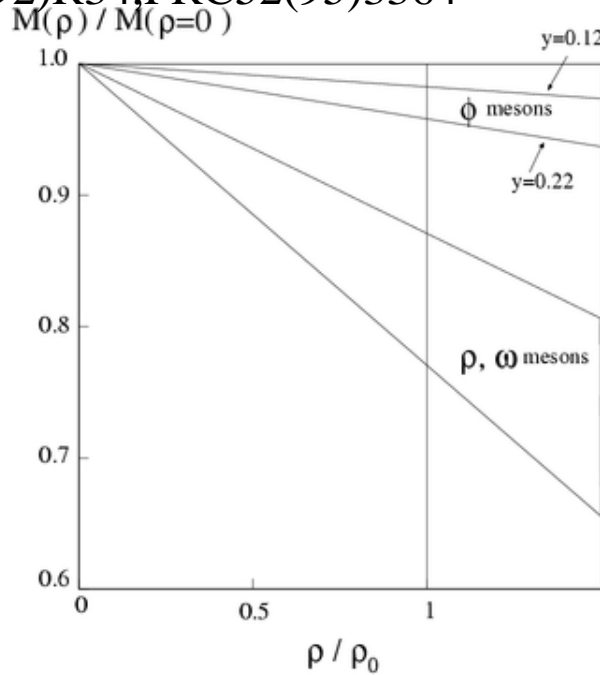
mass decreasing

- 16(±6)% for ρ/ω

- 0.15(±0.05)*y
= 2~4% for ϕ

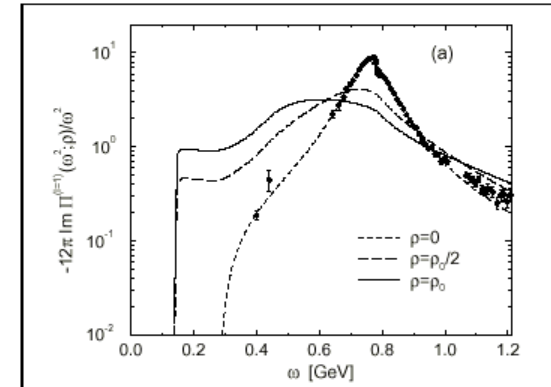
(for y=0.22)

at the normal nuclear density

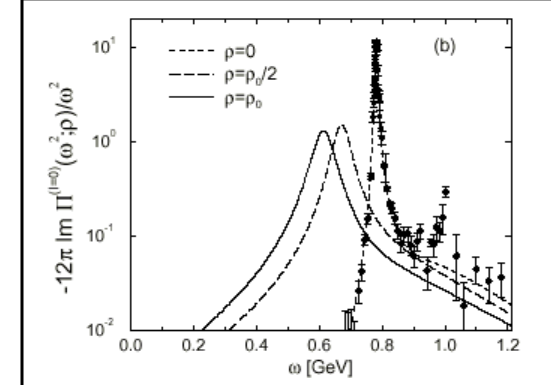


Klinge, Kaiser, Weise, NPA624(97)527

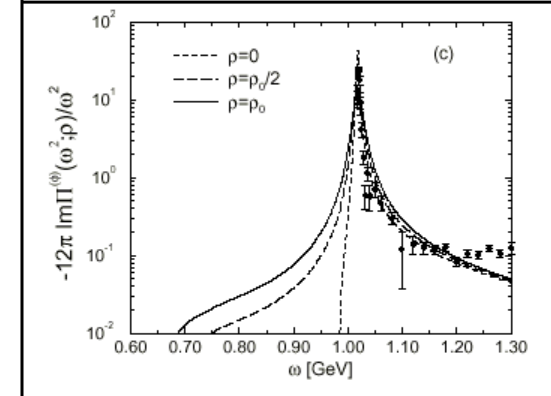
ρ



ω



ϕ



Oset and Lamos

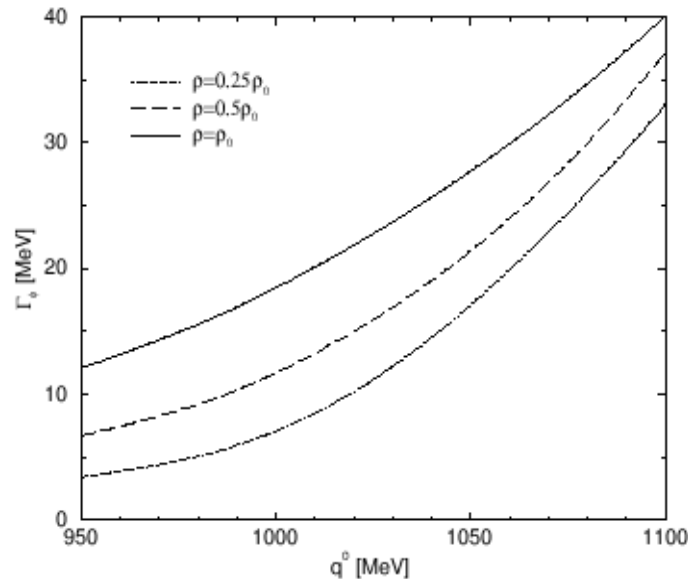
NPA 679 (01) 616

ϕ mass shift

< 1%

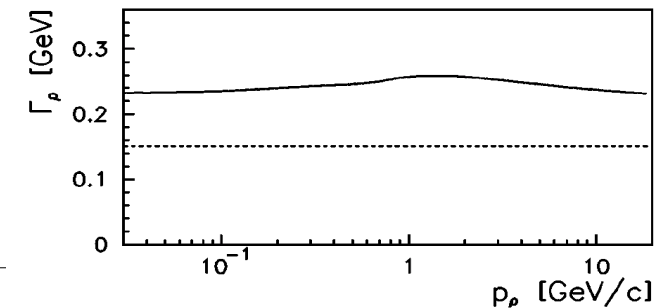
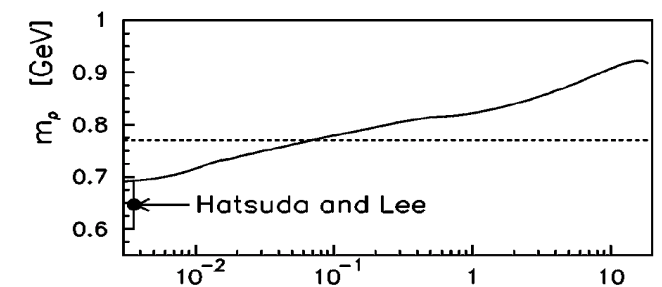
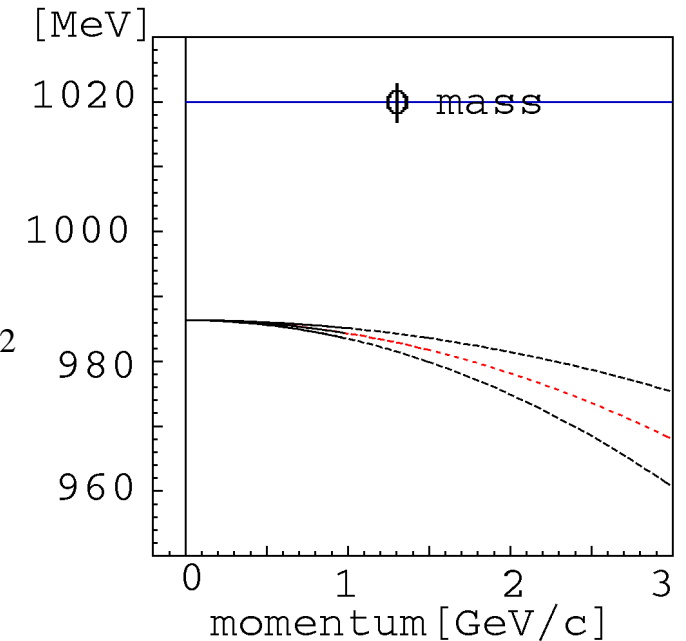
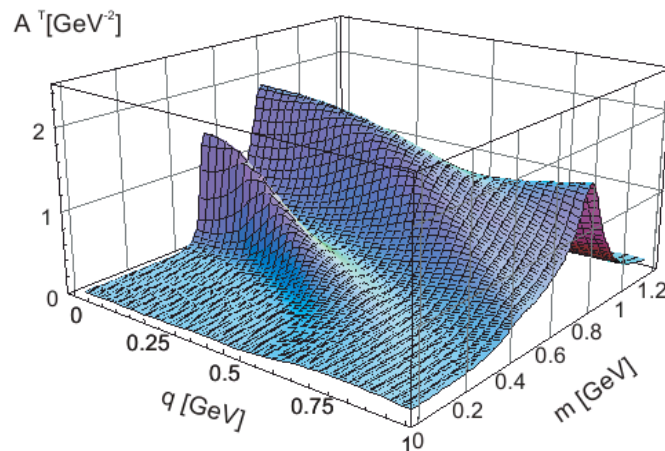
width broadening

