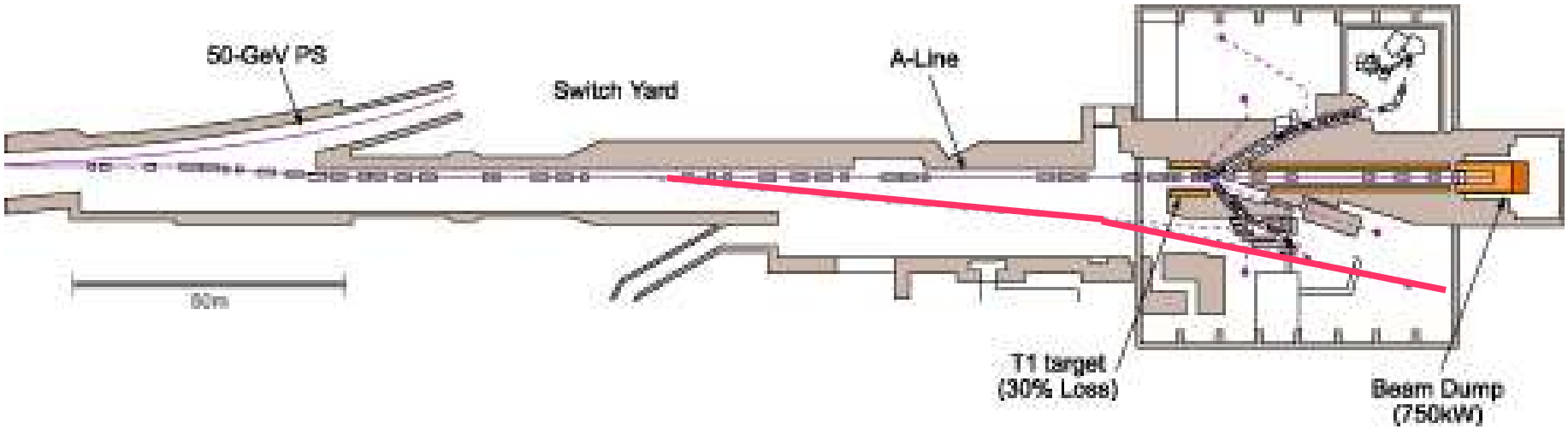
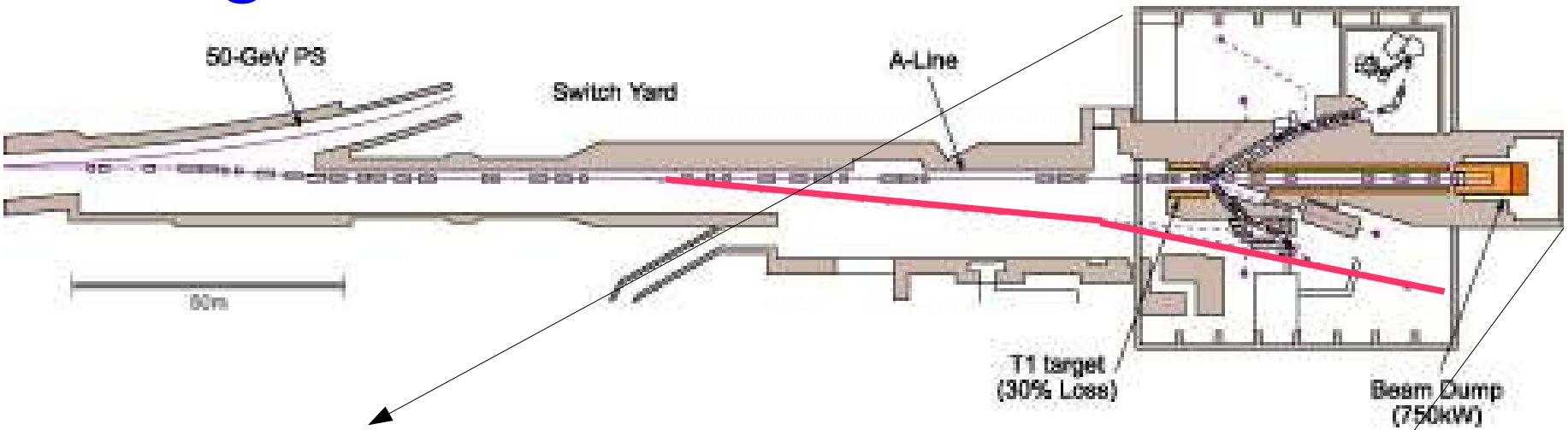
Low mass dielectron measurement and the high momentum beamline

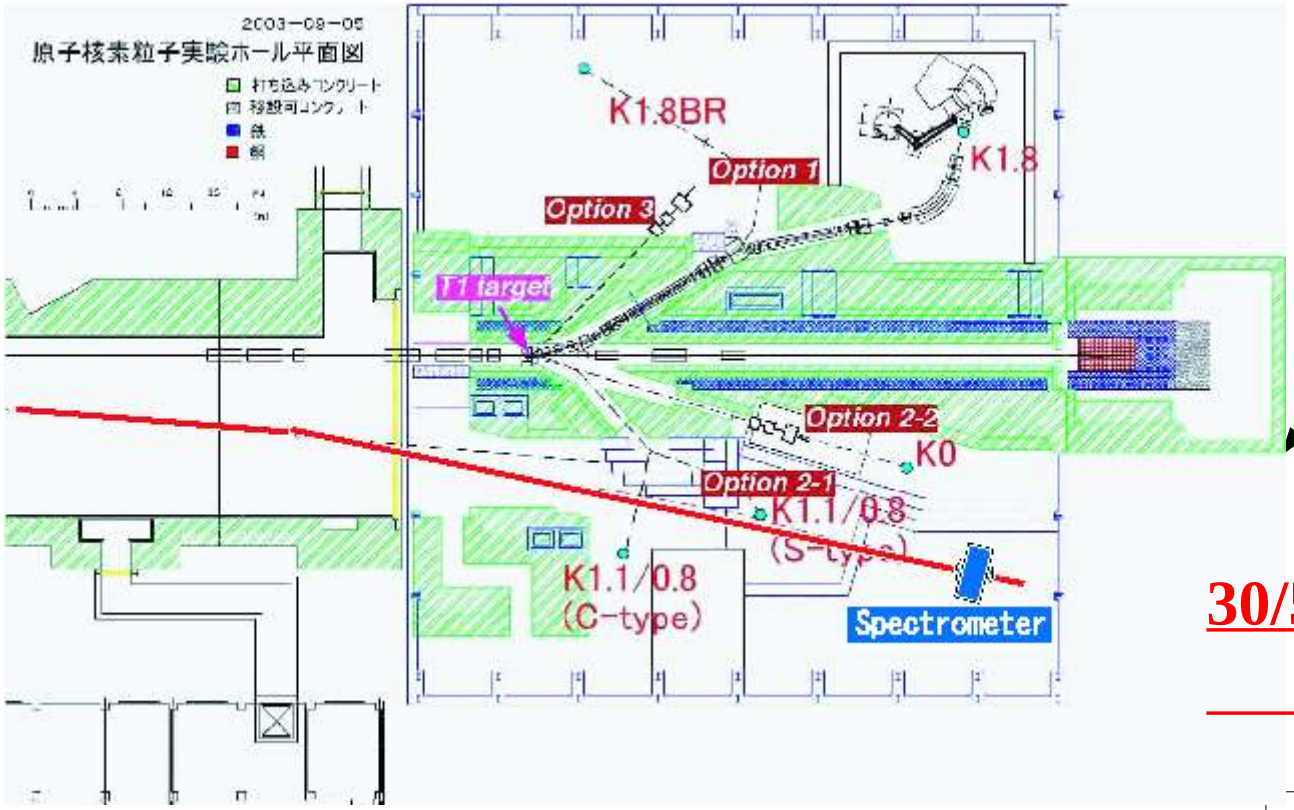
Satoshi Yokkaichi
(RIKEN Nishina Center)

- E16 experiment
- related topics...



High momentum Beamline

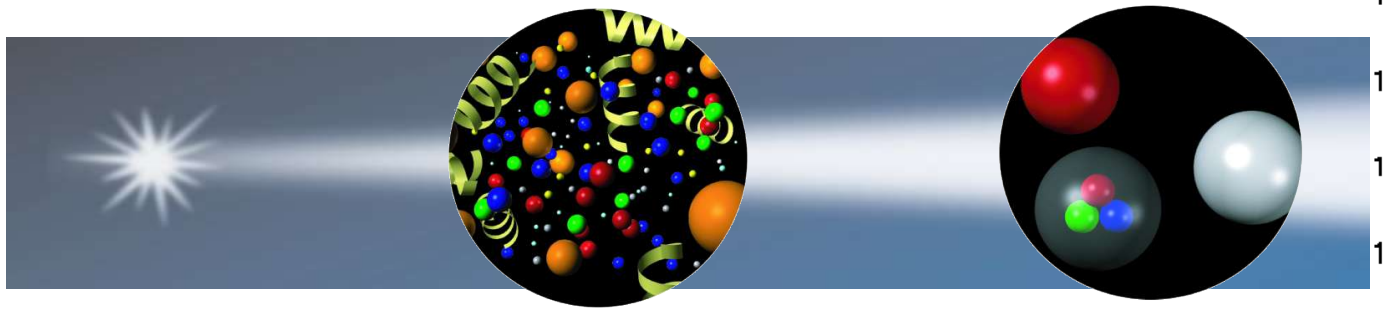


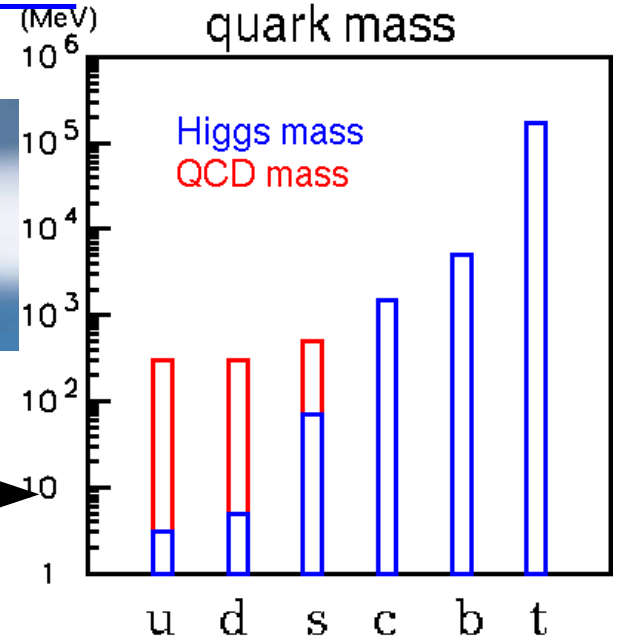


30/50GeV proton beam

(upto 10^{12} /sec)

Chiral symmetry in dense matter

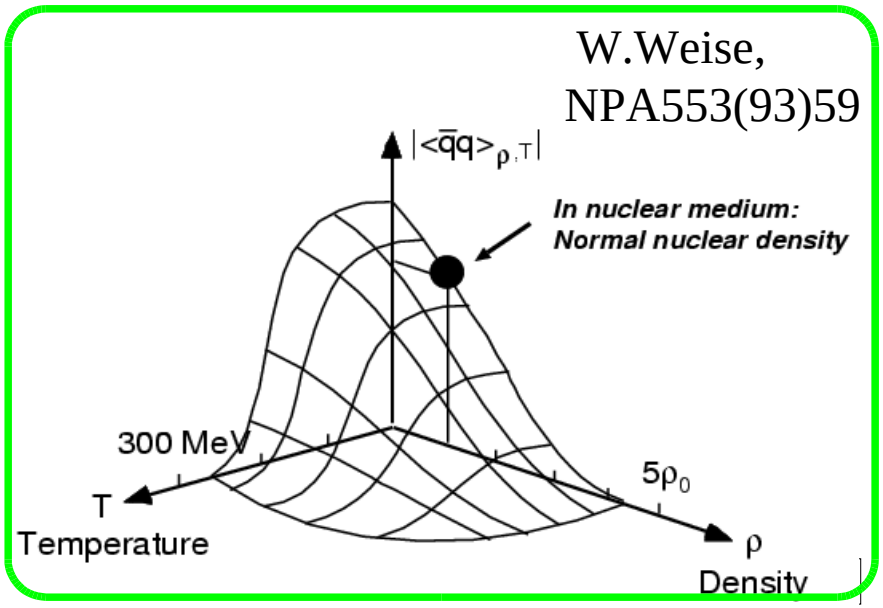




big bang — 10psec — 0.1msec

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...



