E16 Status & Plan as of 2013/9

Proposal title :

Electron pair spectrometer at the J-PARC 50 GeV PS to explore the chiral symmetry in QCD

Satoshi Yokkaichi
(RIKEN Nishina Center)

- physics motivation
- experiment
- progress in the detector development
- schedule
- summary

Collaboration
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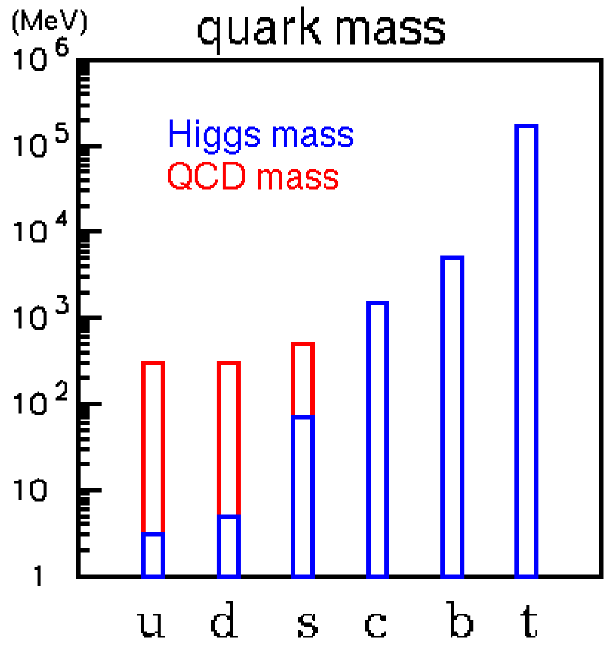
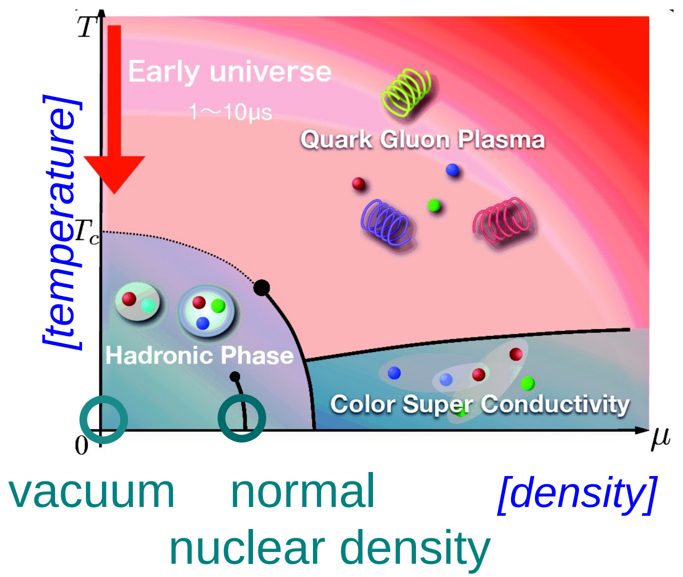
U-Tokyo Y.S. Watanabe, Y.Komatsu, S.Masumoto, K.Kanno, W.Nakai,Y.Obara, T.Shibukawa, H.Murakami
CNS, U-Tokyo H. Hamagaki Kyoto-U M. Naruki
Hiroshima-U K. Shigaki JASRI A. Kiyomichi

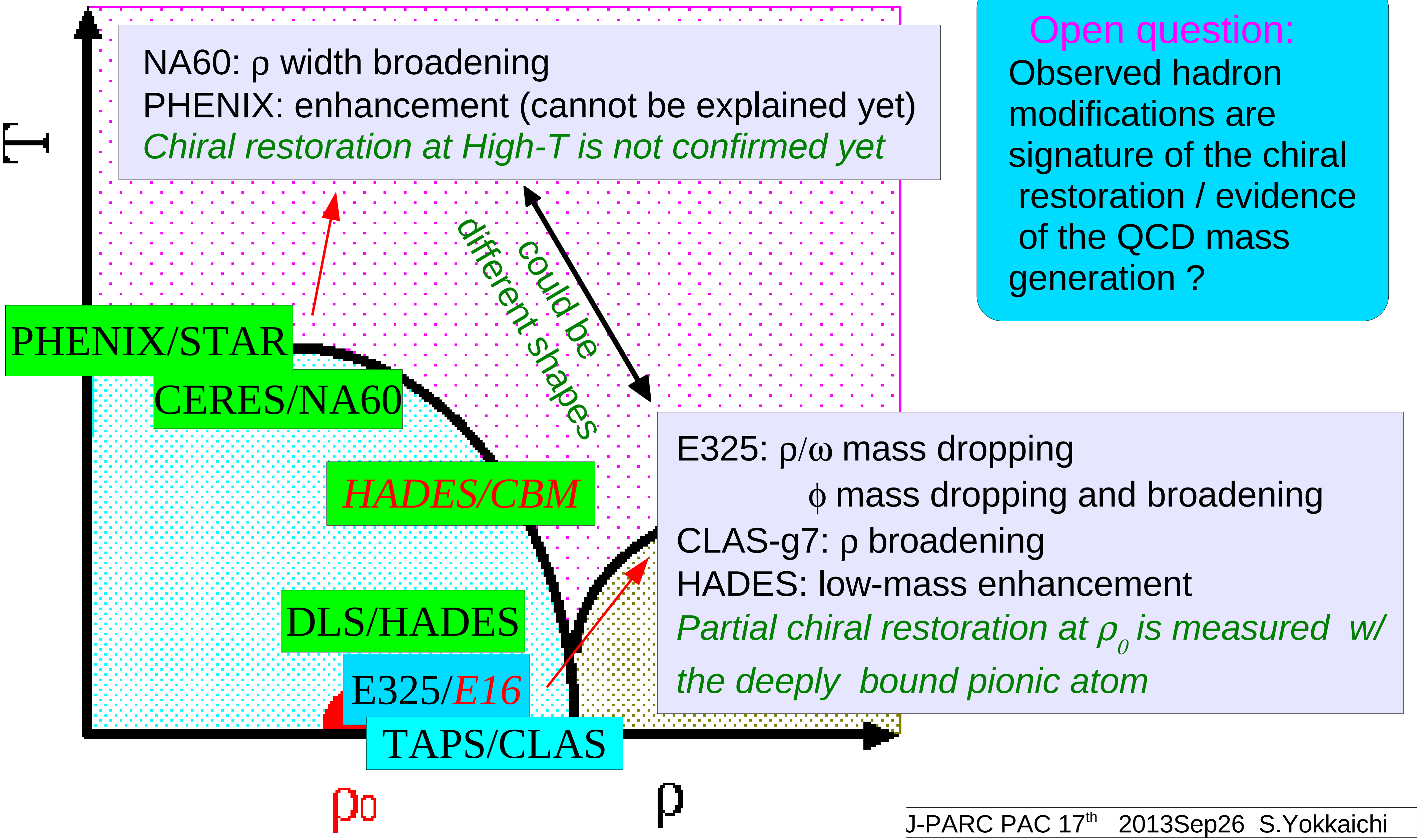
Mass and chiral symmetry in nuclear matter