x5 (22MeV) at ρ_0



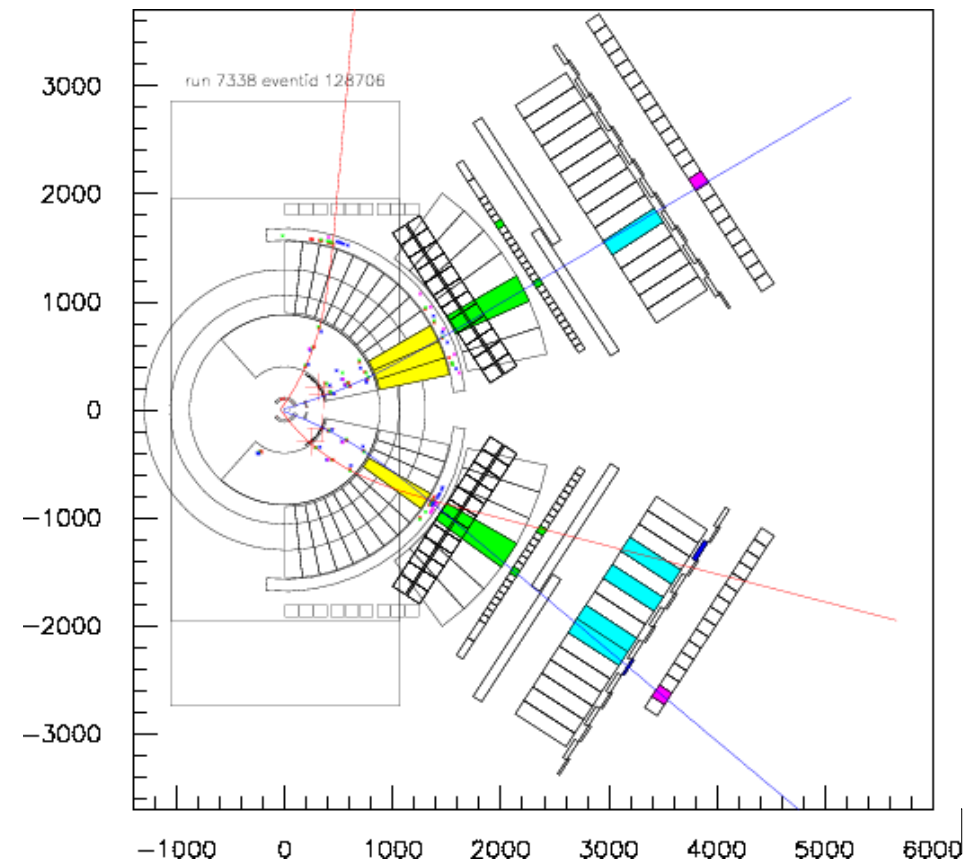
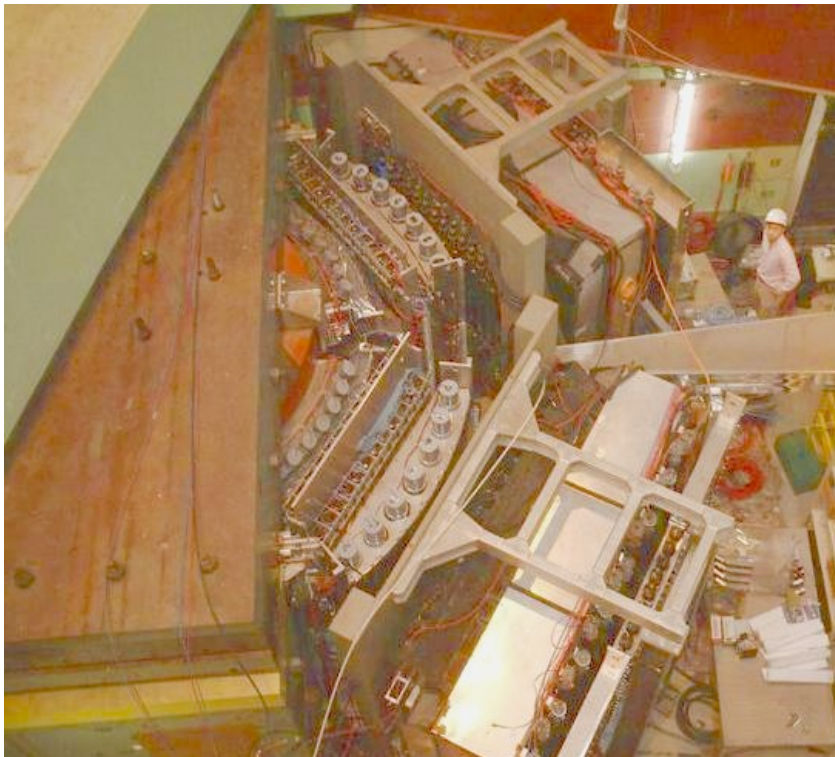
dispersion relation (mass VS momentum)

- S.H.Lee (PRC57(98)927) $m^*/m_0 = 1 - k \rho/\rho_0$
 - ρ/ω : $k=0.16\pm 0.06+(0.023\pm 0.007)(p/0.5)^2$
 - ϕ : $k=0.15(\pm 0.05)*y + (0.0005\pm 0.0002)(p/0.5)^2$
 - for $p < 1 \text{ GeV}/c$
- Kondratyuk et al. (PRC58(98)1078) : ρ meson
- Post & Mosel (NPA699(02)169) : ρ meson



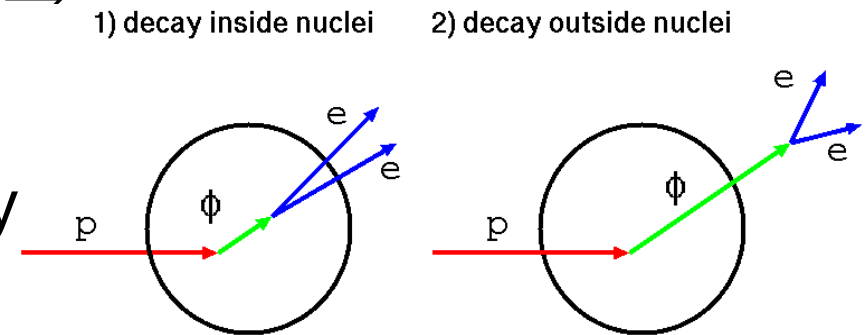
KEK-PS E325

- to observe the vector meson modification in the cold nuclear matter at the normal nuclear density
- $12\text{GeV } p+C/\text{Cu} \rightarrow \rho/\omega/\phi + X$ ($\rho/\omega/\phi \rightarrow e^+e^-$, $\phi \rightarrow K^+K^-$),
 $1 < p < 3\text{GeV}/c$ for ϕ
- run 1997-2002



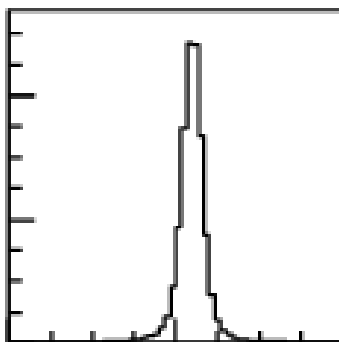
expected signal

- $12\text{GeV } p+C/\text{Cu} \rightarrow \rho/\omega/\phi + X$ ($\rho/\omega/\phi \rightarrow e^+e^-$, $\phi \rightarrow K^+K^-$), $1 < p < 3\text{GeV}/c$ for ϕ
- finite size of matter and finite velocity mesons : only a part of mesons are decay in nuclei and modified.