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

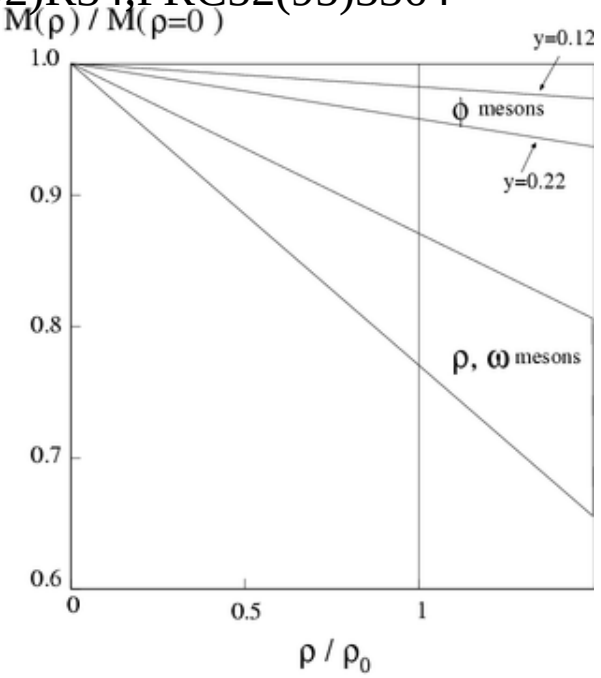
linear dependence on density

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

mass decreasing

- 16(±6)% for ρ/ω
- 0.15(±0.05)*y
  =2~4% for ϕ
  (for y=0.22)

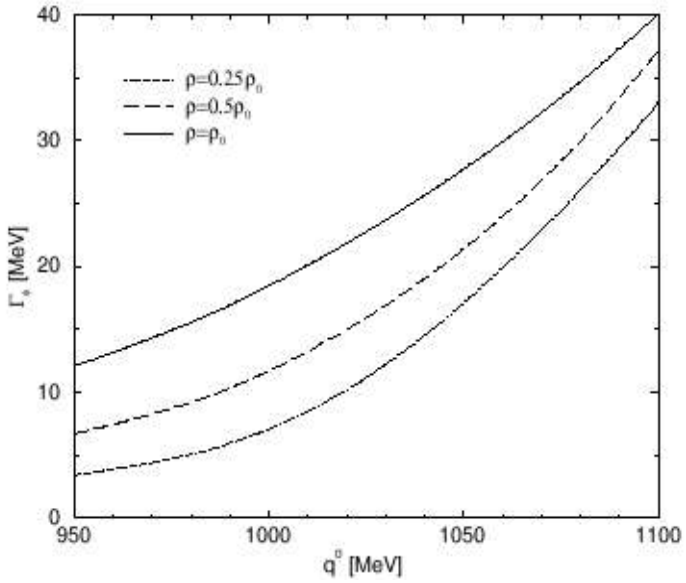
at the normal nuclear density



Oset and Lamos

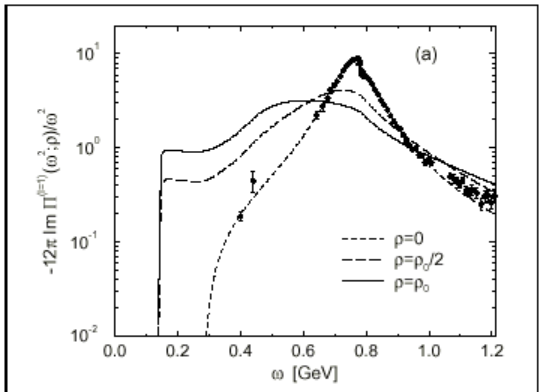
NPA 679 (01) 616

ϕ mass shift
< 1%
width broadening
x5 (22MeV) at ρ_0

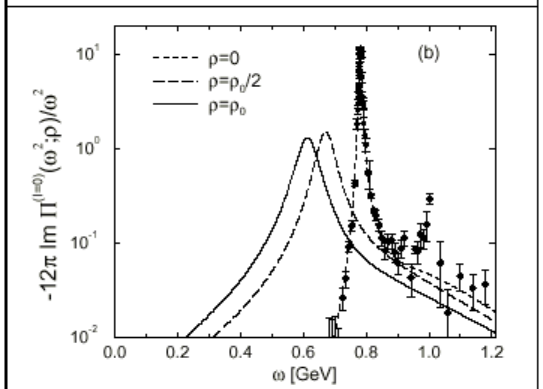


Klingle,Kaiser,Weise,
NPA624(97)527

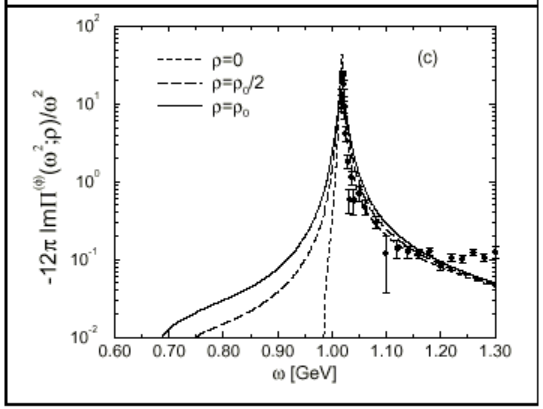
ρ



ω

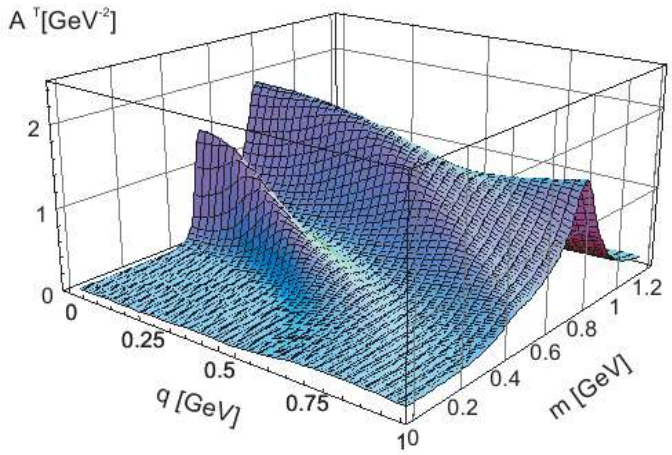


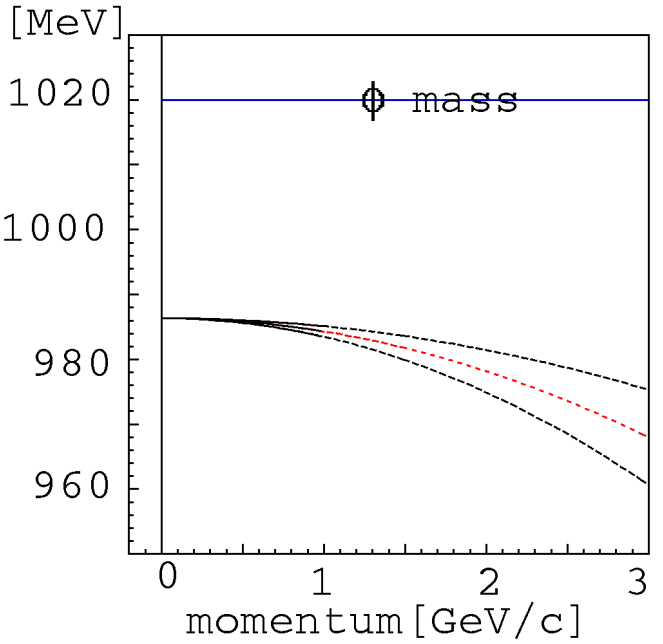
ϕ

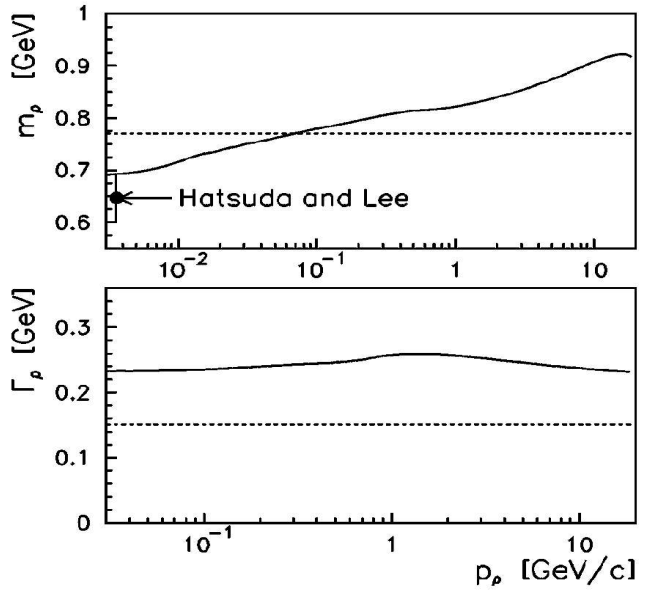


dispersion relation (mass VS momentum)

- 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
- Kondratyuk et al. (PRC58(98)1078) : ρ meson
- Post & Mosel(NPA699(02)169) : ρ meson