- Origin of quark and hadron mass : spontaneous breaking of chiral symmetry
- In hot/dense matter, chiral symmetry is expected to be restored
  - hadron spectral modification is also expected
  - many theoretical and experimental approaches
- Hadron modification is observed in many experiments, but the origin is not determined
  - NA60(SPS), PHENIX(RHIC) : ρ and/or low mass
  - CLAS-g7(JLab) : ρ
  - E325(KEK-PS) : ρ/ω, and ϕ
    - best mass resolution and high statistics
- Next Step ...
  - put an emphasis on ϕ : not ambiguous like ρ/ω





Dilepton spectrum measurements in the world

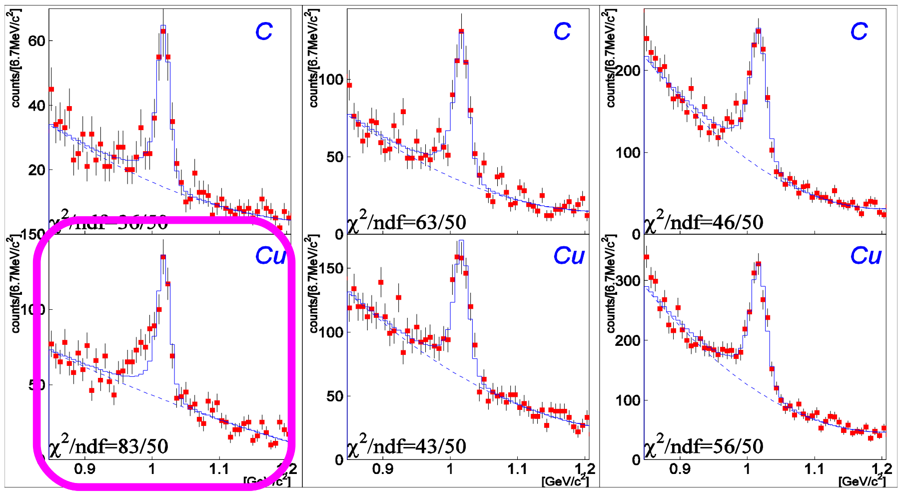


Open question:
Observed hadron modifications are signature of the chiral restoration / evidence of the QCD mass generation ?

J-PARC E16 experiment

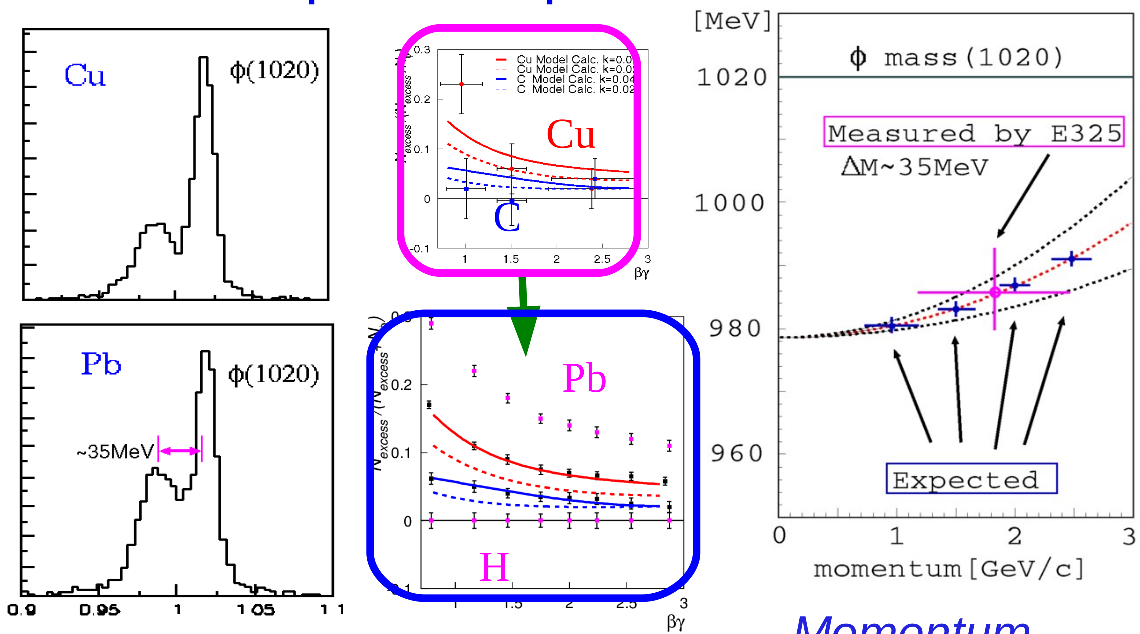
- Measure the vector-meson mass modification in nuclei systematically with the e^+e^- invariant mass spectrum
- A 30 GeV primary proton beam (10^{10}/spill) / 5 weeks of physics run to collect ~10^5 $\phi \rightarrow e^+e^-$ for each target with an improved mass resolution, 5MeV.
- confirm the E325 results, and provide new information as the matter size/momentum dependence of modification

Precedent exp.(KEK-PS E325)



φ–mass is modified in large nuclei for slowly moving mesons... consistent with the prediction based on the QCD sum rule