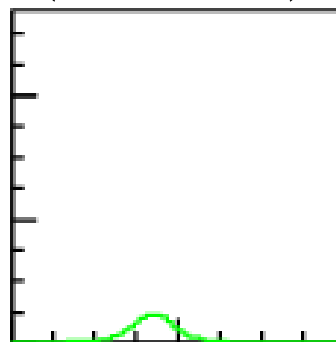
longer-life meson(ω & ϕ) cases : Schematic picture

outside decay
(natural)

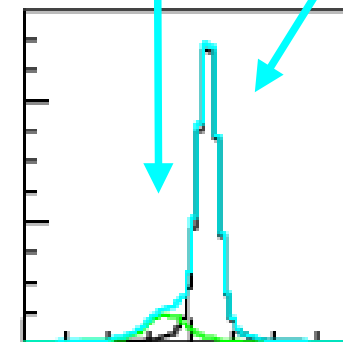


+

inside decay
(modified)



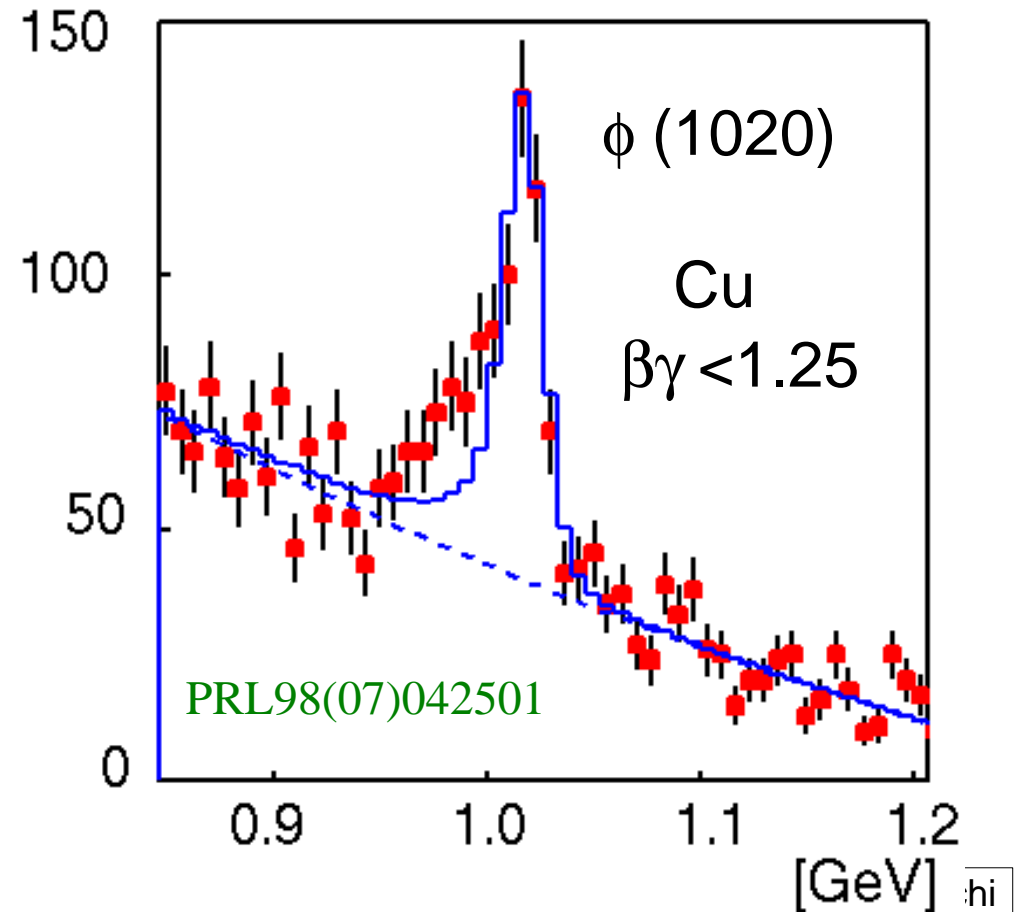
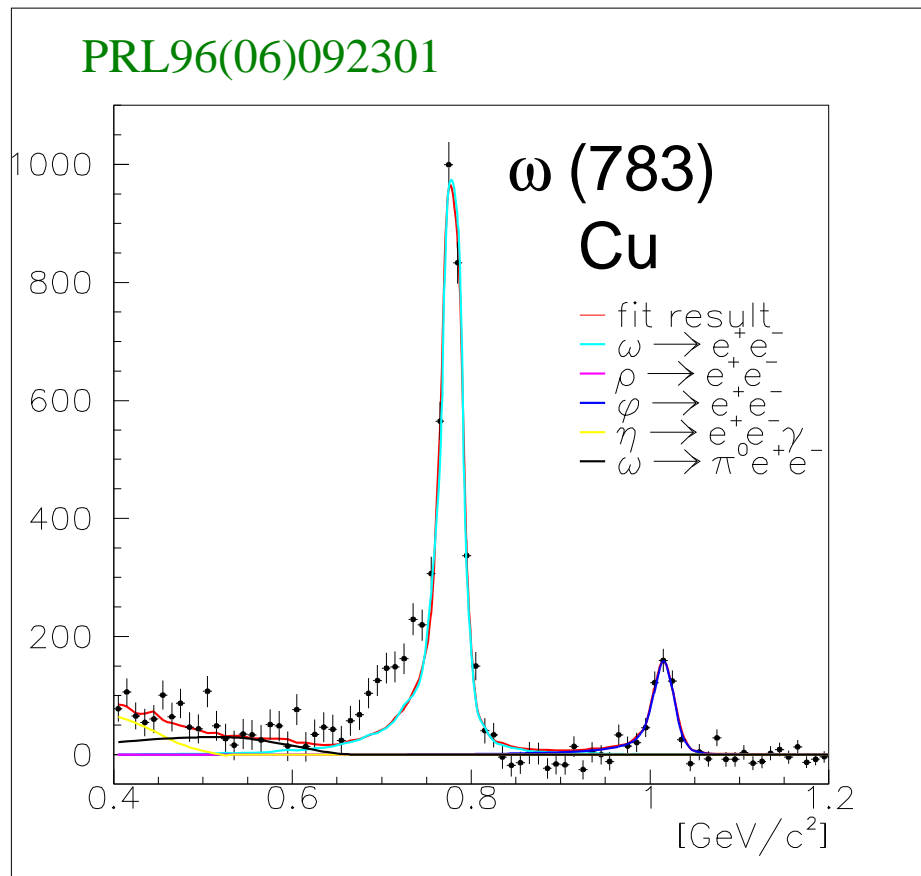
=



expected
to be observed

E325 observed meson modification

- below the ω and ϕ , statistically significant excesses over the known hadronic sources including experimental effects