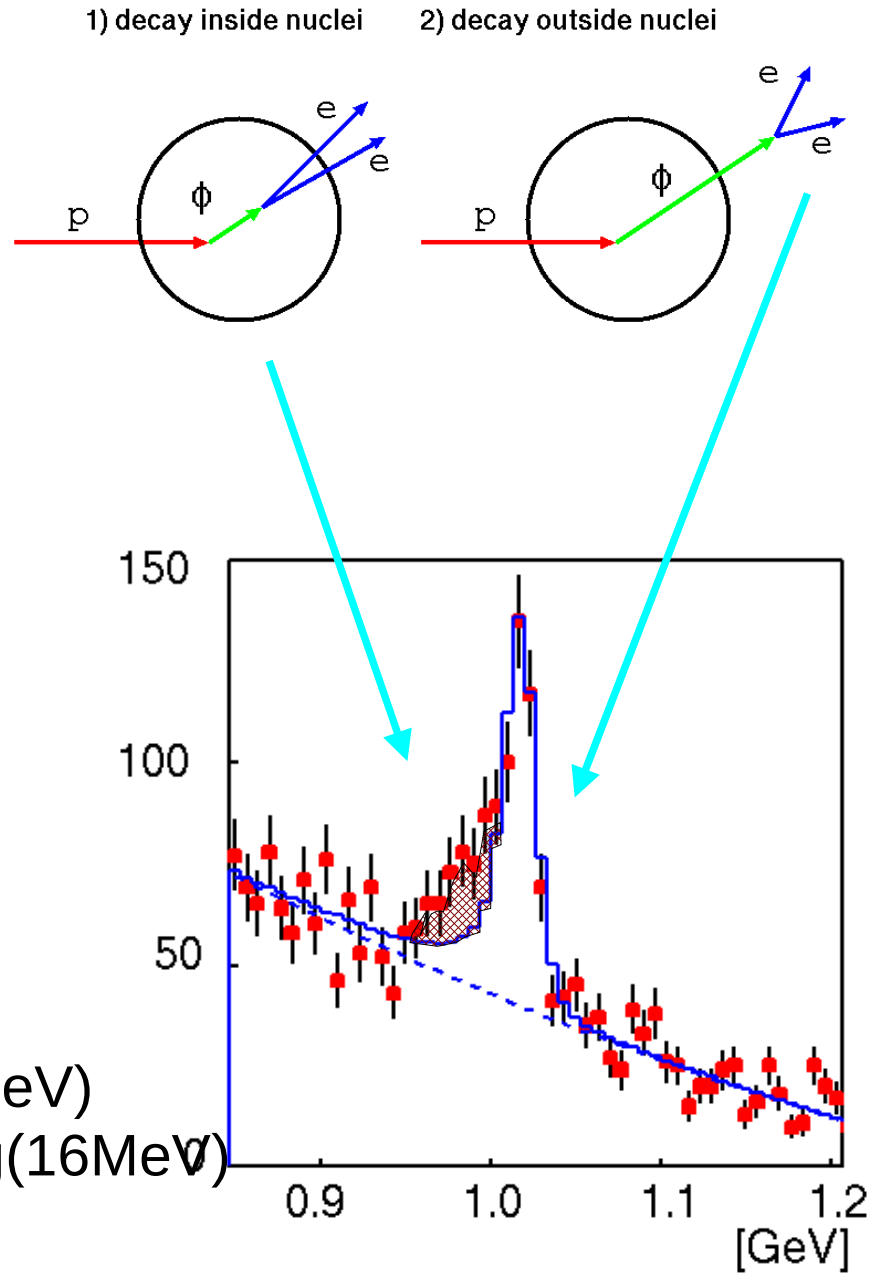






E325 : interpretation

- 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



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

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

3.4% mass reduction (35MeV)
3.6 times width broadening(16MeV)
at ρ_0

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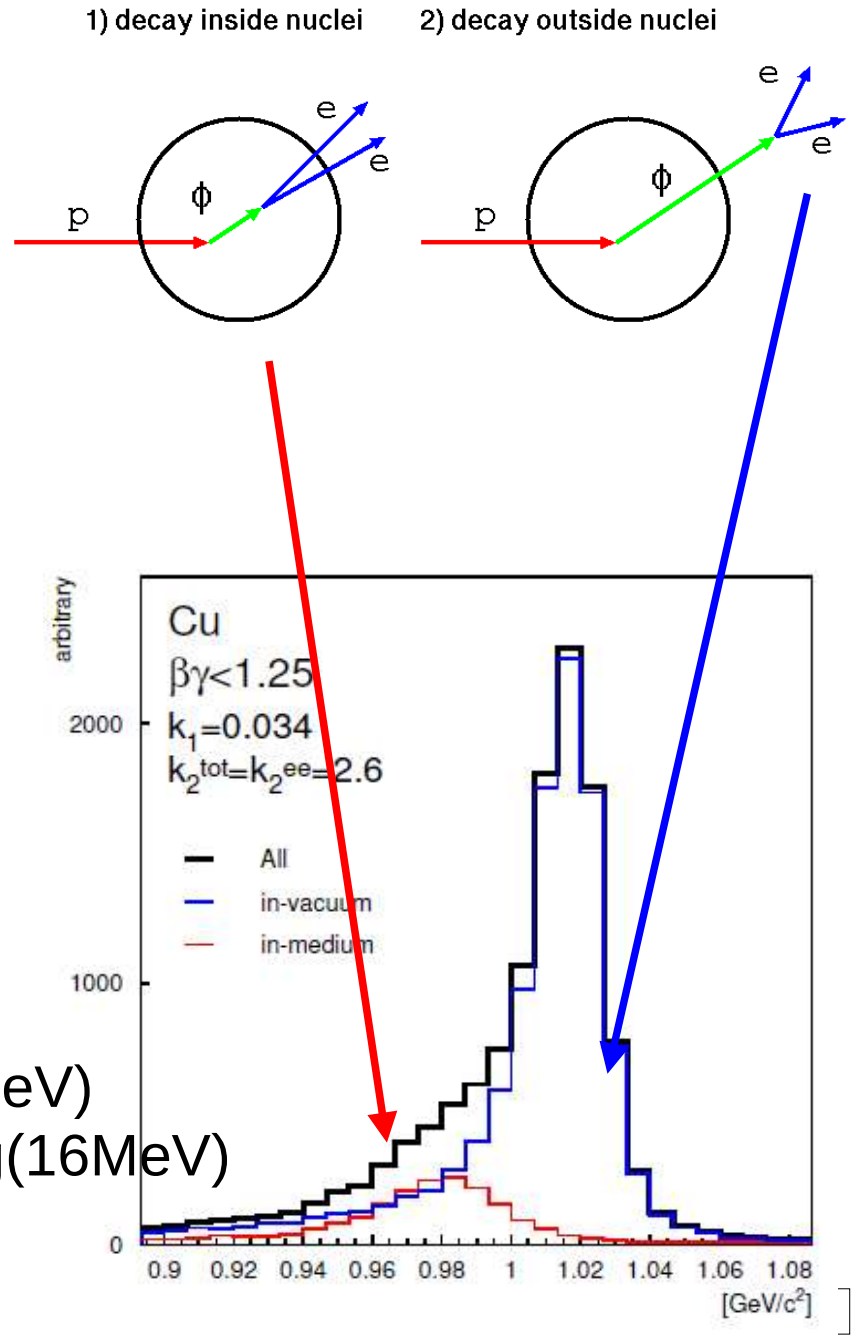

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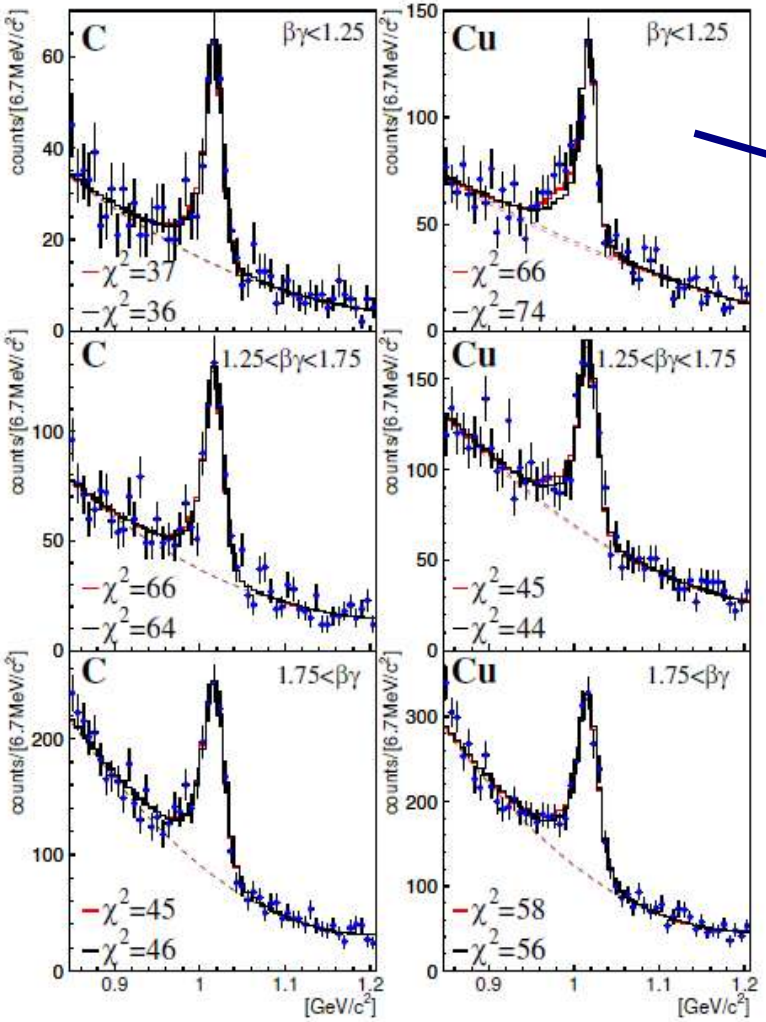
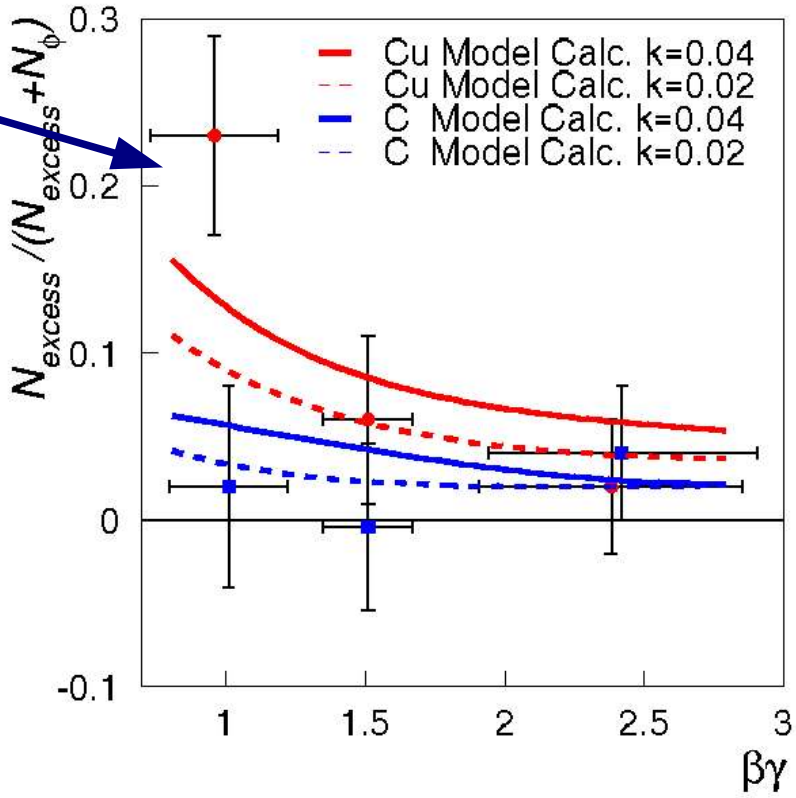
J-PARC E16 experiment

- Same concepts as KEK-PS E325
  - thin target (0.1% interaction) / primary beam (~10^{10} /sec)/ slowly moving vector mesons in the ee channel
- Main goal : collect ~1-2 x 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)
    - check the interpretation models
    - 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

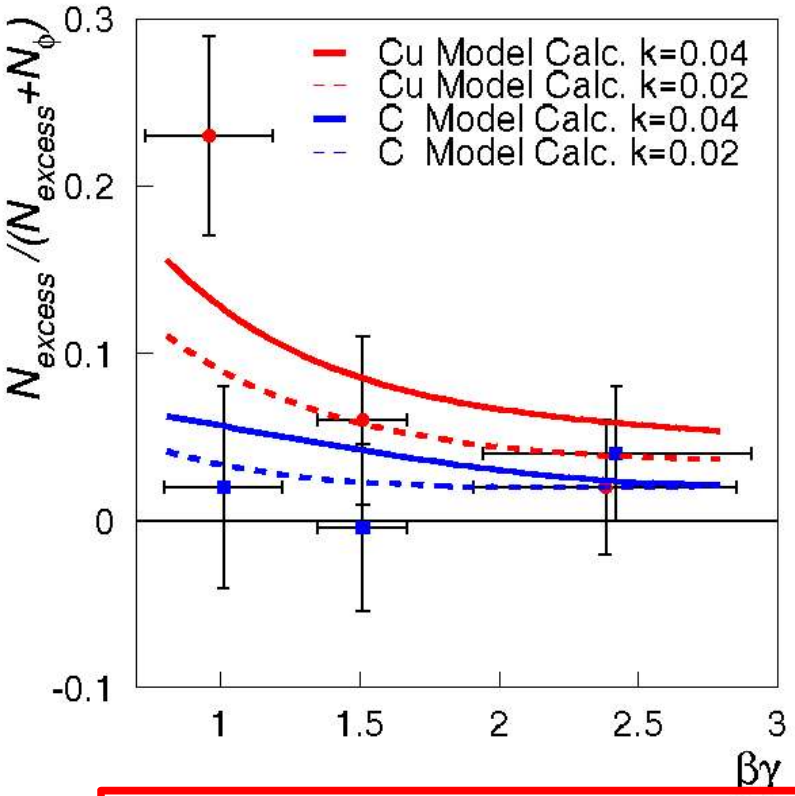
- velocity dependence of excesses ('modified' component)
- E325 only one data point for ϕ (slow/Cu) has significant excess



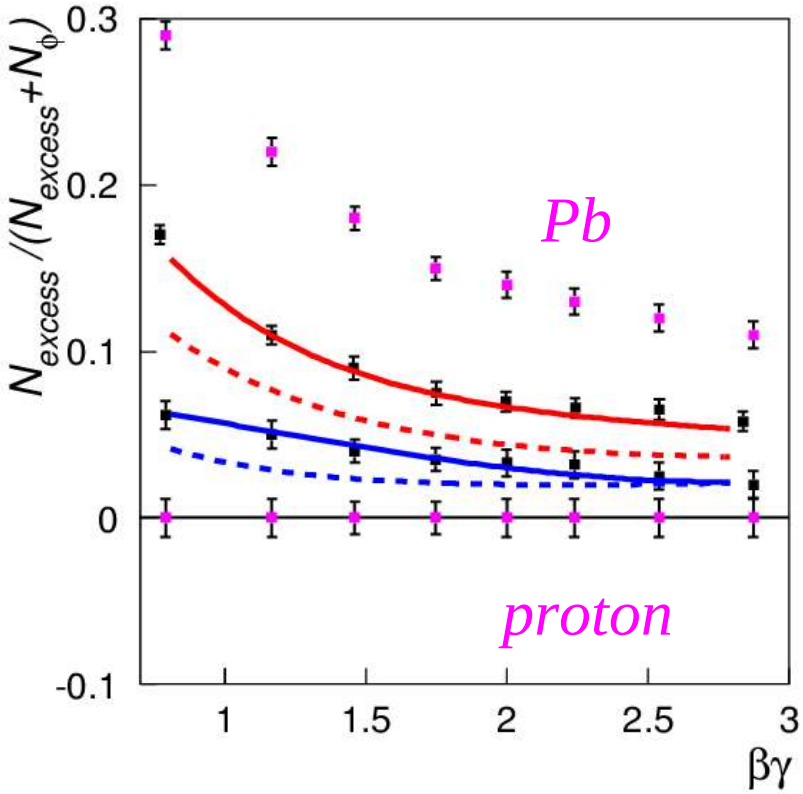


velocity and nuclear size dependence

- 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



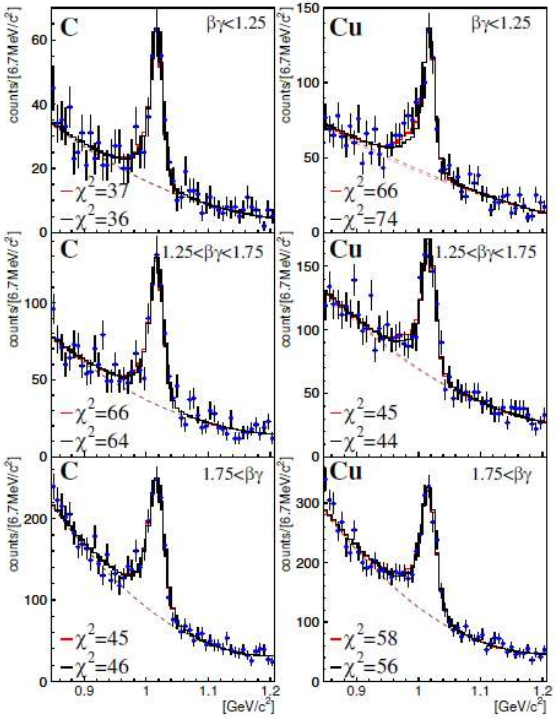
x 100 stat.