Proposed exp. E16

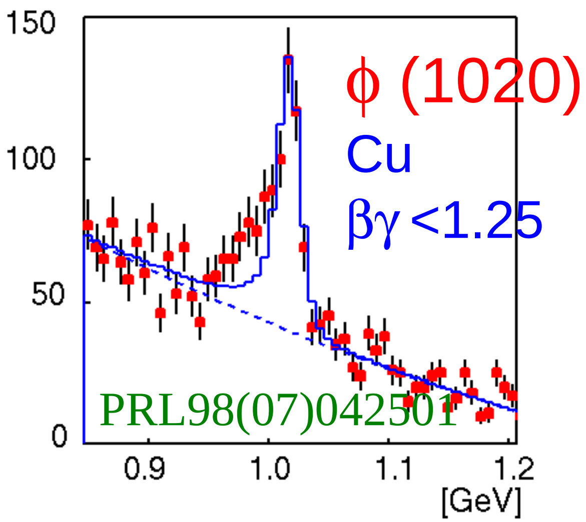


Nuclear matter size dependence & *Momentum dependence*
of mass modification are measured

J-PARC E16 experiment

- confirm the E325 results, and provide new information
  - check the interpretation model : explain the data for many nuclei, many velocity bins.
  - momentum dependence is compared with the QCD prediction.
  - 'mass shift' of ϕ is connected to the s-quark condensate in finite-density medium.

Precedent exp.(KEK-PS E325)



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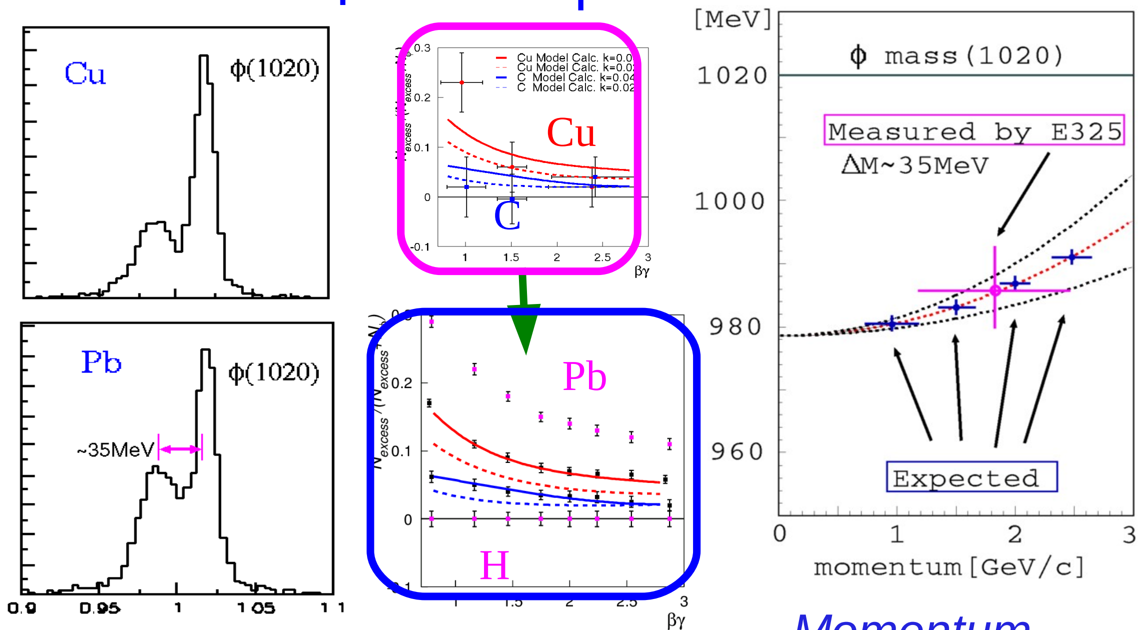
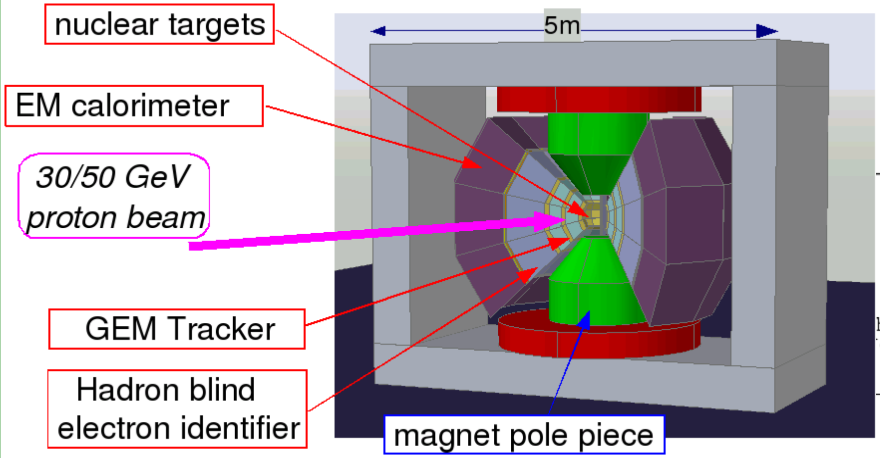


Nuclear matter size dependence & *Momentum dependence*
of mass modification are measured

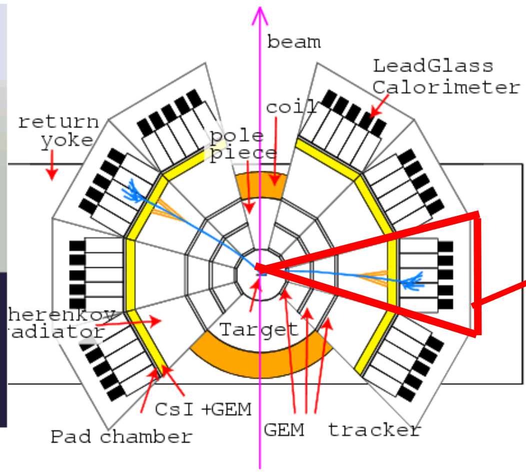
To collect high statistics

- For the statistics 100 times as large as E325, a new spectrometer and a primary beam in the High-p line are required.
  - 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)
  - to cope with the high rate, new detectors (GEM Tracker & HBD) are required.