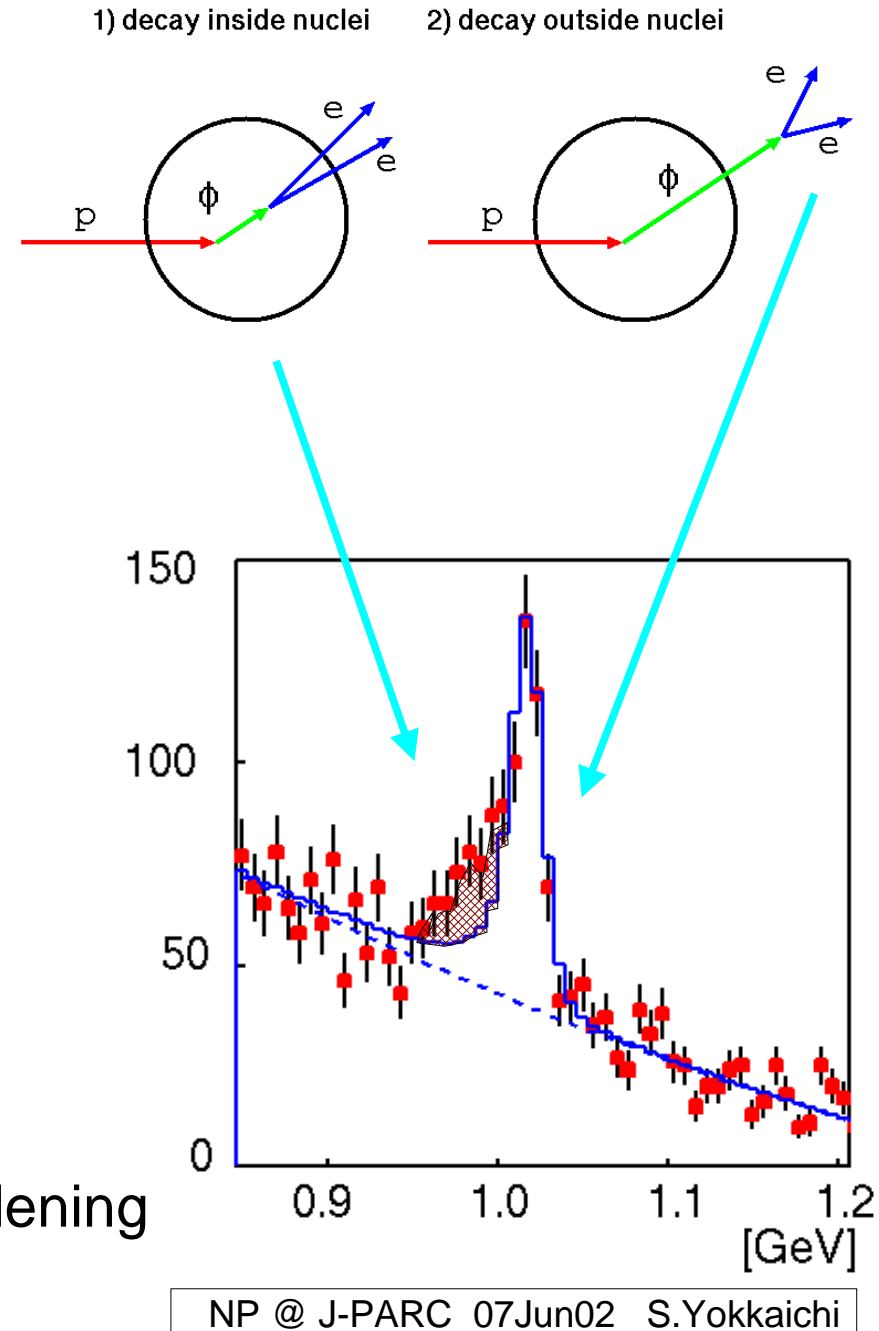
E325 : interpretation

- MC type model analysis to include the nuclear size/meson velocity effects
 - generation point : uniform for ϕ meson
 - from measured A-dependence
 - measured momentum distribution
 - Woods-Saxon density distribution
 - decay in-flight : linearly dependent on the density of the decay point
 - dropping mass: $M(\rho)/M(0) = 1 - k_1 (\rho/\rho_0)$
 - width broadening: $\Gamma(\rho)/\Gamma(0) = 1 + k_2 (\rho/\rho_0)$
- consistent with the prediction

$$k_1 = 0.034^{+0.006}_{-0.007}$$

$$k_2^{\text{tot}} = 2.6^{+1.8}_{-1.2}$$

3.4% mass reduction
3.6 times width broadening
at ρ_0

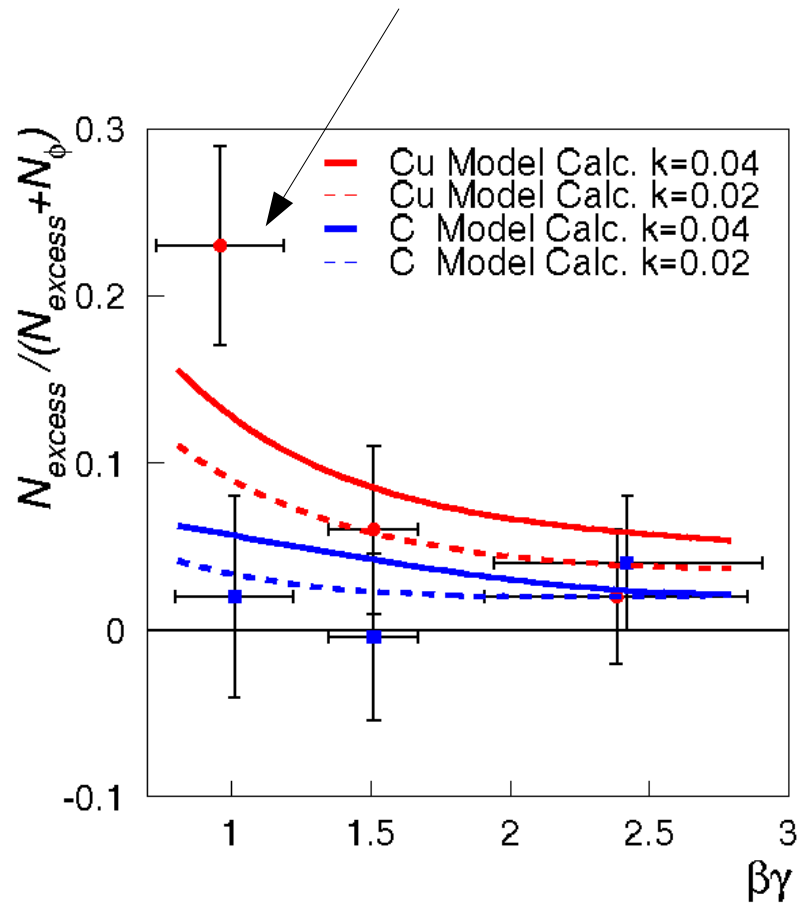


J-PARC E16 experiment

- Same concepts as KEK-PS E325
 - thin target (0.1% interaction) / primary beam ($\sim 10^{10}$ /sec)/ slowly moving vector mesons in the ee channel
- **Main goal** : collect $\sim 1-2 \times 10^5$ $\phi \rightarrow ee$ for each target in 5 weeks
 - **~ 100 times** as large as E325
 - **new nuclear targets** : proton (CH_2 -C subtraction), Pb
 - **collision geometry** for Pb target (by multiplicity)
 - systematic study of the **velocity & nuclear size dependence** of excess ('modified' component)
 - extract the **dispersion relation**
 - mass resolution : keep ~ 10 MeV
- ρ , ω and J/ψ can be collected at the same time
- 2007/3 : stage1 (physics) approval
- R&D is on going

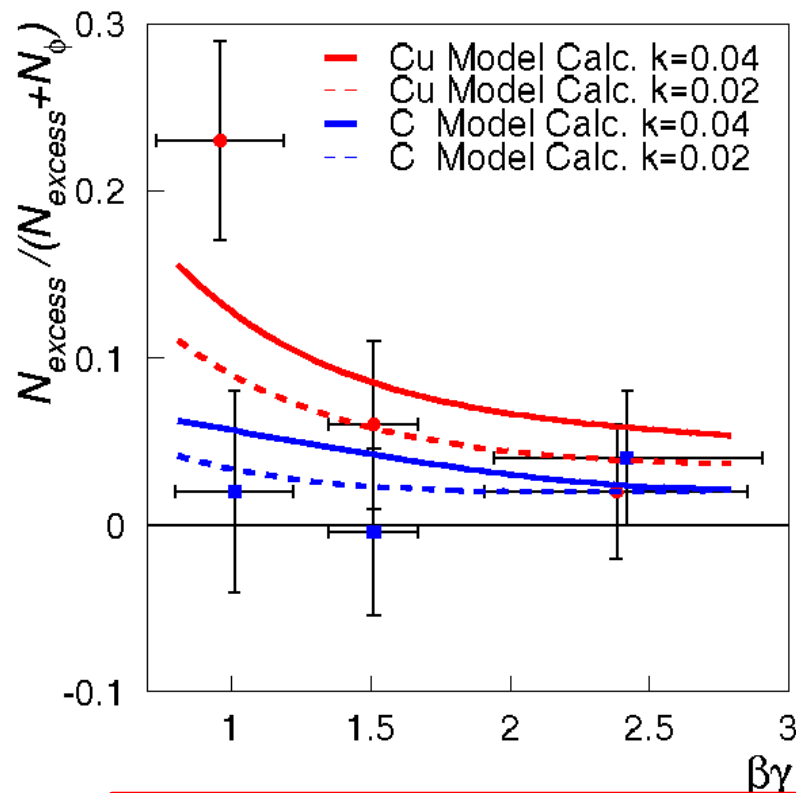
velocity and nuclear size dependence

- **velocity dependence** of excesses ('modified' component)
- E325 only one data point for ϕ (slow/Cu) has significant excess

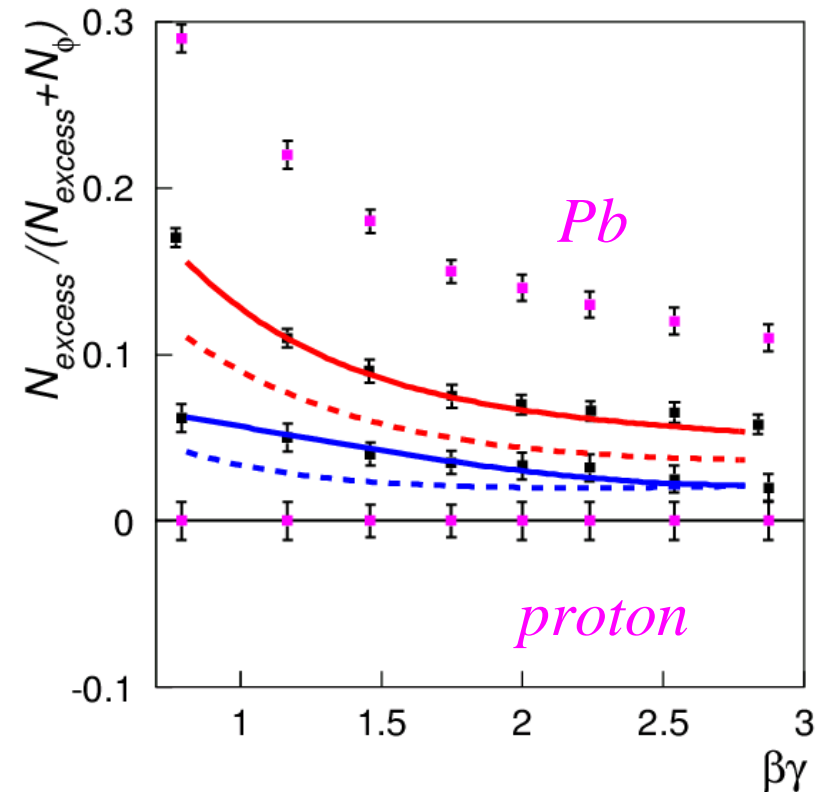


velocity and nuclear size dependence

- **velocity dependence** of excesses ('modified' component)
- E325 only one data point for ϕ (slow/Cu) has significant excess
- systematic study : all the data should be explained the interpretation model