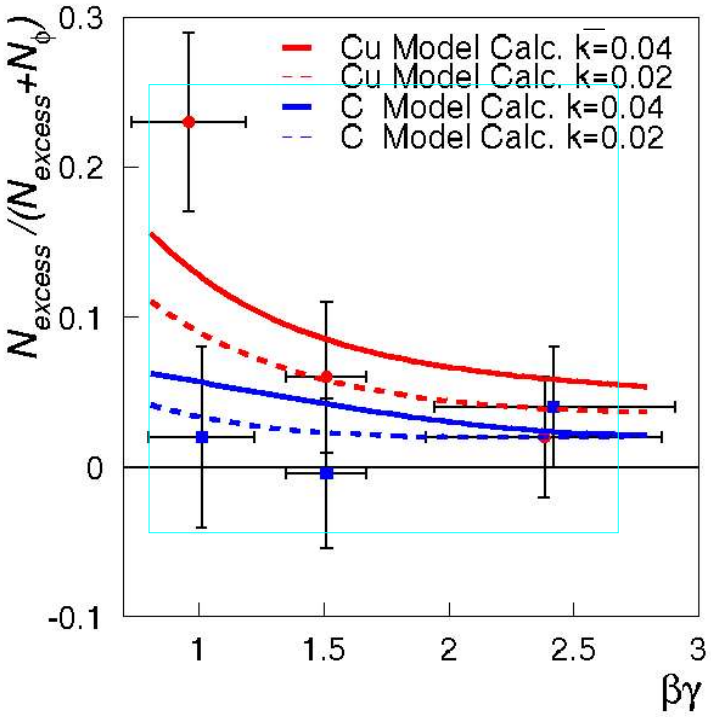


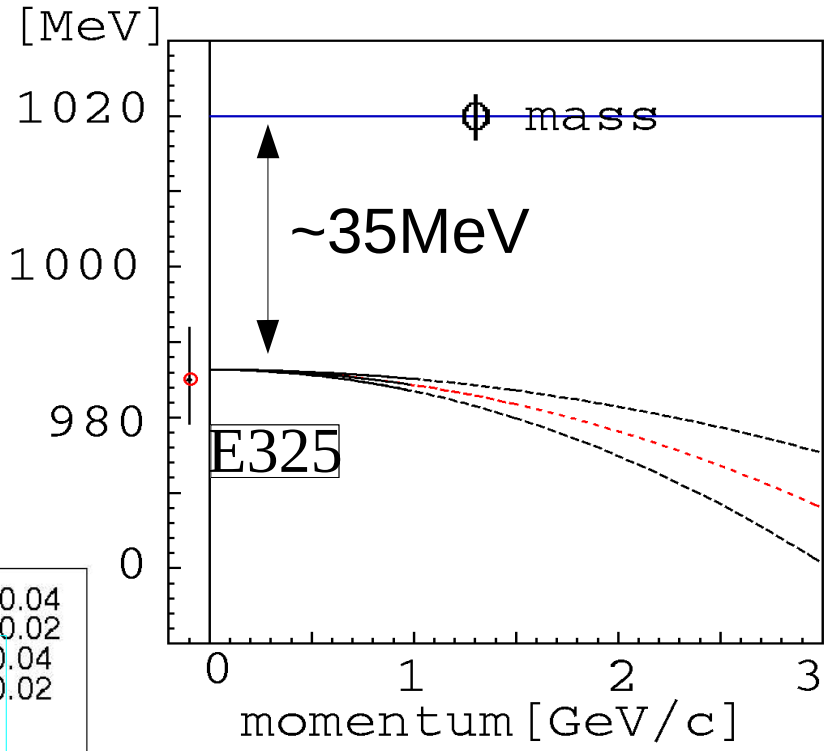
- establish the modification
- check the interpretation model w/ shape analysis

dispersion relation(mass VS momentum)

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







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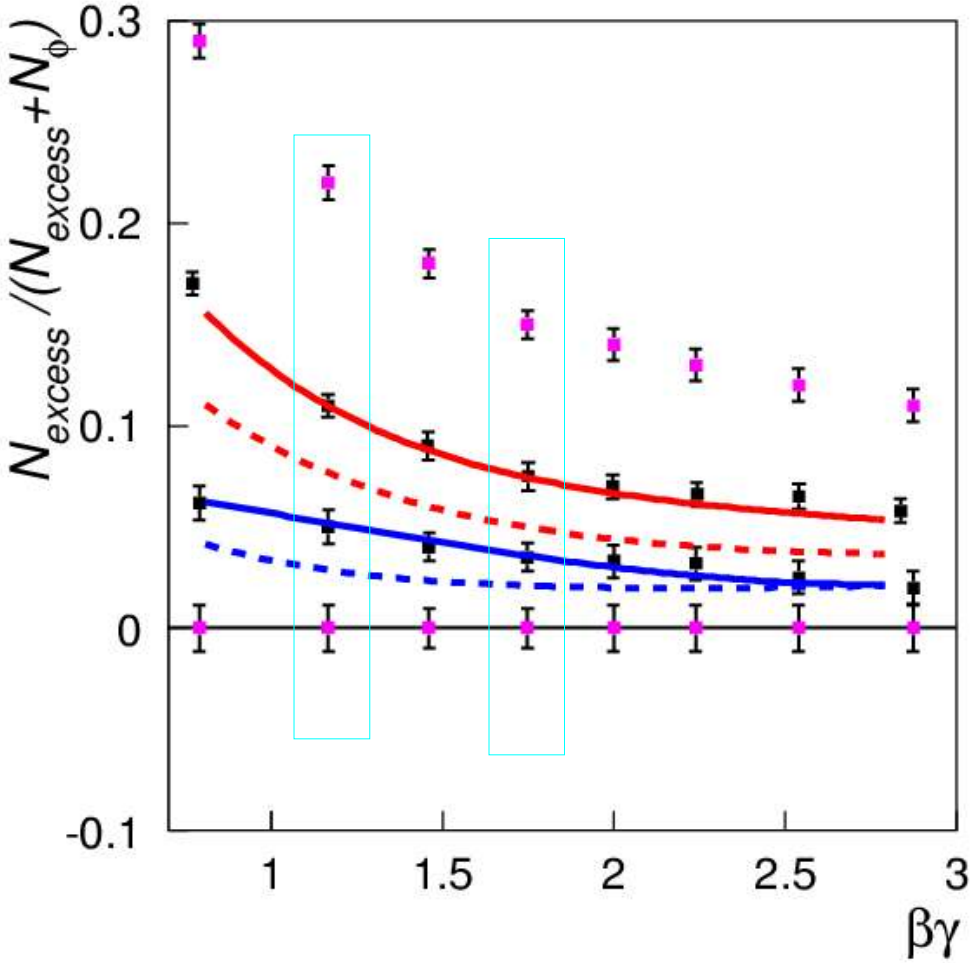

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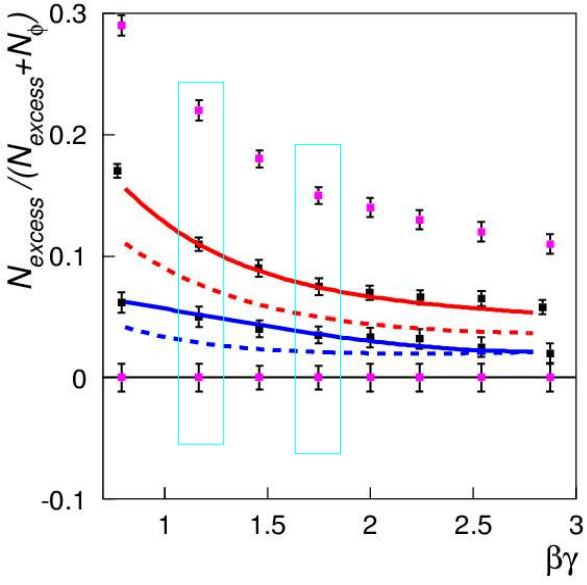
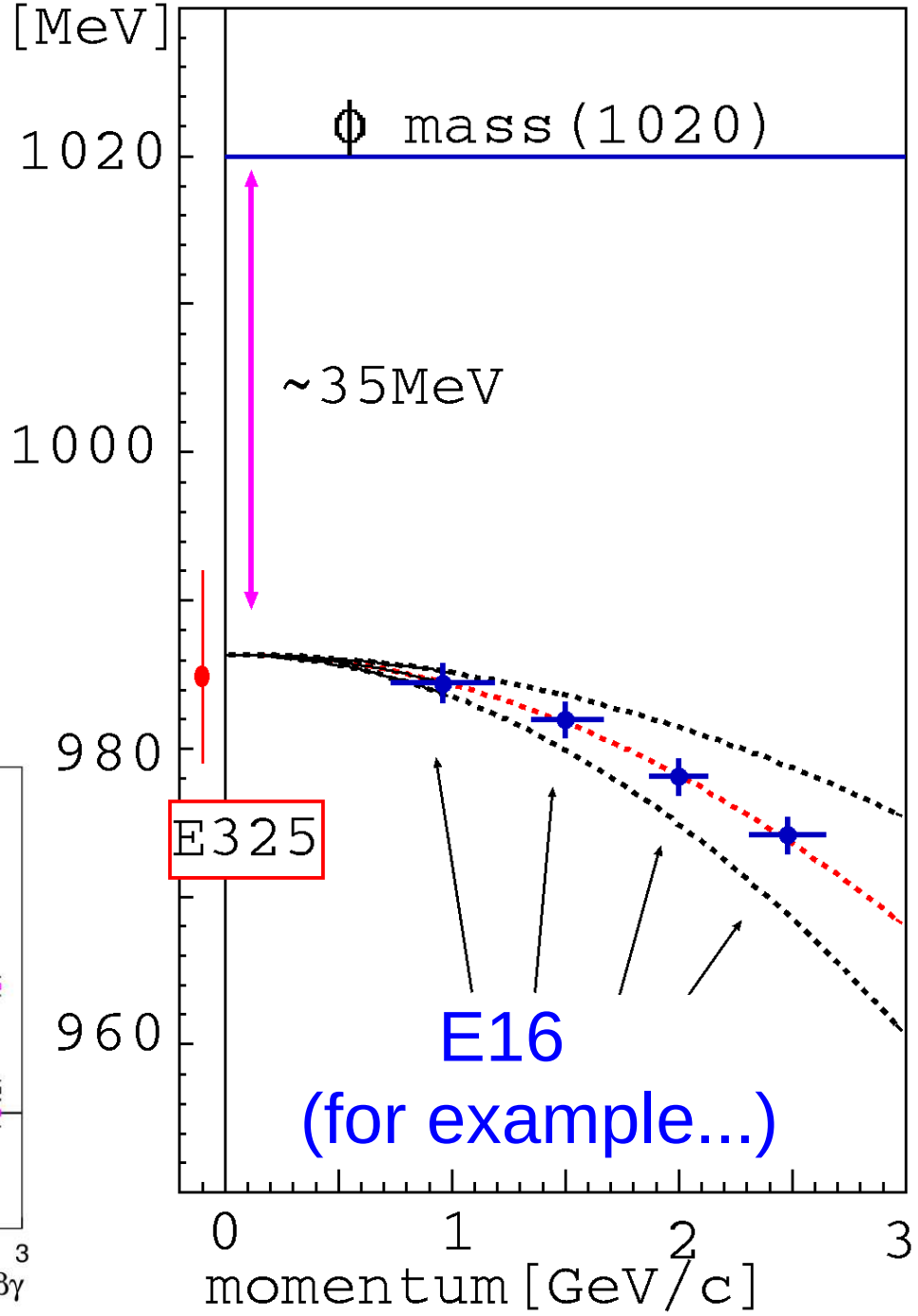




Intermission...