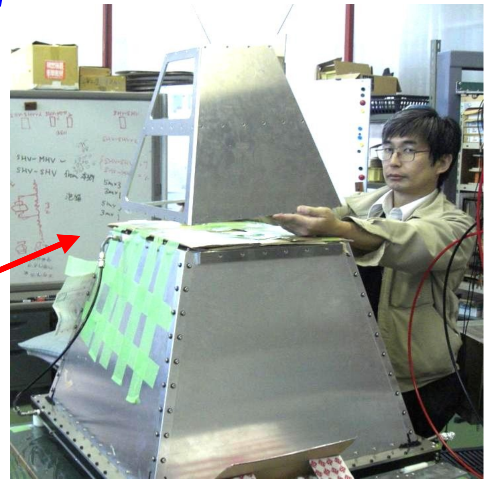
Proposed Spectrometer



Plan View

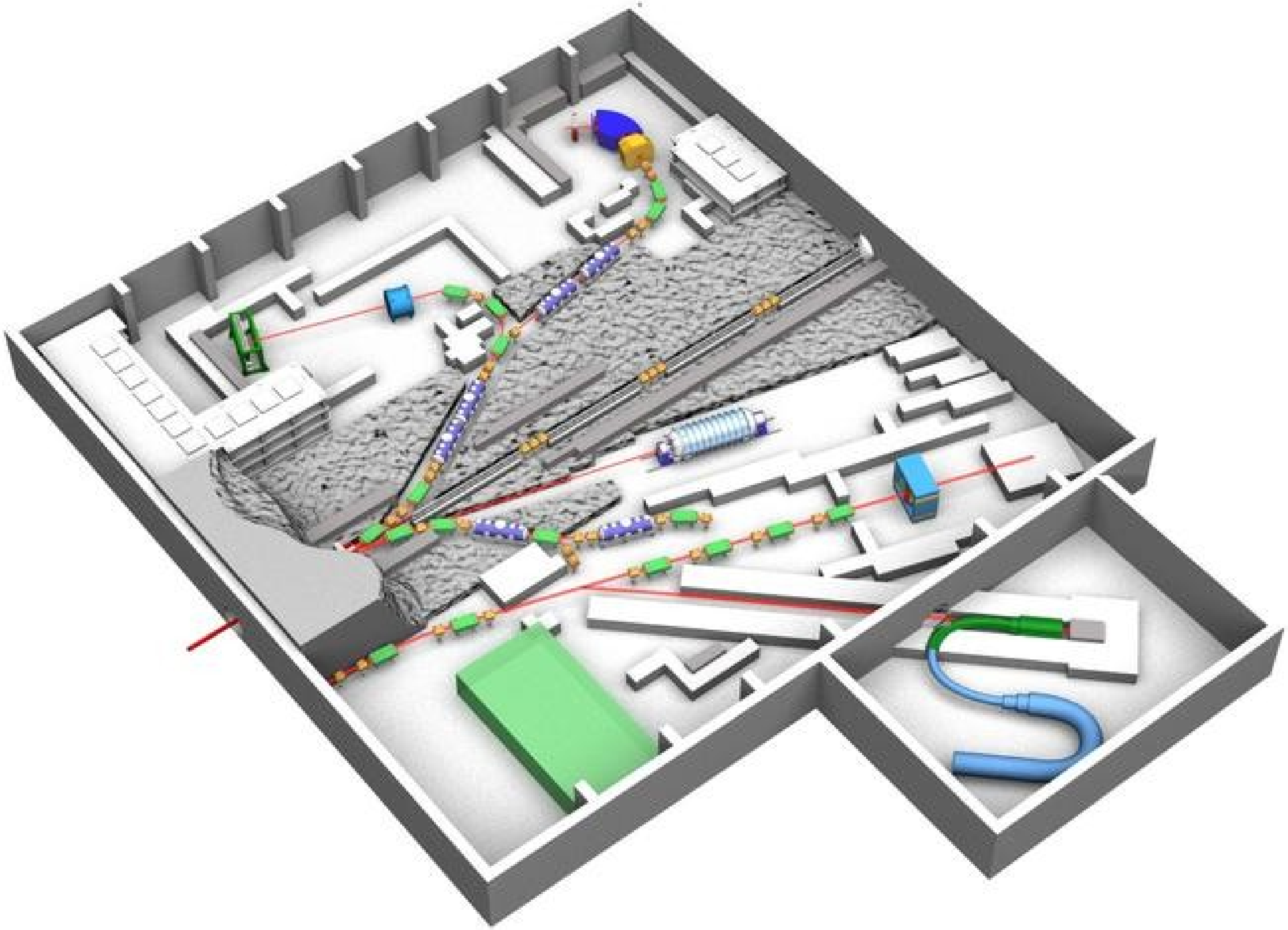


Prototype Module

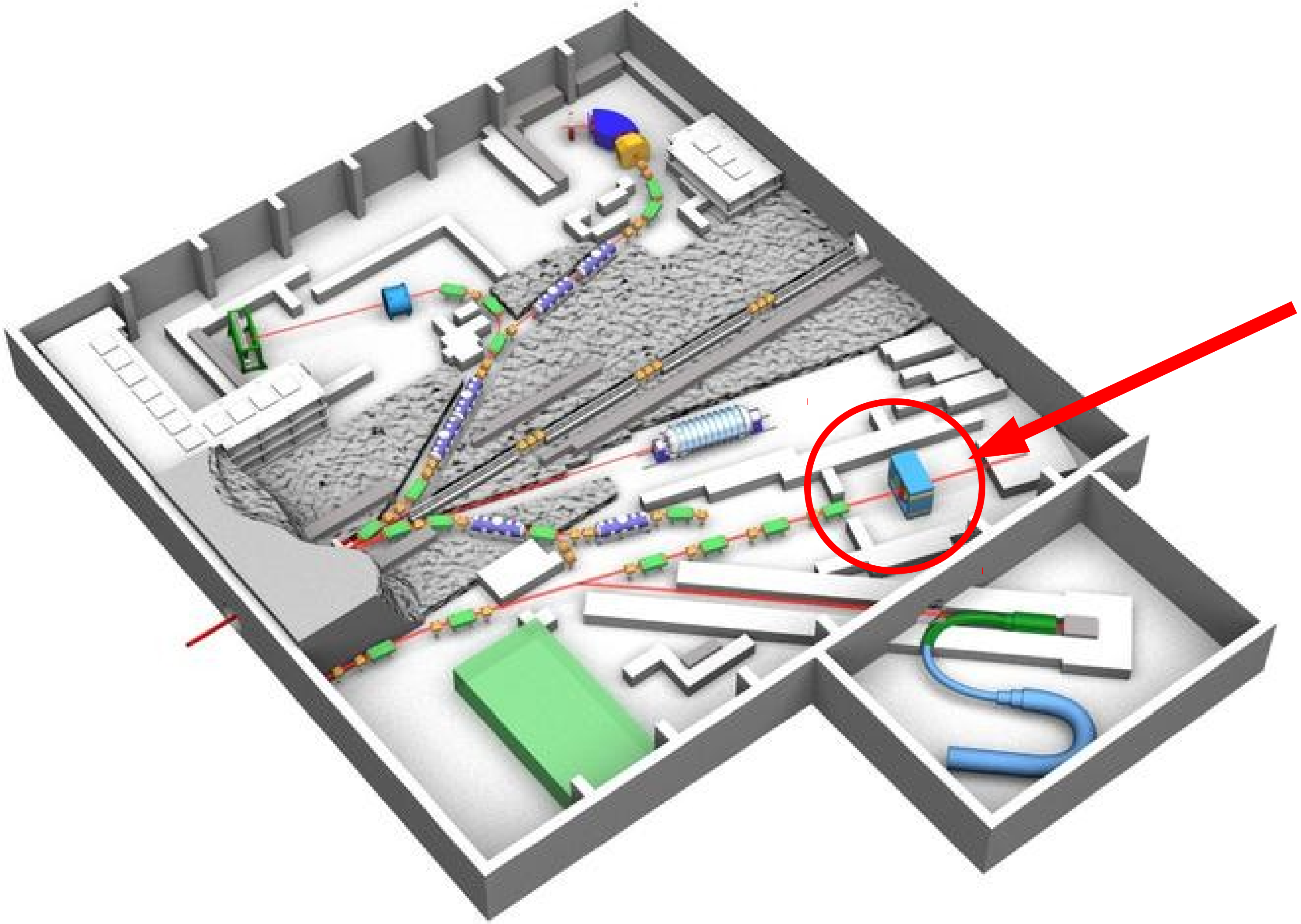


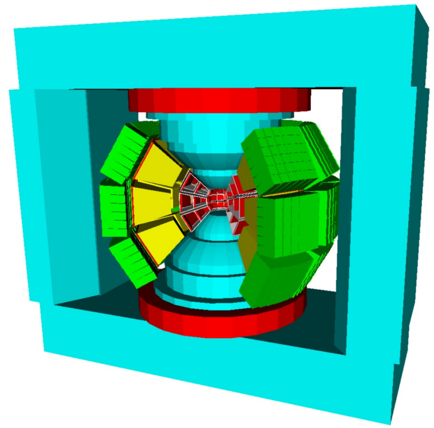