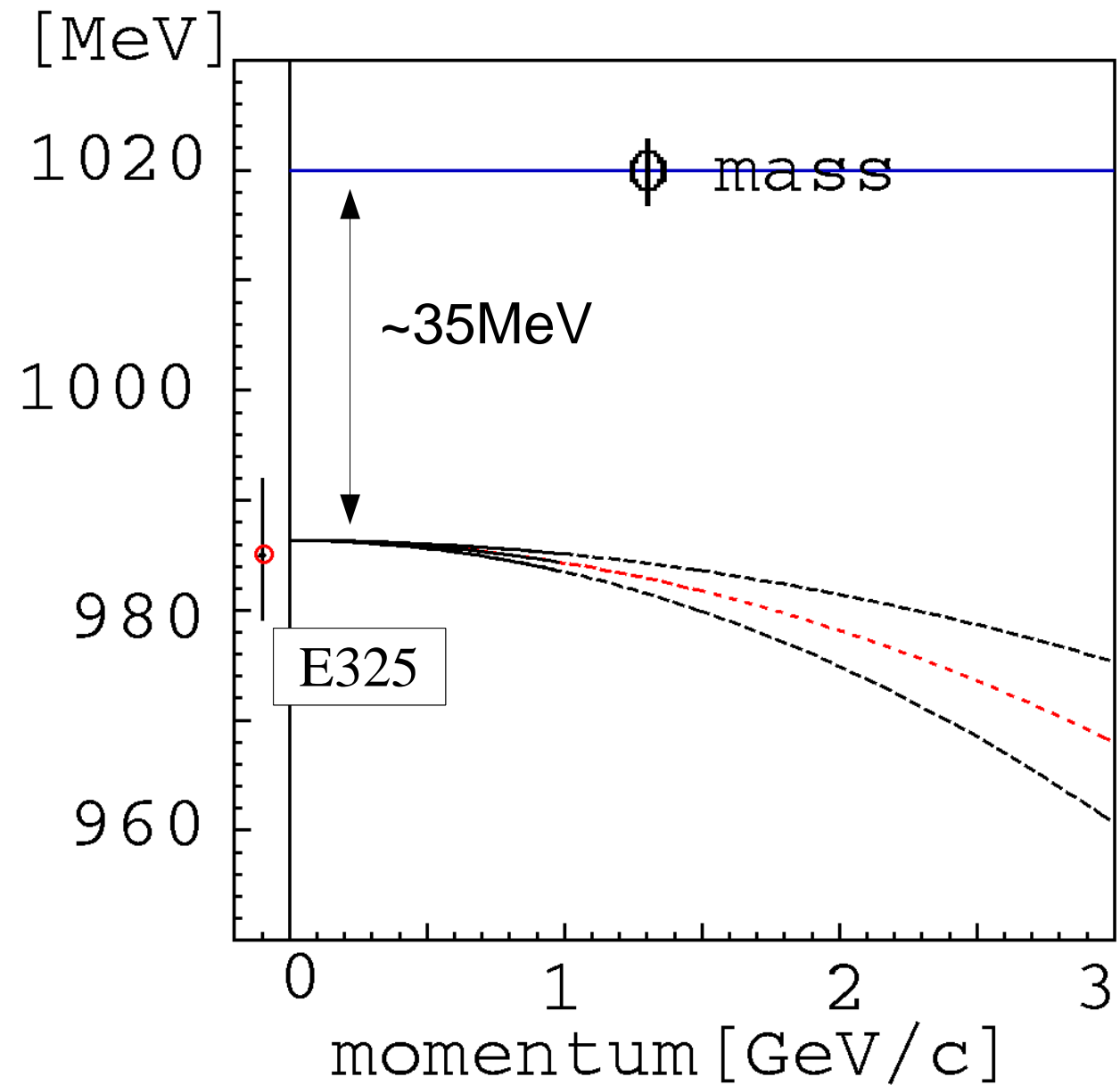
x 100 stat.



- establish the modification
- check the interpretation model w/ shape analysis

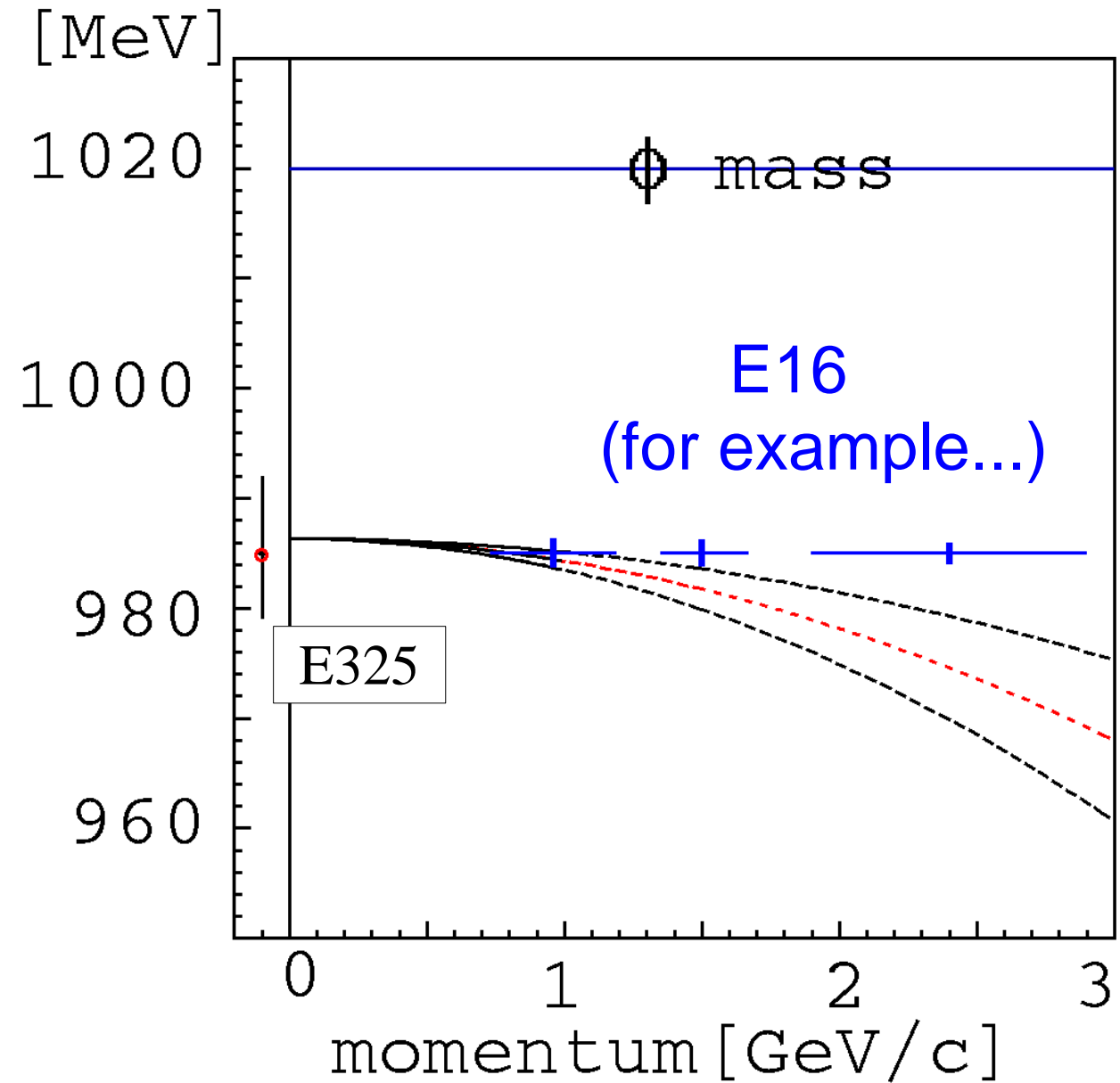
dispersion relation(mass VS momentum)