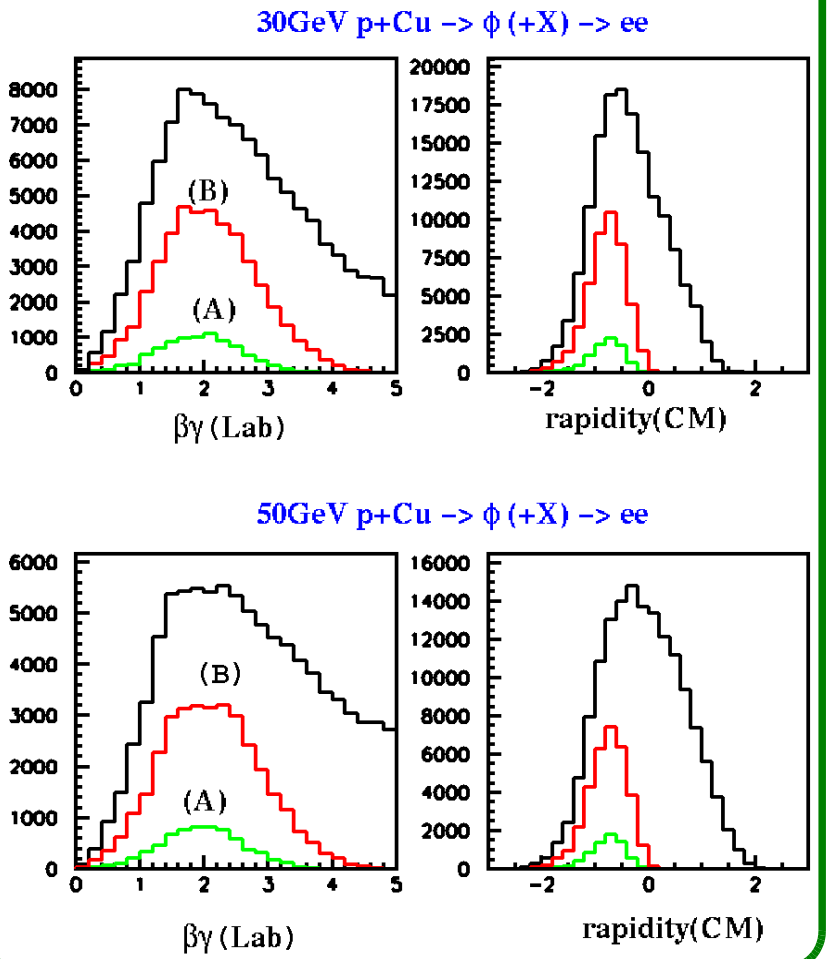
beam energy and spectrometer acceptance

A) Reuse of E325 spectrometer
B) Proposed larger acceptance spectrometer

expected ϕ yield for two options (using JAM)

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

spectrometer acceptance $\phi \rightarrow e^+e^-$ (estimated by JAM)



10 times can be collected by larger acceptance and beam energy (both 30 and 50 GeV are acceptable)

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

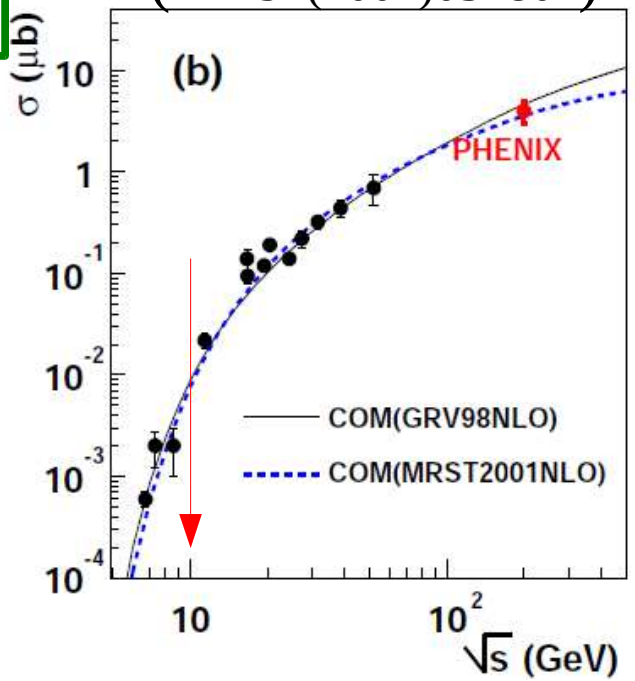
J/ yield @E16

- very rough estimation w/ the production CS ratio

	φ		J/ψ	ratio
	12GeV	50GeV	50GeV	
p+p	~70 μb[*1]		~0.01 μb	
p+Cu	~1 mb[*1]	5 mb[*2]	0.5 μb[*3]	1/10000
ee branch	0.03%		6%	200
yield		100000	2000	1/50

$p+p \rightarrow J/\psi + X$

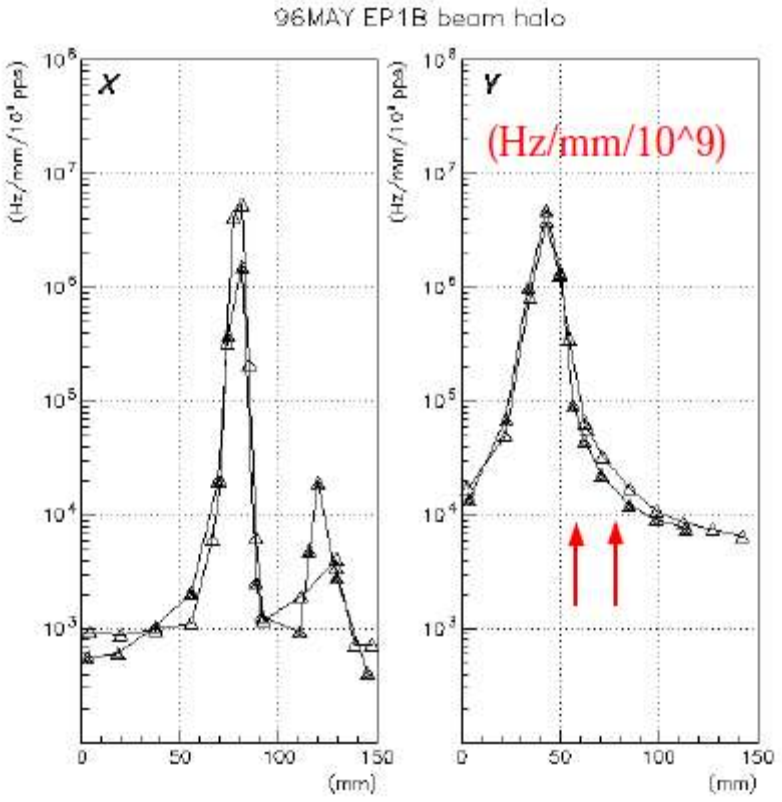
(PRL92(2004)051802)



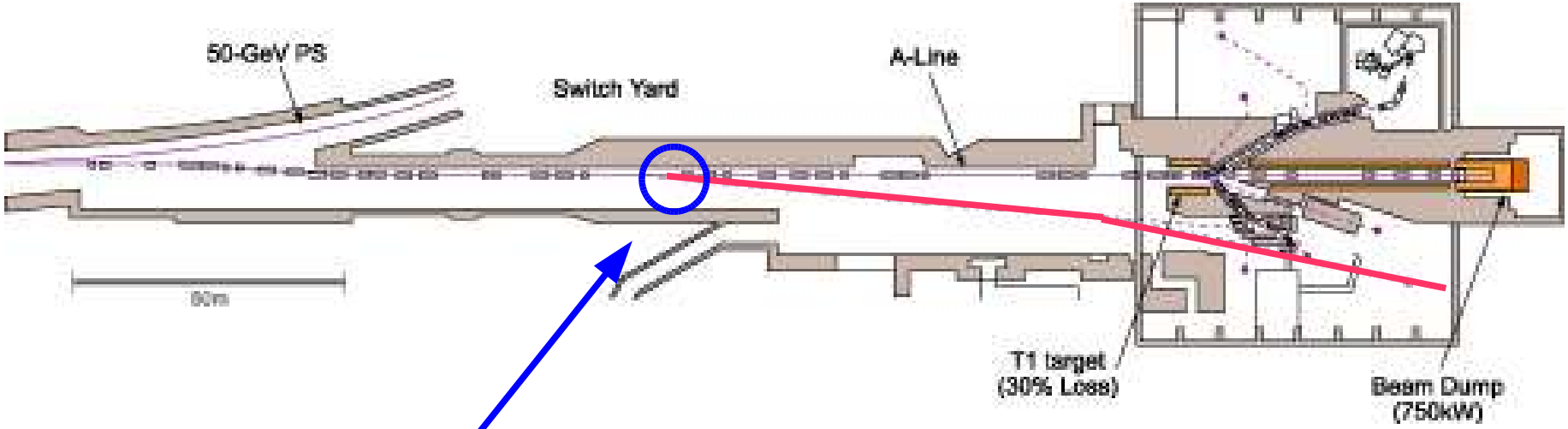
- *1 : E325 (12GeV) data
- *2 : JAM & empirical formula, from 12GeV data
- *3 : nuclear dependence ~A , from p+p data
- 10^{10} ppp, 0.1% int. target

Tandem operation w/ dimuon exp.

- beam intensity and halo
  - E16 : 10^{10} ppp vs dimuon 10^{12} ppp
  - 1mm beam x wire target (~100μm ϕ) = 1/100
    - beam FWHM 0.8~1.6 mm @ EP1B
  - halo @ EP1B
    - intensity x 10^-4/mm(w) @ 20mm
    - intensity x 10^-5/mm(w) @ 40mm
    - .... x 1/100 is required

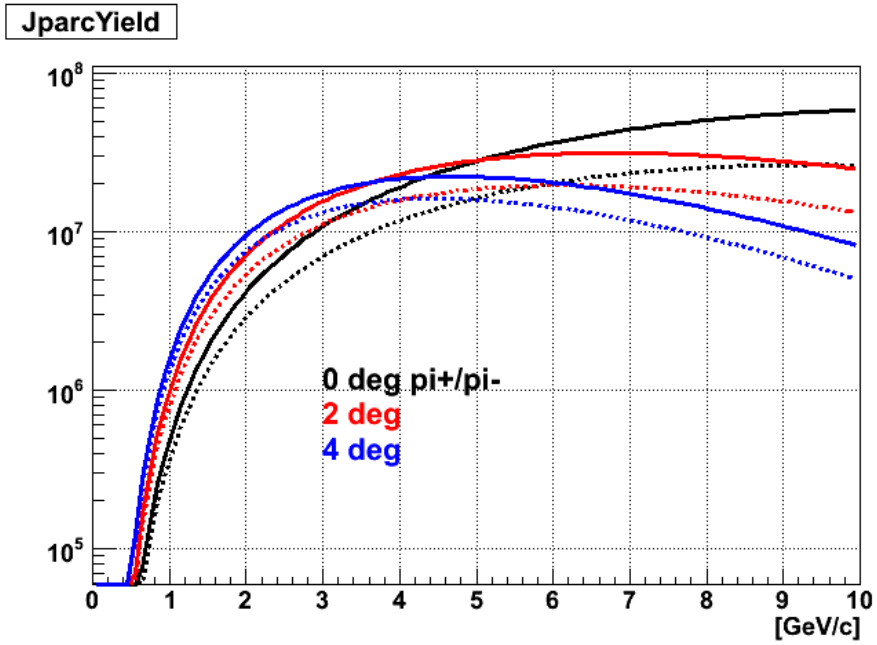


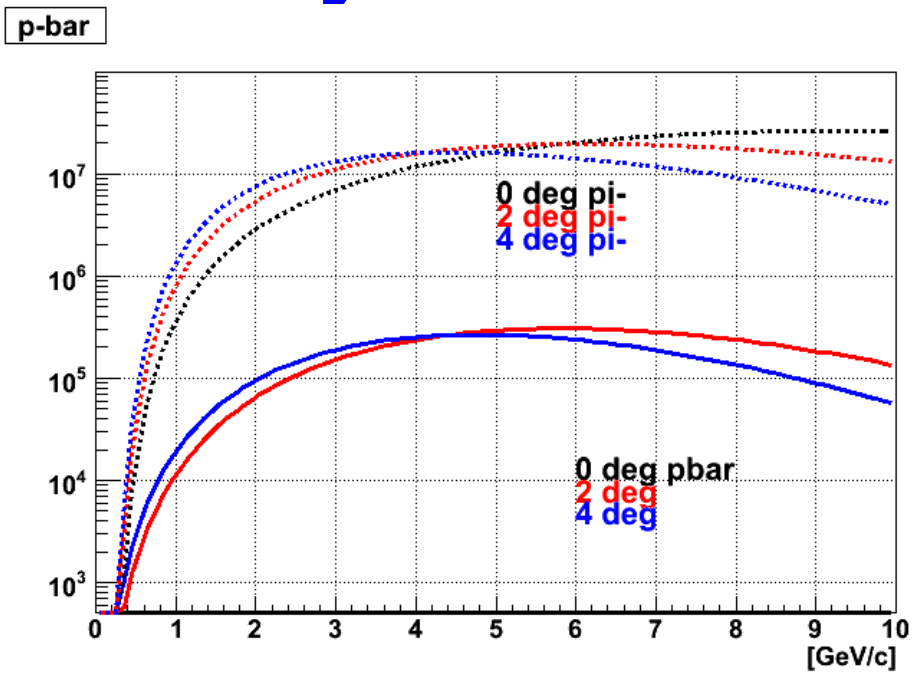
Secondary Beam intensity



- Sanford-Wang
  - 2% loss target, 0.2msr%, production angle 4 degree
  - 30GeV, 1x10^{14} proton/spill, 120m
- Then
  - 2 GeV π^- : ~1x10^7 /spill Ozawa (, Ohnishi)
  - 1.3 GeV pbar : ~4x10^4 /spill ~~Ohnishi~~