26 detector modules

High-p line in the Hadron hall

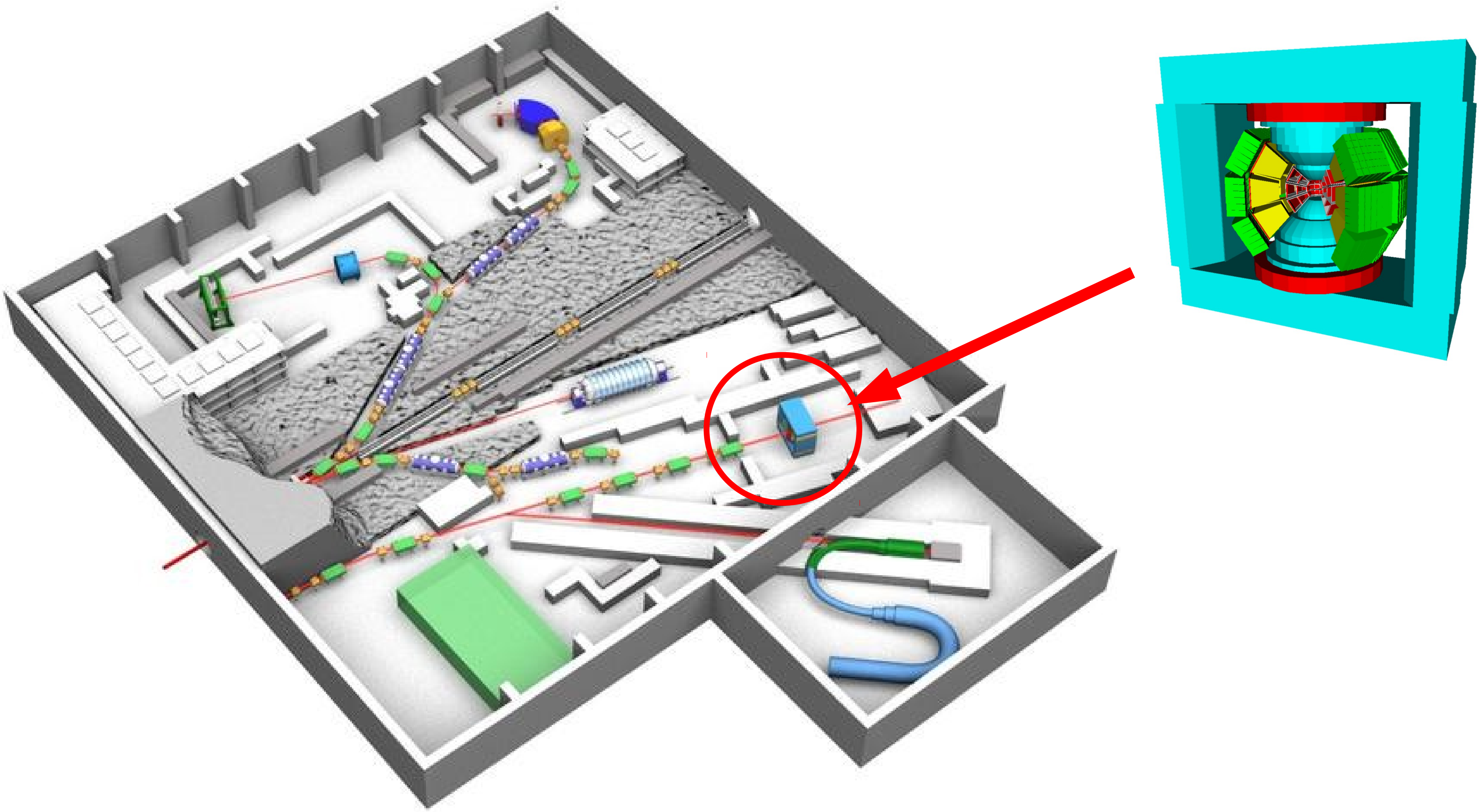


High-p line in the Hadron hall





High-p line in the Hadron hall

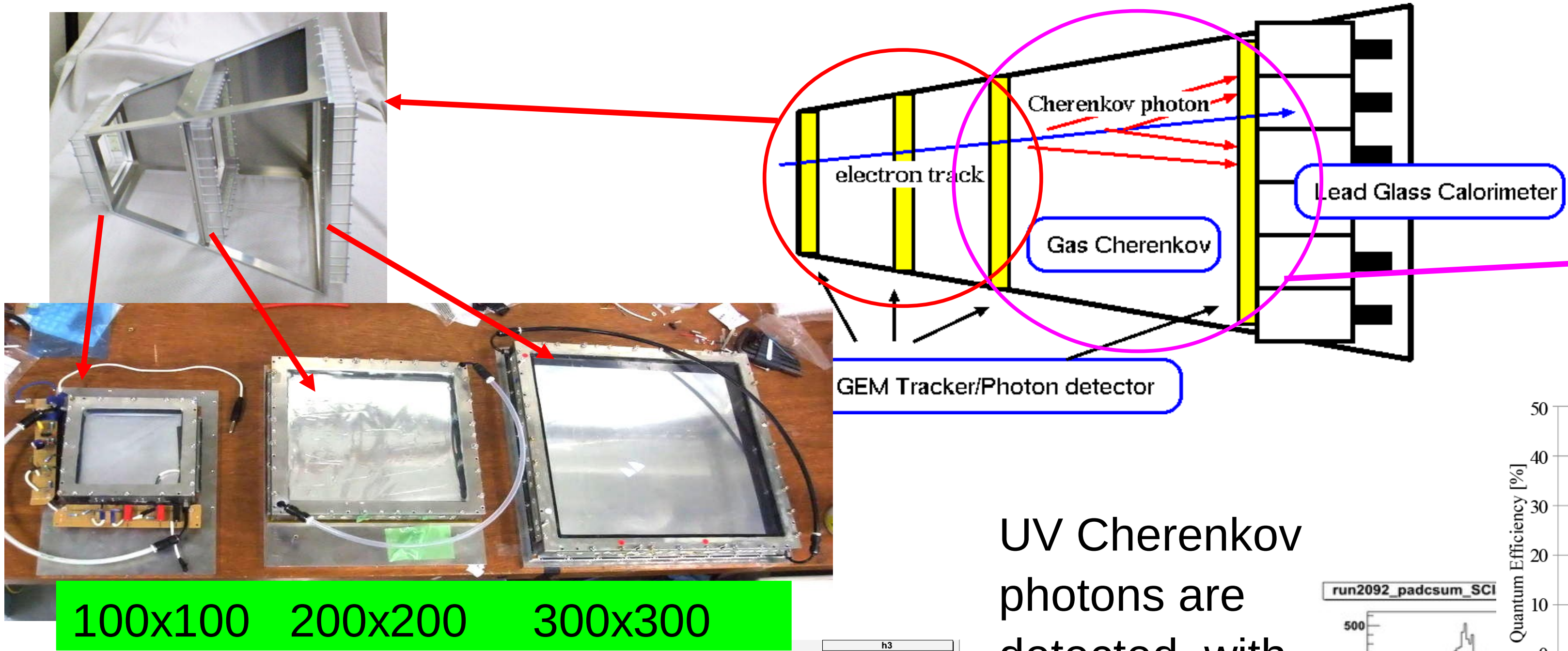


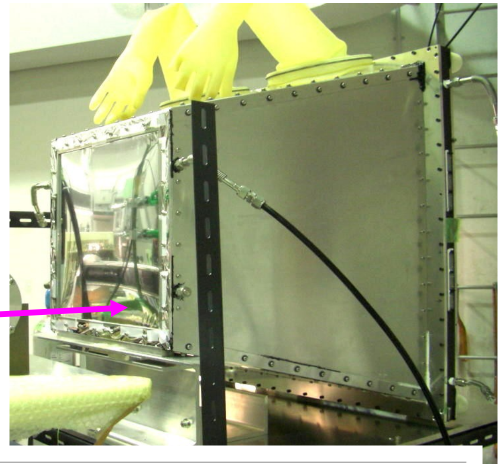
- budget requested by KEK to MEXT : finally funded
  - thanks to KEK staffs

Beam test results of prototype detectors (2012)

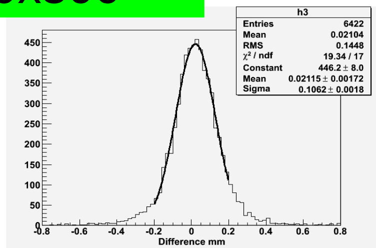
GEM Tracker

HBD (Hadron-Blind Cherenkov detector)