- prediction for ϕ by S.H.Lee($p < 1 \text{ GeV}$)
- current E325 analysis neglects the dispersion (limited by the statistics)



dispersion relation(mass VS momentum)

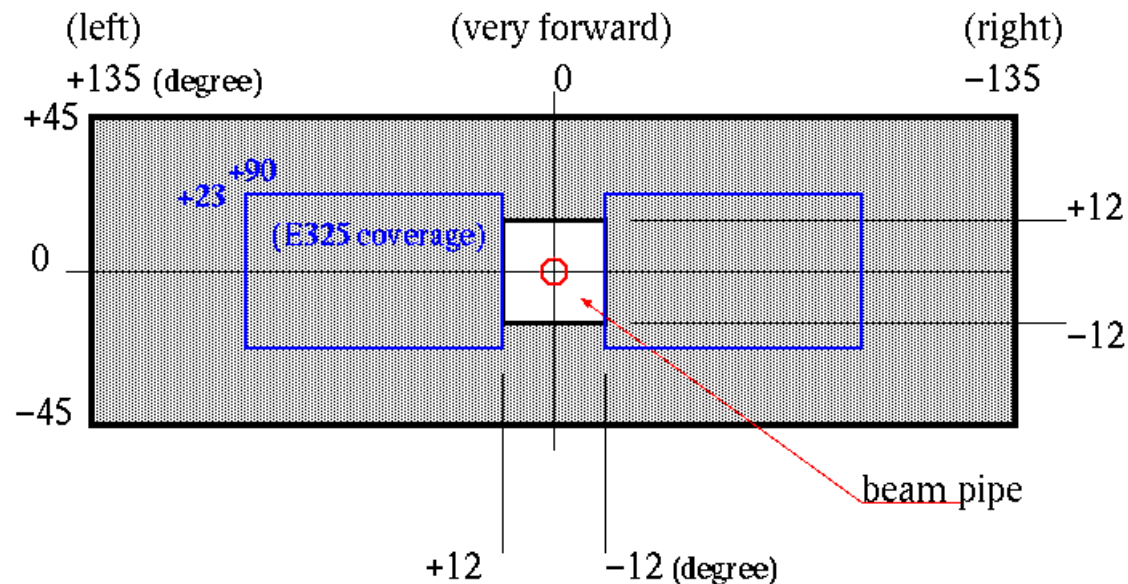
- prediction for ϕ by S.H.Lee($p < 1 \text{ GeV}$)
- current E325 analysis neglects the dispersion (limited by the statistics)
-
- fit with common shift parameter $k_1(p)$, to all nuclear targets in each momentum bin



To collect high statistics

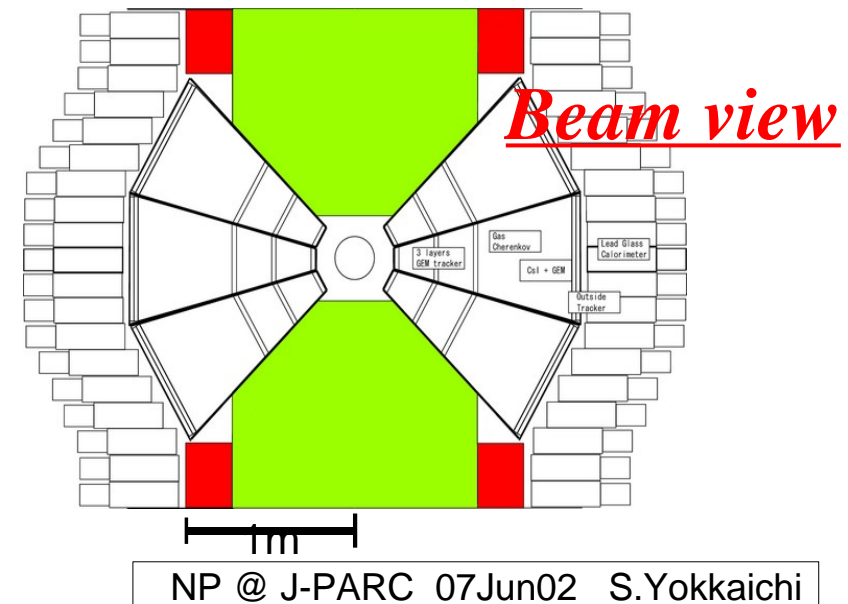
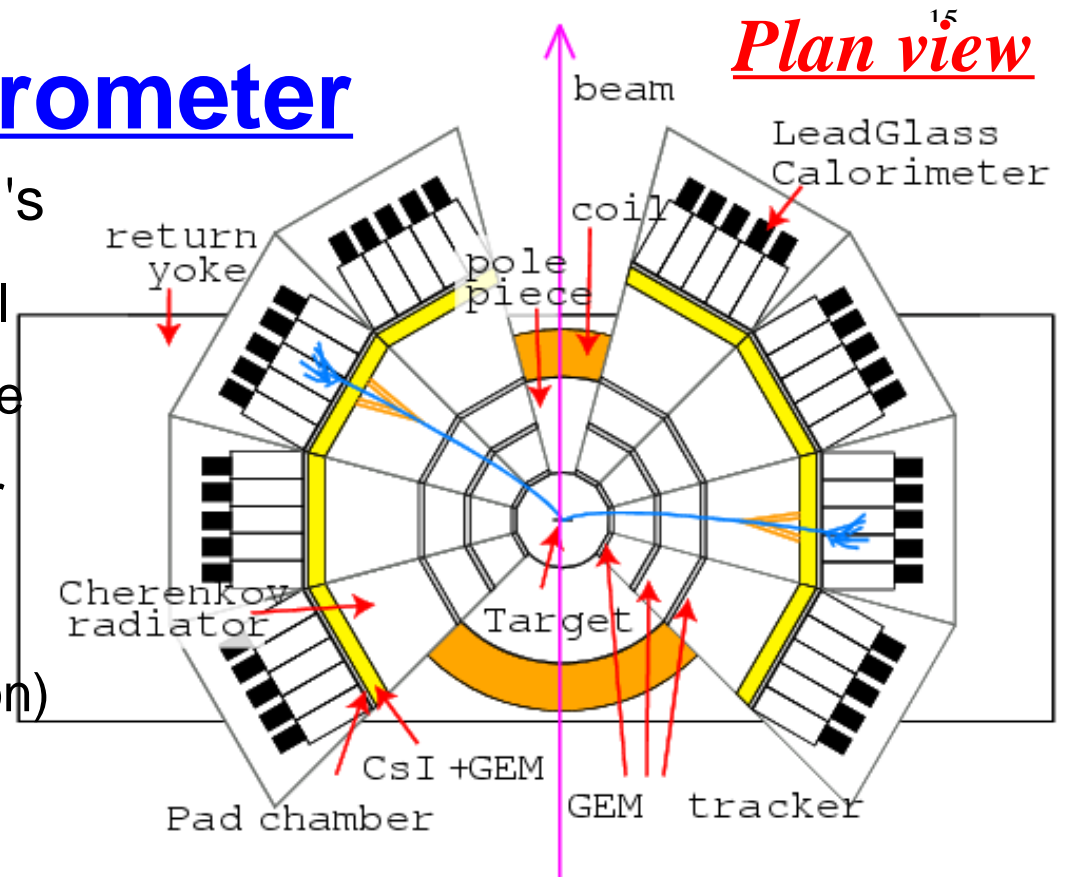
- For the 100 times as large as E325:
 - To cover larger acceptance : $x \sim 5$
 - Higher energy beam (12 \rightarrow 30/50 GeV) : $x \sim 2$ of production
 - Higher intensity beam ($10^9 \rightarrow 10^{10}$ /spill (1sec)) : $x \sim 10$ (\rightarrow 10MHz interaction on targets)