Secondary Beam intensity





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ee pair measurement in other channels

- E325 : 12GeV p+A $\rightarrow \phi$ +X , 10^9 proton/spill, 0.1% int. target
  - p+p ~70μb
- K+A $\rightarrow \phi$ +X
  - K+p cross section : ~10 times of p+p,
  - however 10^4~10^5 Kaon/spill @12GeV, high mom. beamline
- pbar
  - 1.3 GeV/c pbar +p $\rightarrow \phi\phi$: 4μb, 10^7 pbar/spill ~ x 1/1000
    - slow component enhance?
      - $\beta\gamma < 1.25$: 20% (E325) vs 100% ~ x 5
      - $\beta\gamma < 0.5$: 1.5% vs ?
  - stopped pbar + p $\rightarrow \phi\gamma, \phi\pi^0$: monochromatic ϕ
    - difficulties : ee : thin target, μμ : μ ID at low momentum (~500MeV/c)

Summary

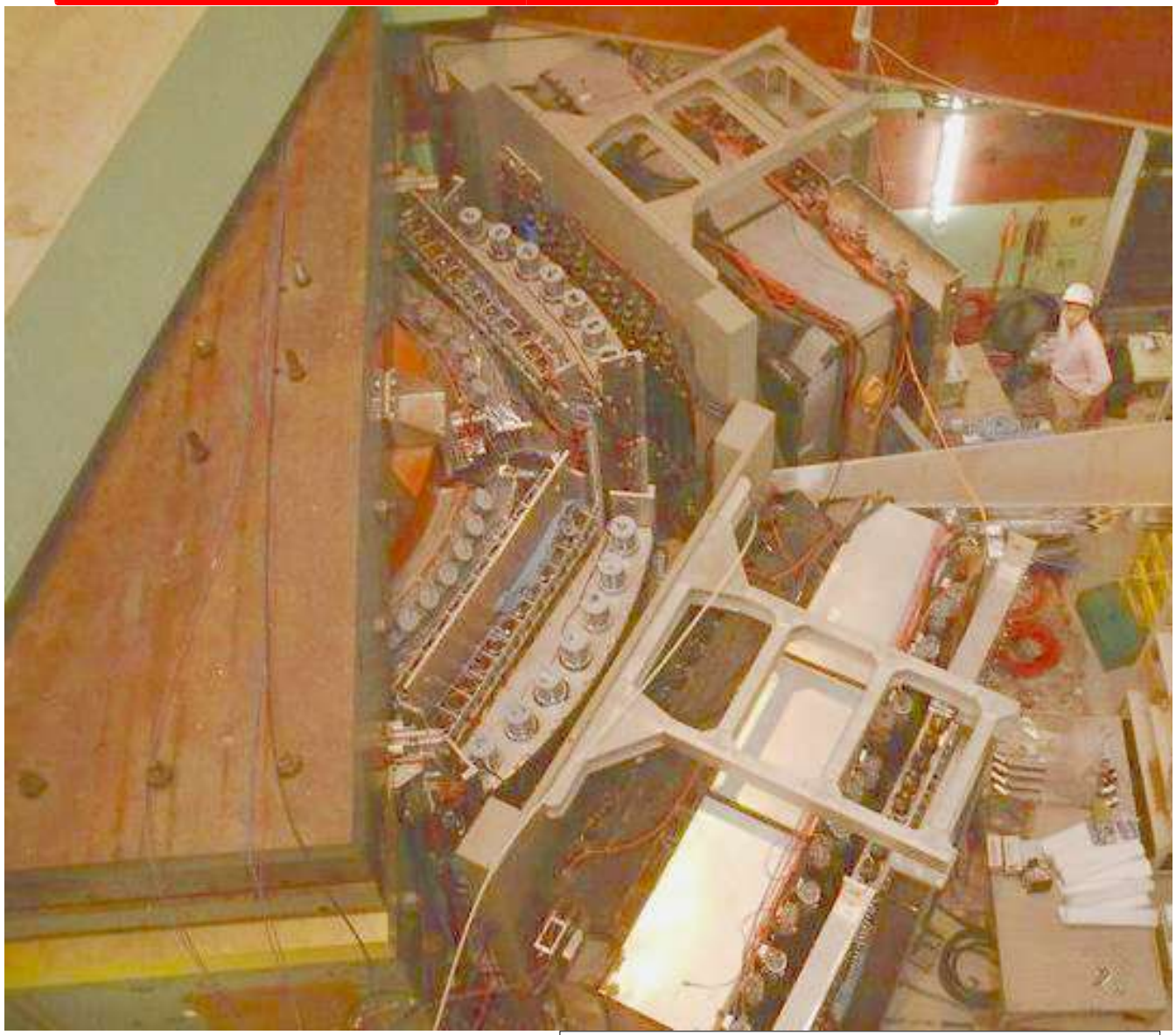
- Vector meson measurements in e^+e^- channel at J-PARC E16
  - to investigate the chiral symmetry in dense hadronic matter
- 30 (or 50) GeV primary proton beam (~1×10^{10} /sec)
  - especially collect ~10^5 $\phi \rightarrow e^+e^-$ for each target in ~5weeks (100 shift) operation : 100 times as large as KEK-PS E325's statistics
- New spectrometer using new technology (GEM tracker/HBD)
  - R&D is on going at U-Tokyo and RIKEN w/ grant-in-aid
- 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

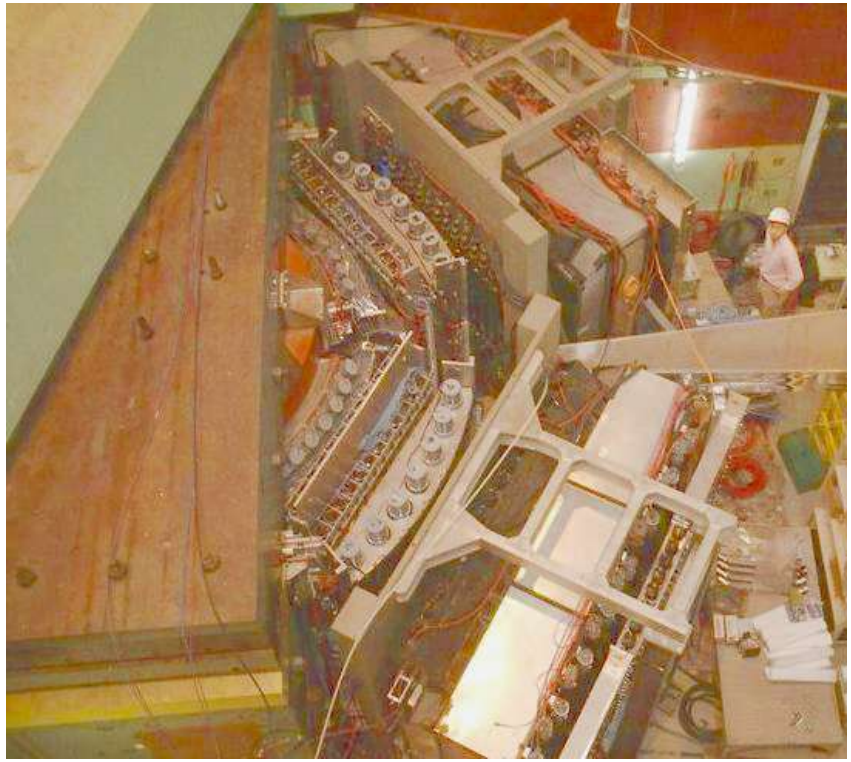
- 1993 proposed
- 1994 R&D start
- 1996 construction start
- '97 data taking start
- '98 first ee data
  - PRL86(01)5019 ρ/ω (ee)
- 99,00,01,02....
  - x100 statistics
  - PRL96(06)092301 ρ/ω (ee)
  - PRC74(06)025201 α (ee)
  - PRL98(07)042501 φ (ee)
  - PRL98(07)152302 φ (KK),α
- '02 completed
- spectrometer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

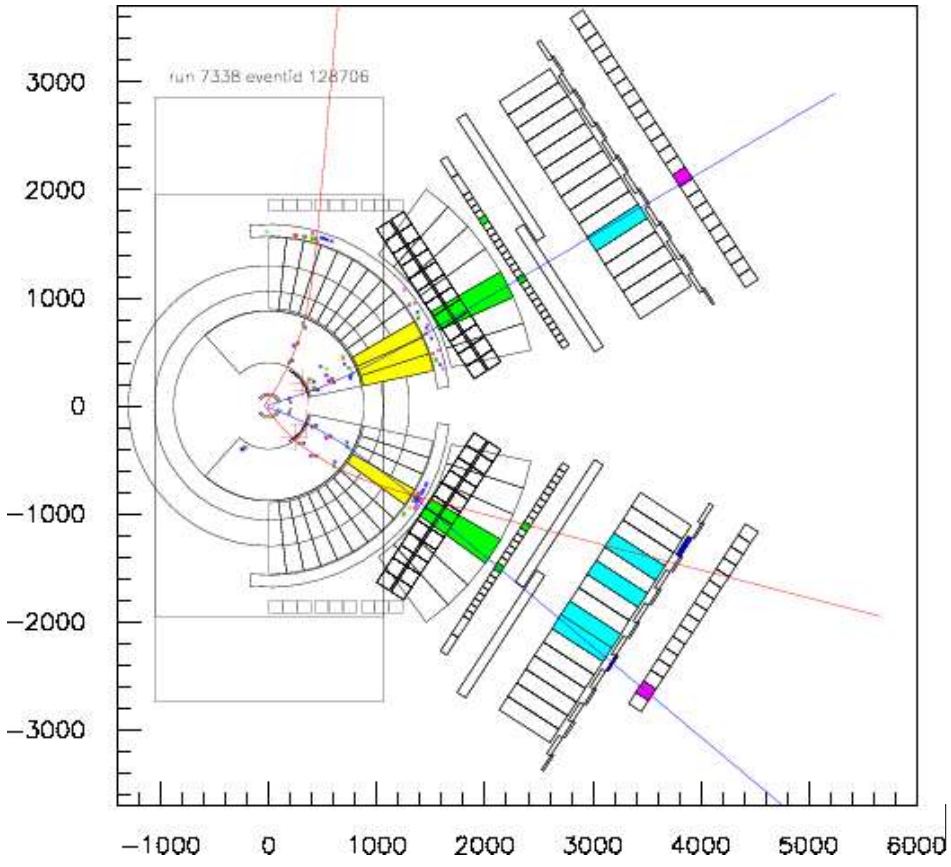
E325 spectrometer
located at KEK-PS EP1-B primary beam line