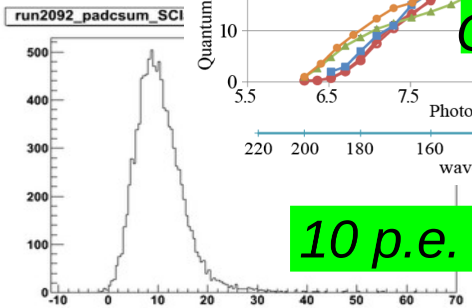


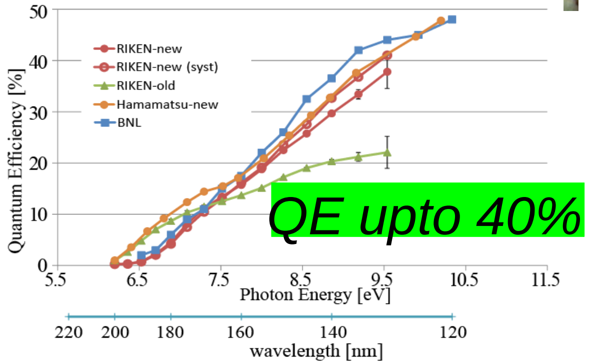


Required position resolution (~100µm) is achieved



UV Cherenkov photons are detected with CsI-evaporated LCP-GEM and CF_4 gas



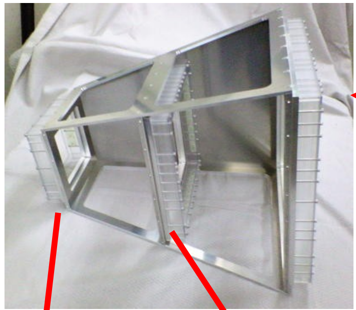


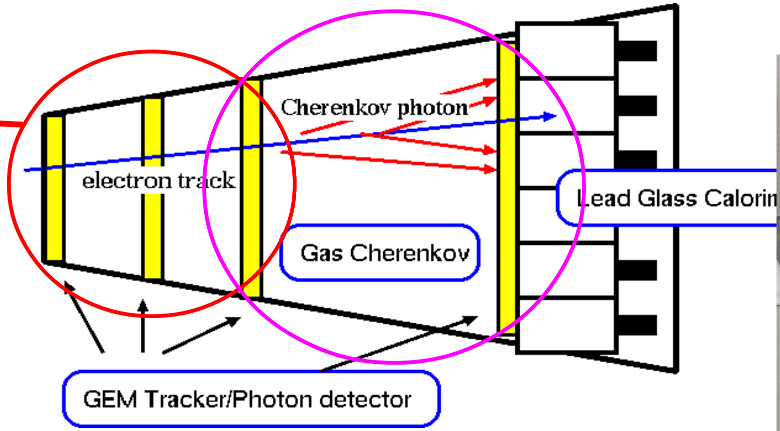
- Large size (300x300mm) PI- and LCP-GEM are successfully worked for a electron beam
  - Stability and response for a pion beam should be checked at J-PARC.
- GEM Tracker is successfully worked.
- Improvement of the photo-detection efficiency of HBD is on going.

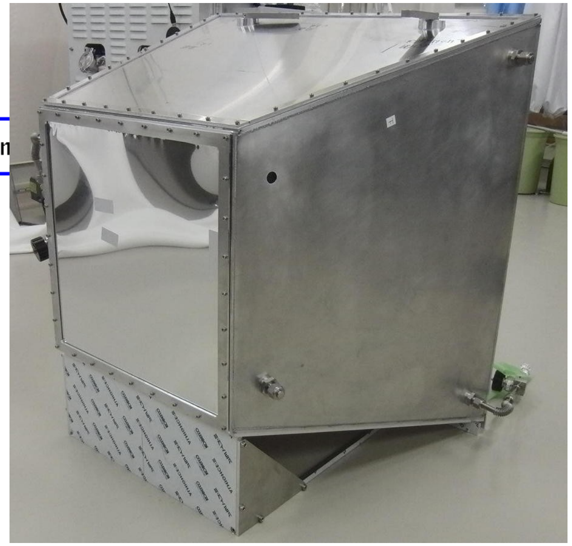
prototype to mass-production type

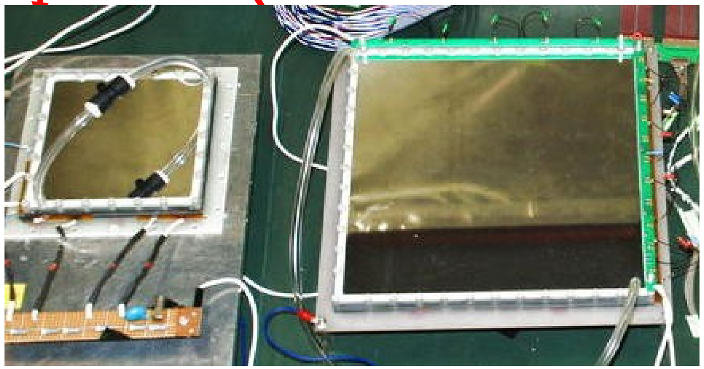
GEM Tracker

HBD (Hadron-Blind Cherenkov detector)









- Large size (300x300mm) PI- and LCP-GEM are successfully worked for a electron beam
  - Stability for a pion beam is proved for the PI (50um) triple stack but LCP(100um) double stack
- GEM Tracker is successfully worked with a new preamp board.
- HBD optimization (gap size, pad size...) improves the pion-rejection factor.

Progress since 2012/1 (PAC-13)

- R/O electronics (Takahashi, Nakai, Kawama, Morino)
  - 1st version of preamp board for GEM detectors are tested w/ beam.
  - trigger modules from Belle-II (UT3, FTSW) test are on-going.
  - LG-FEM prototype is delivered.
  - SRS modules for GEM readout are proved to have enough performance for the data transfer.
- LG (Aramaki, Sekimoto)
  - All LGs are decomposed.
  - A few samples are tested with beam successfully.
- Spectrometer Magnet (Muto, Ozawa)
  - Additional parts (yokes,poles and a coil) are delivered.
  - Pit is dug in the High-p experimental area, where the magnet should be located.