Geometrical (horizontal & vertical) coverage of the spectrometer

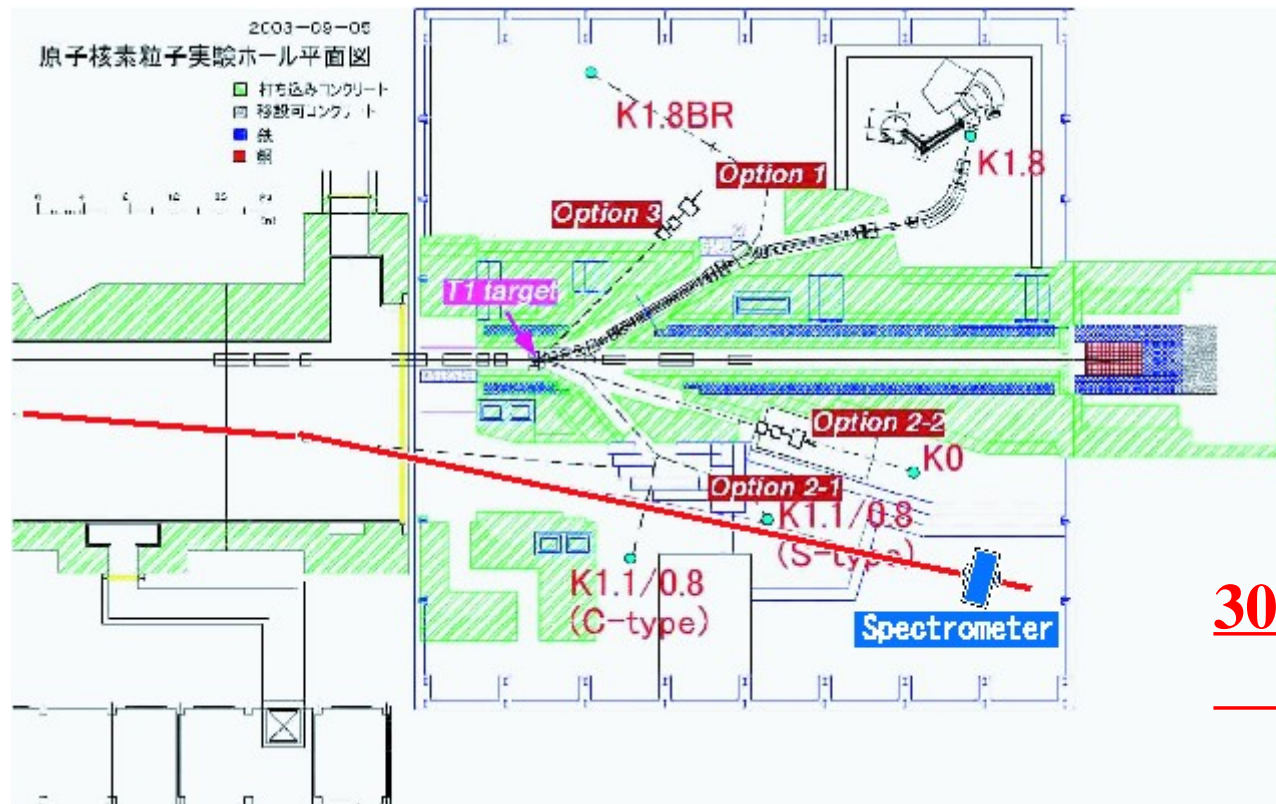
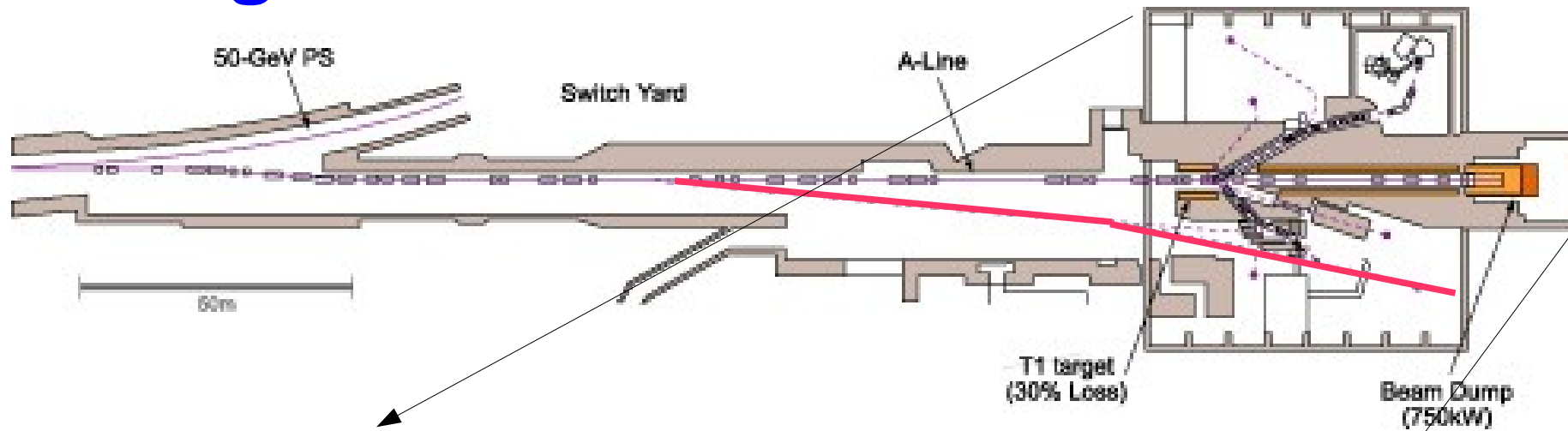


Proposed spectrometer

- Spectrometer Magnet : reuse E325 's
 - remodeling the pole / repairing the coil
 - stronger field for compact detector size
- GEM(Gas electron multiplier) Tracker
 - 0.7mm pitch strip readout
- Two-stage Electron ID (10^{-4} π rejection)
 - Gas Cherenkov(*HBD*)
 - GEM+CsI photocathode
 - hexagonal pad readout ($\sim 30\text{mm } \phi$)
 - Leadglass EMC: reuse of TOPAZ
- $\sim 70\text{K}$ Readout Channels (in 27 segments)
 - cf. E325: 3.6K, PHENIX: $\sim 300\text{K}$
- Cost : $\sim \$5\text{M}$ (including $\sim \$2\text{M}$ electronics)
 - cf. E325: $\$2\text{M}$ not including electronics



High momentum Beamline



30/50GeV proton beam
(upto 10^{12} /sec)

Detector R&D status

- GEM : domestic products works well
 - high gain GEM / larger size
- HBD (Gas Cherenkov using GEM + CsI photocathod)
 - PHENIX prototype / working model
 - In Japan:
 - CsI photocathod (Hamamatsu)
 - CF₄ operation
 - Beam test @ HiSOR (Hiroshima-U)
 - long term operation
- GEM Tracker for high rate
 - low material strip read-out board / read out circuit
- prototype module of the spectrometer:
 - Tracker + HBD in real-size

already done

test is on going/scheduled

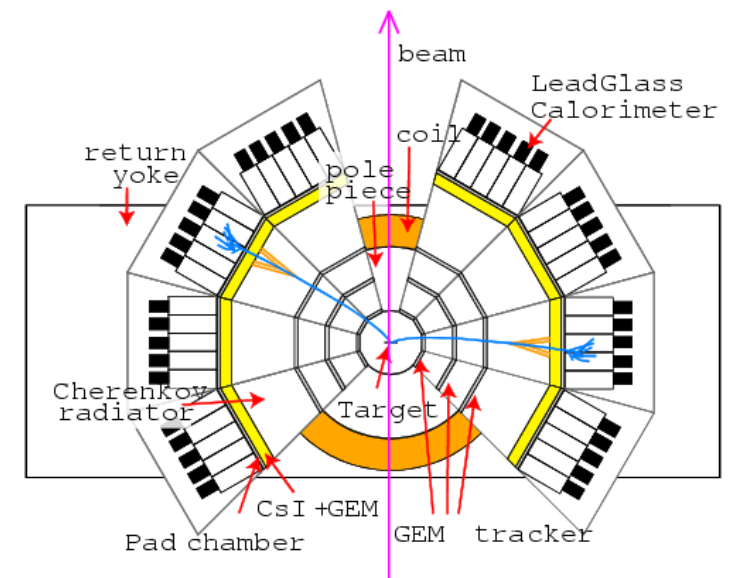
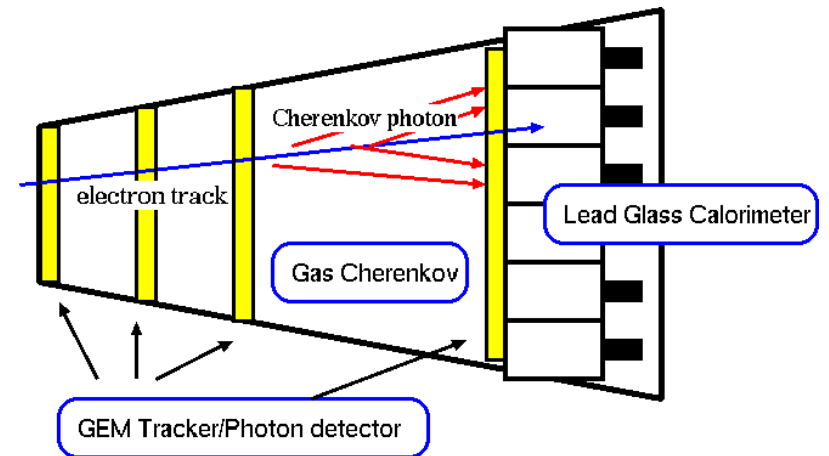
using CNS and RIKEN budget

funded

(2007 Grant-in-Aid)