KEK-PS E325

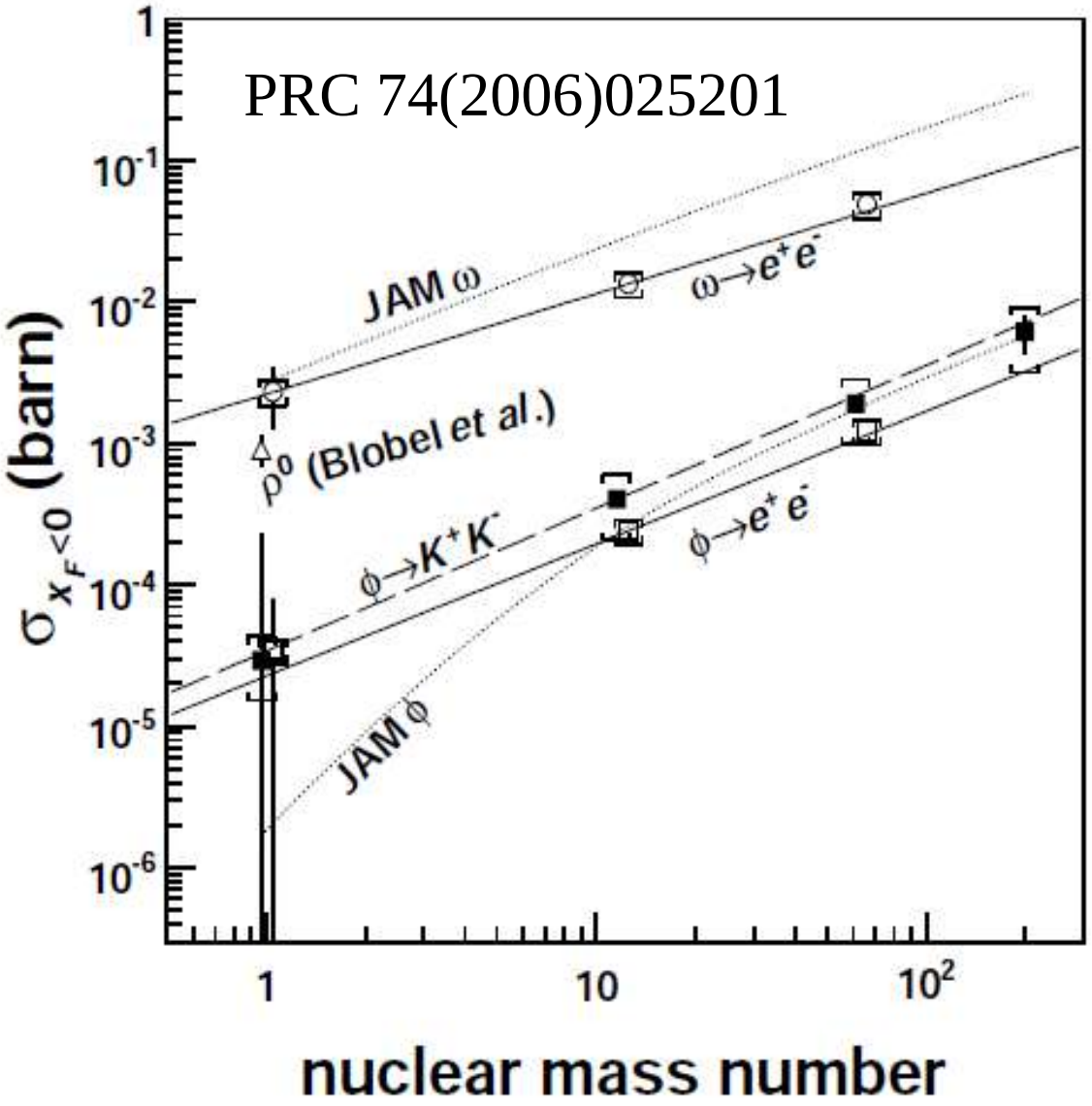
- to observe the vector meson modification in the cold nuclear matter at the normal nuclear density
- 12GeV p+C/Cu $\rightarrow \rho/\omega/\phi$ +X ($\rho/\omega/\phi \rightarrow e^+e^-$, $\phi \rightarrow K^+K^-$) , 1<p<3GeV/c for ϕ
- run 1997-2002





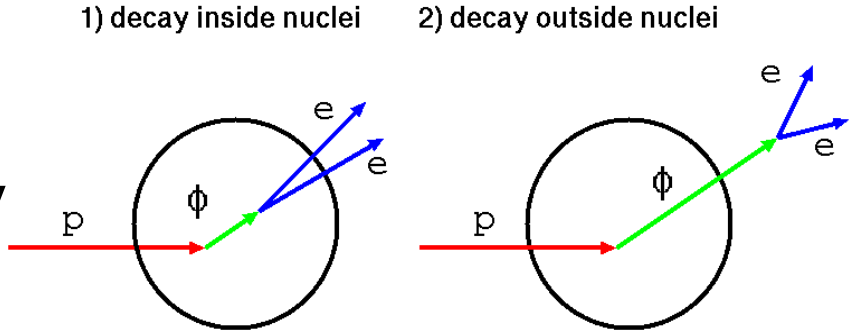
measured production CS by E325

- values for the CM backward
-

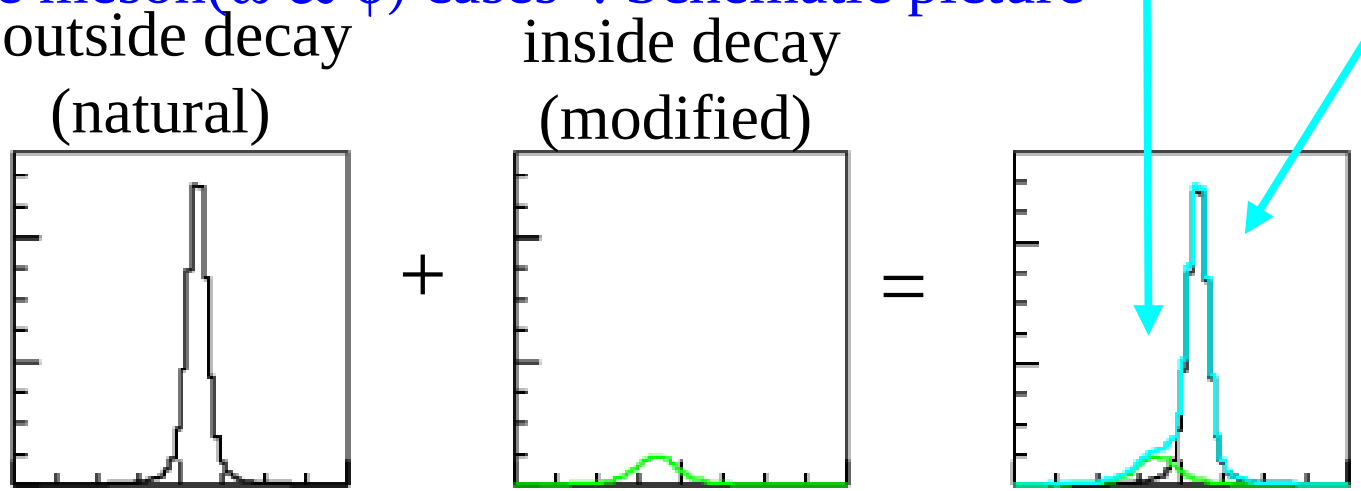


expected signal

- 12GeV p+C/Cu → ρ/ω/ϕ +X (ρ/ω/ϕ → e^+e^- , ϕ → K^+K^-) , 1<p<3GeV/c for ϕ
- finite size of matter and finite velocity mesons : only a part of mesons are decay in nuclei and modified.

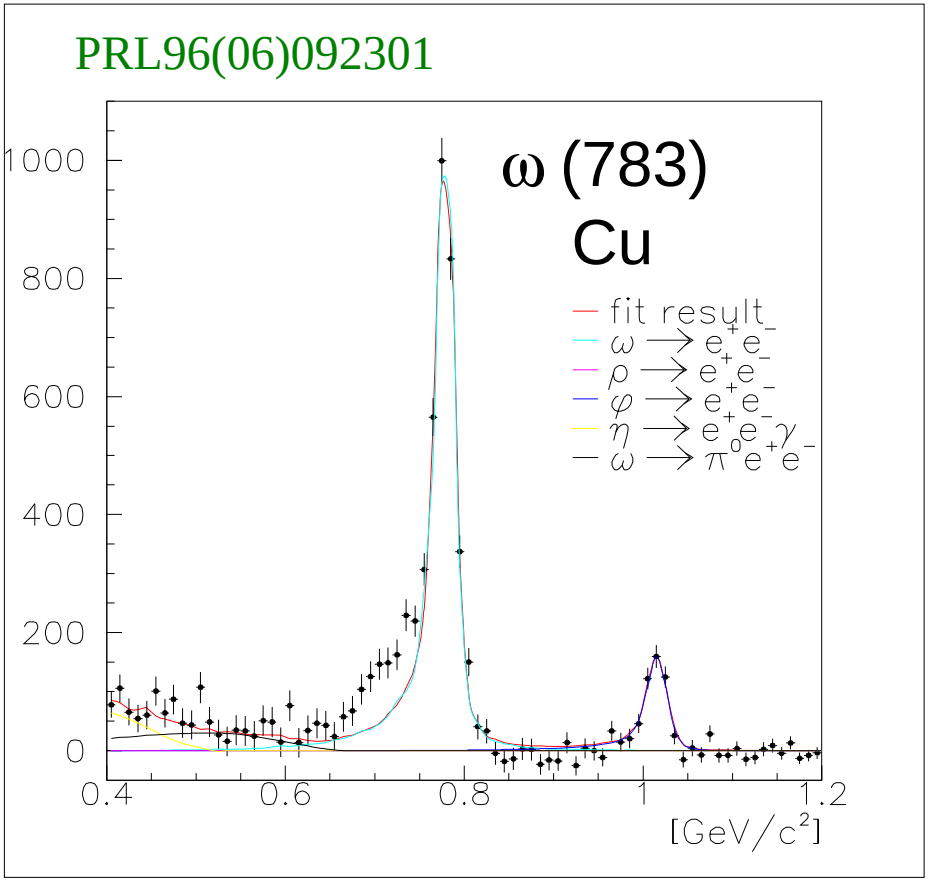


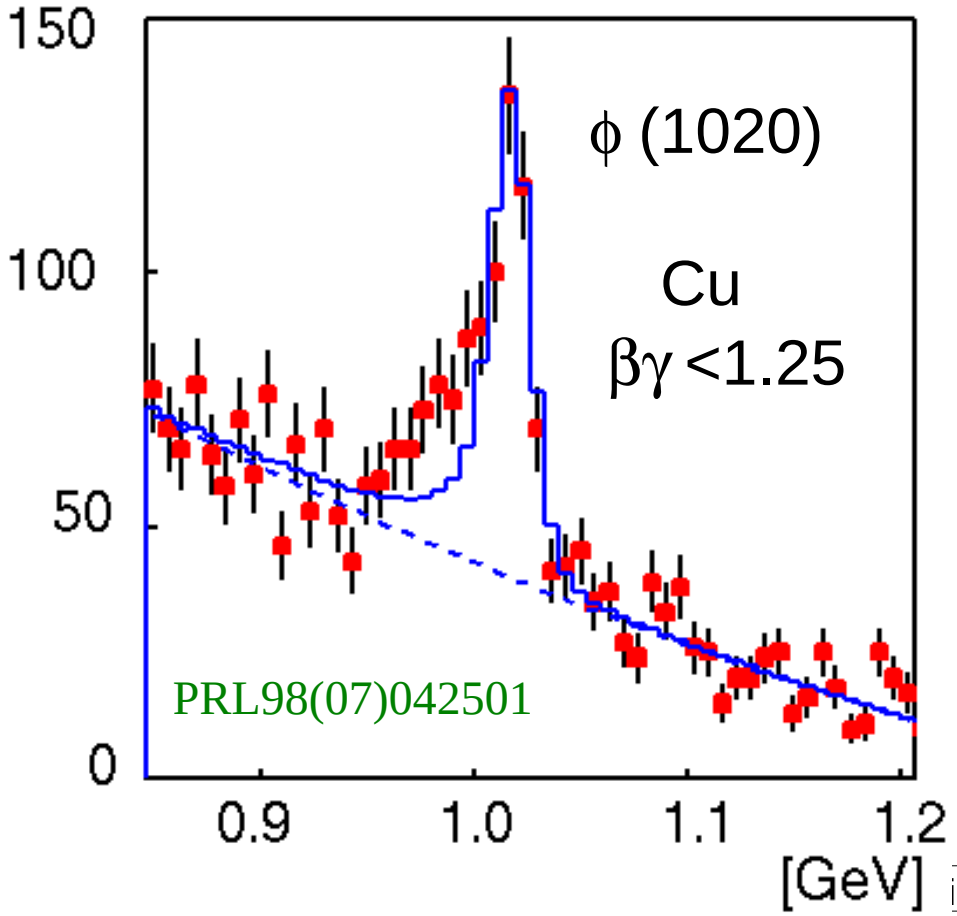
longer-life meson(ω & ϕ) cases : Schematic picture



E325 observed meson modification

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

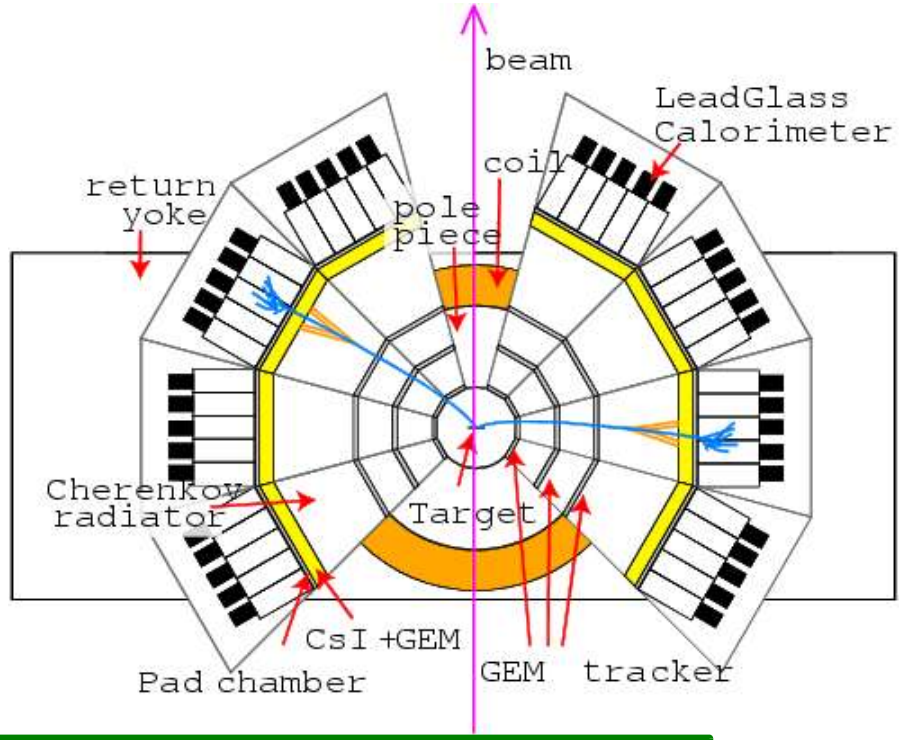




---J-PARC E16 experiment---
Low mass dielectron measurement

Collaboration

RIKEN	S.Yokkaichi, H. En'yo, F. Sakuma
U-Tokyo	K. Ozawa
CNS, U-Tokyo	H. Hamagaki
Hiroshima-U	K. Shigaki
KEK	A.Kiyomichi, M. Naruki, R.Muto, S. Sawada, M. Sekimoto
Kyoto-U	K. Aoki

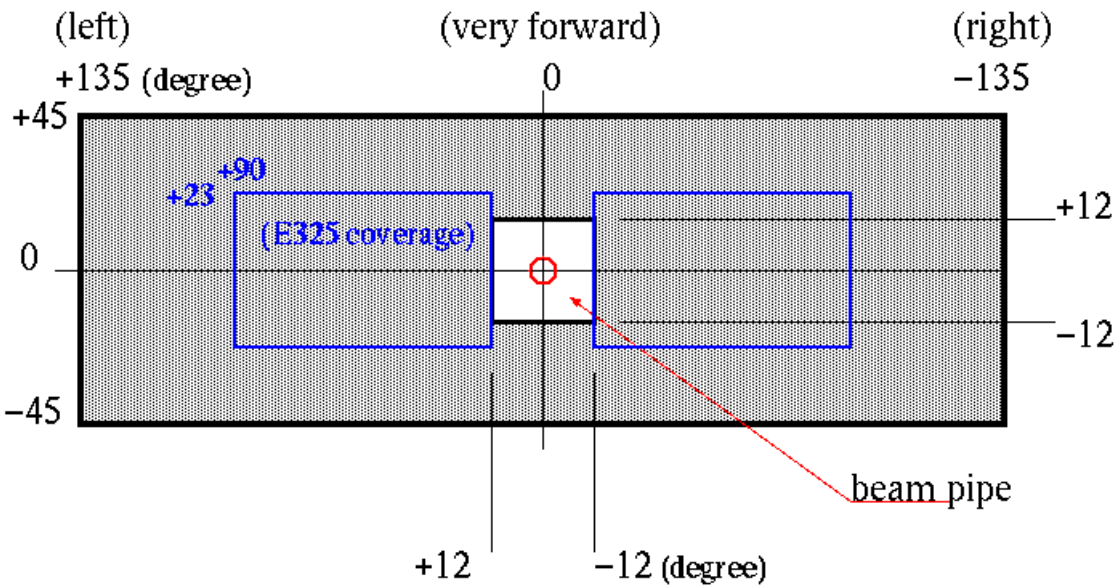


Proposal revised version 1 (2006 June 7) is located on :
http://ribf.riken.jp/~yokkaich/paper/jparc-proposal-0604.pdf

To collect high statistics

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

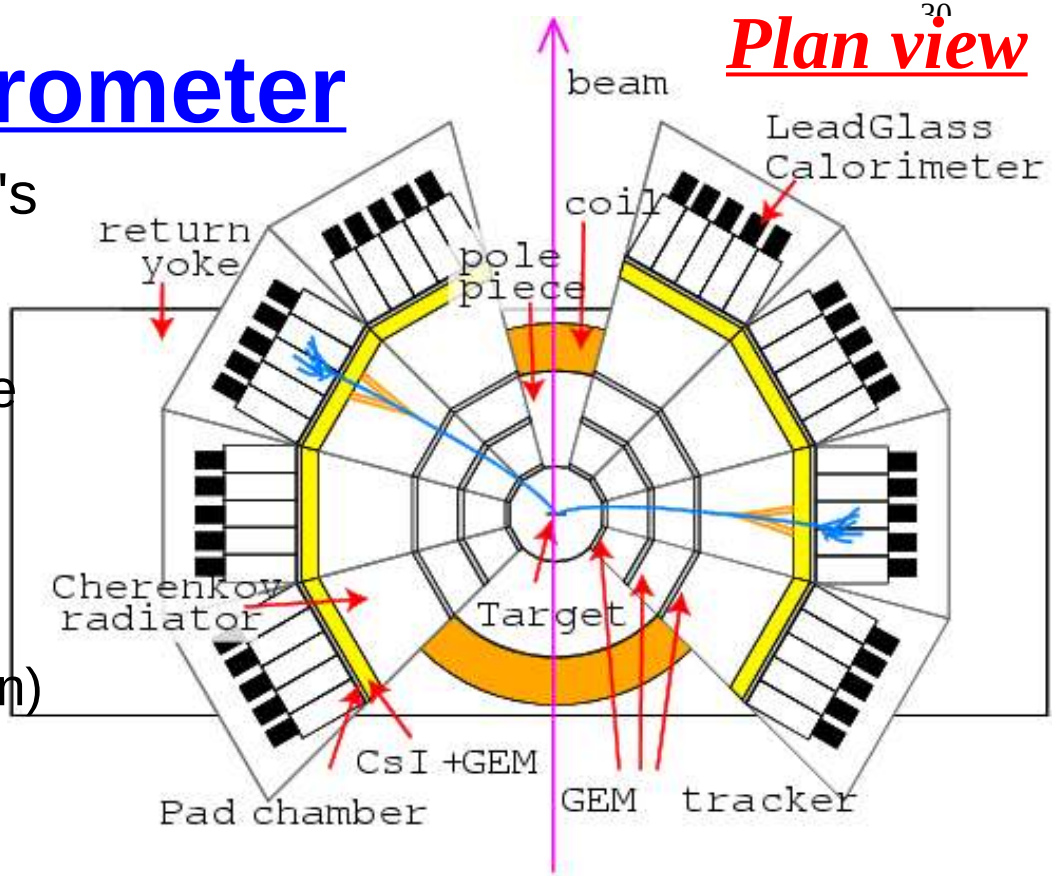
Geometrical (horizontal & vertical) coverage of the spectrometer



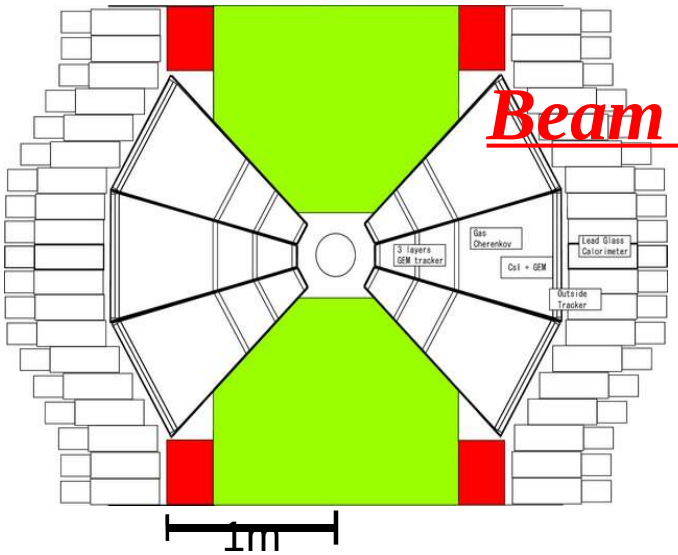
Proposed spectrometer

- 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 (~30mm ϕ)
  - Leadglass EMC: reuse of TOPAZ
- ~70K Readout Channels (in 27 segments)
  - cf. E325: 3.6K, PHENIX:~300K
- Cost : ~$5M (including ~$2M electronics)
  - cf. E325: $2M not including electronics

Plan view

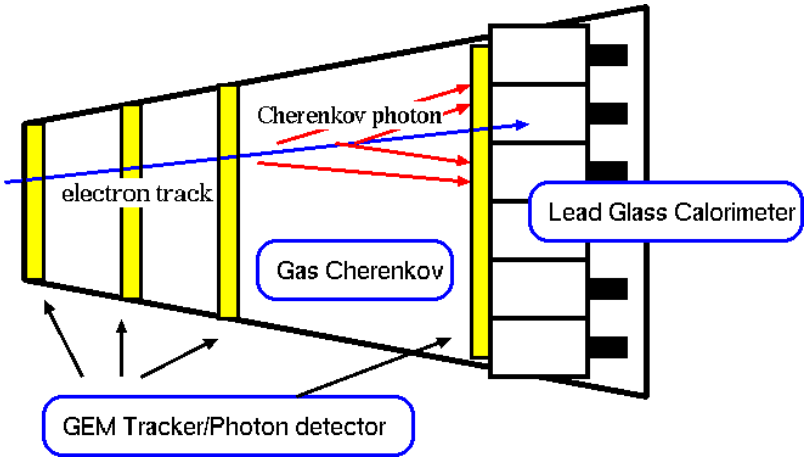


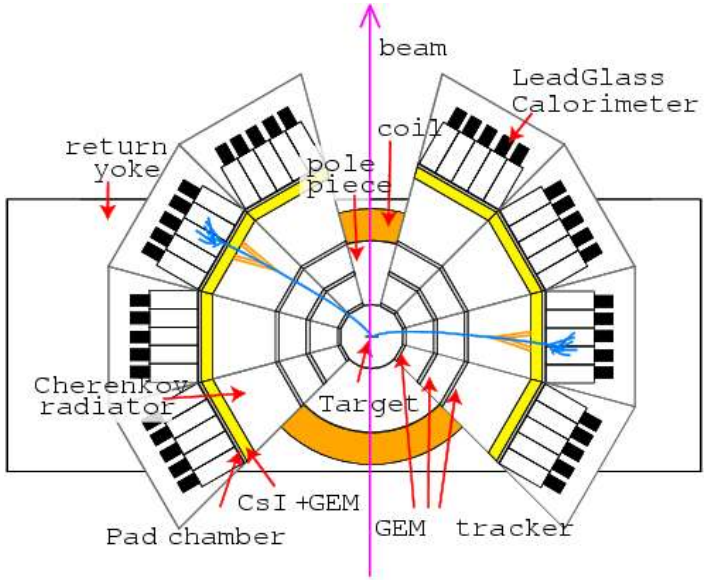
Beam view



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
  - 2011
    - ready for 30GeV proton beam





Detector R&D status

- GEM : domestic products works well
  - high gain GEM / larger size
- HBD (Gas Cherenkov using GEM + CsI photocathord)
  - PHENIX prototype / working model
  - In Japan:
    - CsI photocathord (Hamamatsu)
    - CF_4 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)