Schedule

- (already funded)
 - 2007 -8:
 - prototype spectrometer module test/design finalize
- (budget dependent)
 - 2008-9 :
 - production start
 - 2009-10
 - spectrometer construction at the counter hall
 - 2010-11
 - ready for 30GeV proton beam



Summary

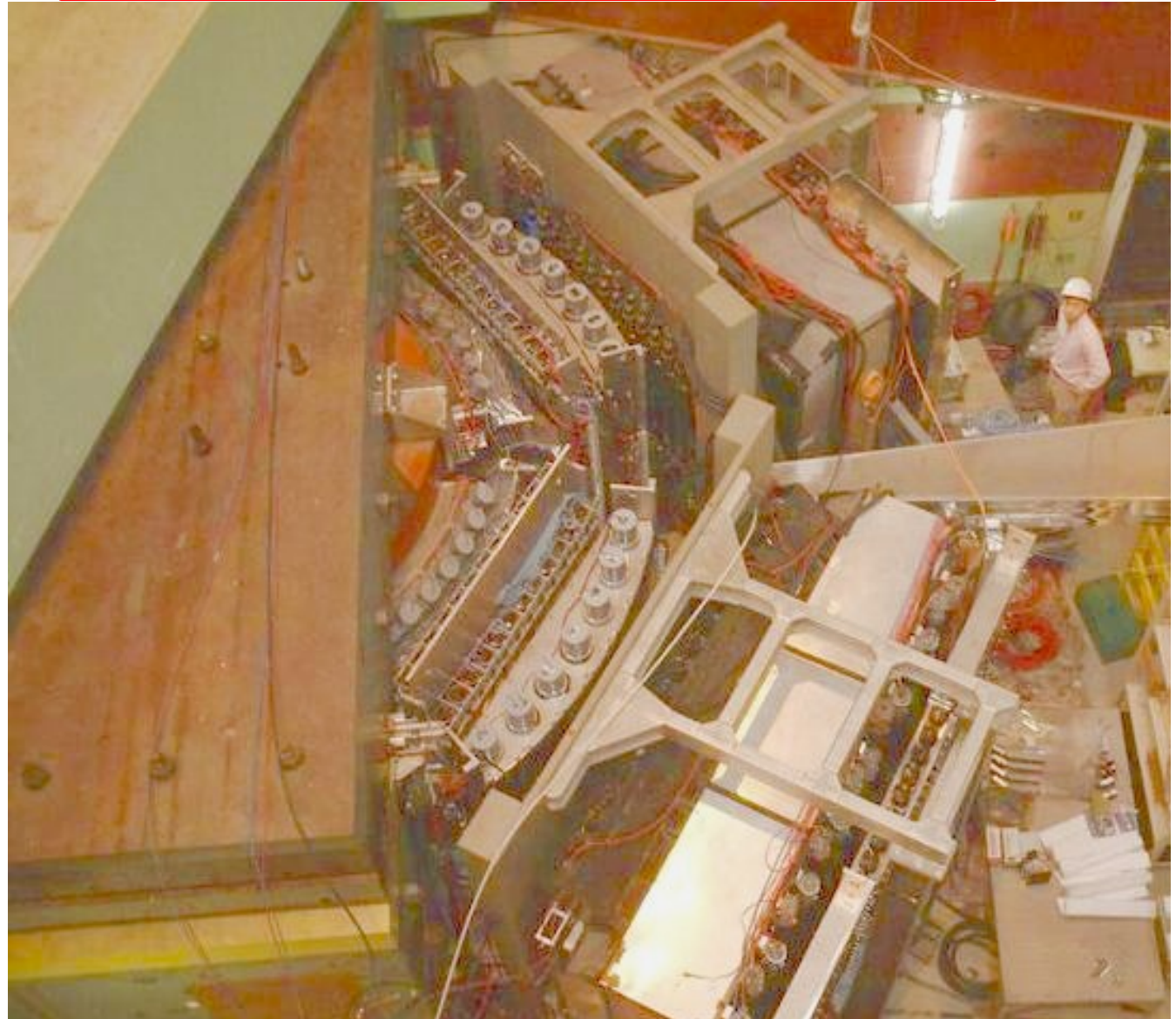
- Vector meson measurements in e^+e^- channel at J-PARC E16
 - to investigate the **chiral symmetry in dense hadronic matter**
- 30 (or 50) GeV primary proton beam ($\sim 1 \times 10^{10}$ /sec)
 - especially collect $\sim 10^5$ $\phi \rightarrow e^+e^-$ for each target in ~ 5 weeks (100 shift) operation : **100 times** as large as KEK-PS E325's statistics
- New spectrometer using new technology (GEM tracker/HBD)
- Impact of the experiment
 - systematic study of the vector meson modification in various size (0~10fm) of dense matter
 - momentum dependence of in-medium mass (dispersion relation)
 - provide the systematic data which motivate to develop new theoretical calculations, including interpretation in the real nuclear matter

Backup slides...

History of E325

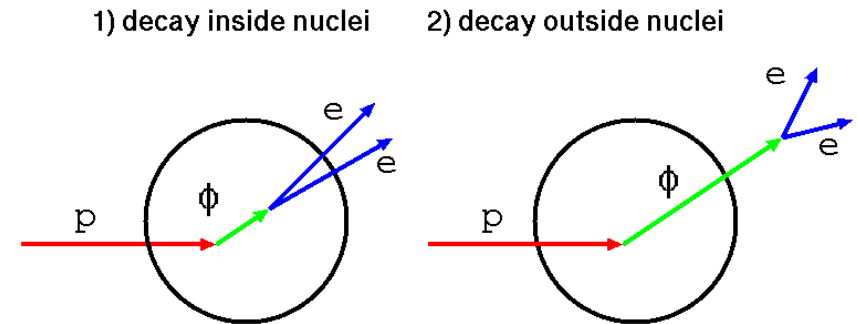
- 1993 proposed
- 1994 R&D start
- 1996 construction start
- '97 data taking start
- '98 first ee data
 - PRL86(01)5019 ρ/ω (ee)
- 99,00,01,02....
 - x100 statistics
 - PRL96(06)092301 ρ/ω (ee)
 - PRC74(06)025201 α (ee)
 - PRL98(07)042501 ϕ (ee)
 - PRL98(07)152302 ϕ (KK), α
- '02 completed
- spectrometer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

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



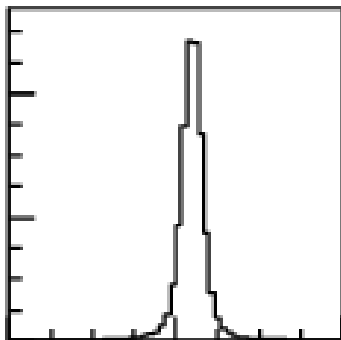
Expected Invariant mass spectra in e^+e^-

- smaller FSI in e^+e^- decay channel
- double peak (or tail-like) structure :
 - second peak is made by **inside-nucleus decay** (modified meson) : amount depend on the nuclear size and meson velocity
 - could be enhanced for slower mesons & larger nuclei



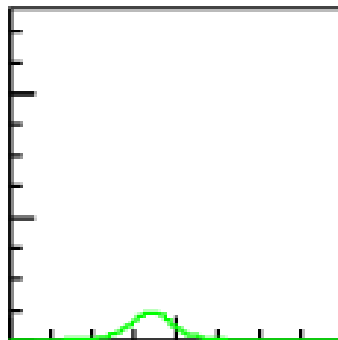
longer-life meson(ω & ϕ) cases : Schematic picture

outside decay
(natural)

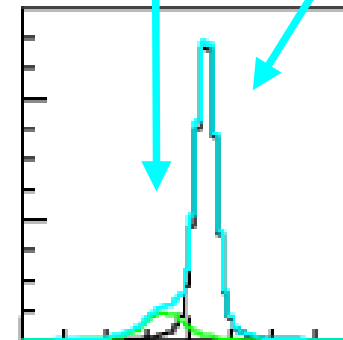


+

inside decay
(modified)



=



expected
to be observed