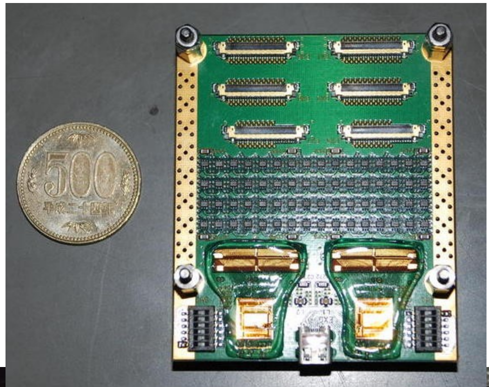
Progress since 2012/1 (PAC-13)

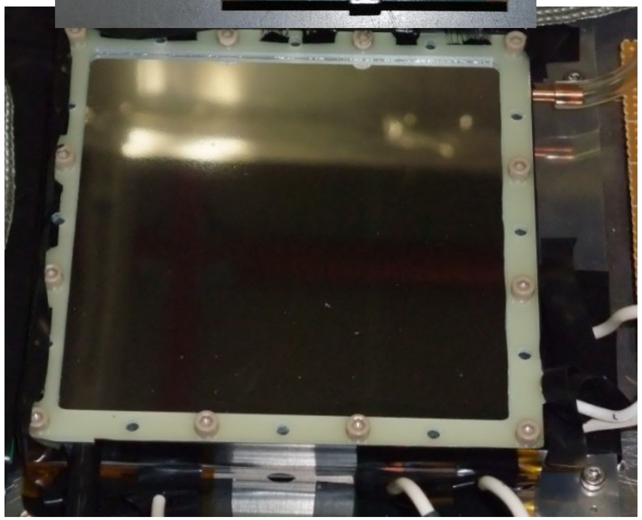
- HBD (Aoki, Kanno)
  - improvement of # p.e. and measurement of the pion rejection factor
  - use the PI-GEM triple stack instead of LCP double stack
  - new configuration of GEMs and R/O pads are tested.
- GEM Tracker
  - 1st mass-production type of 100mm is successfully tested w/ beam
  - trigger signal from the 3rd foil / ASIC is designed (Obara)
  - 1st version of the support frame is delivered (Shibukawa)
  - mass-production type of 200mm and 300mm are tested in Lab. (Komatsu)
- GEM operation in the high-background environment (Kawama, Kanno)
  - The 300mm PI-GEM triple stack with CF4 is operated without any breakdown in 15 hours in the AVF cyclotron room at RIKEN. Observed rate of the background neutron (and gamma-ray) are 100-1000 times as large as that expected in the High-p experimental area.

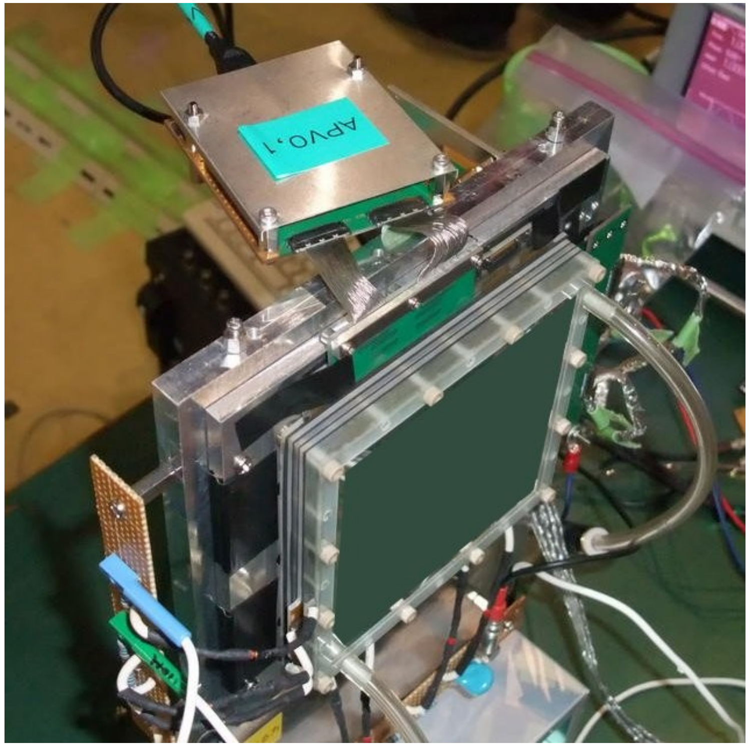
GEM Tracker

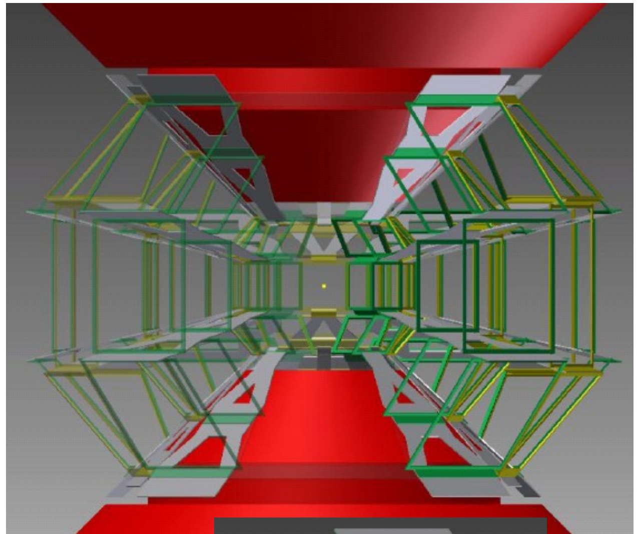
- 1st production type (100x100mm)
  - beam test at LEPS (2011) & J-PARC(2012)
  - trigger signal from the 3rd GEM foil
  - preamp board 1st version is used in the test

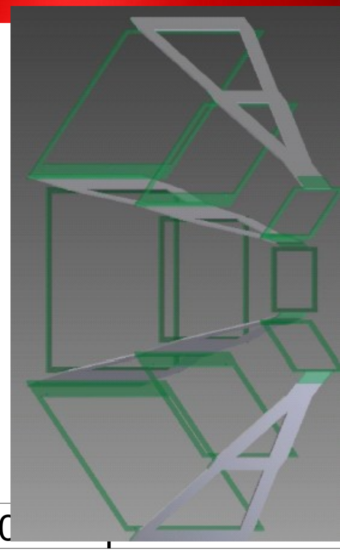
- Support frame made by CFRP
  - prototype is delivered in Mar.





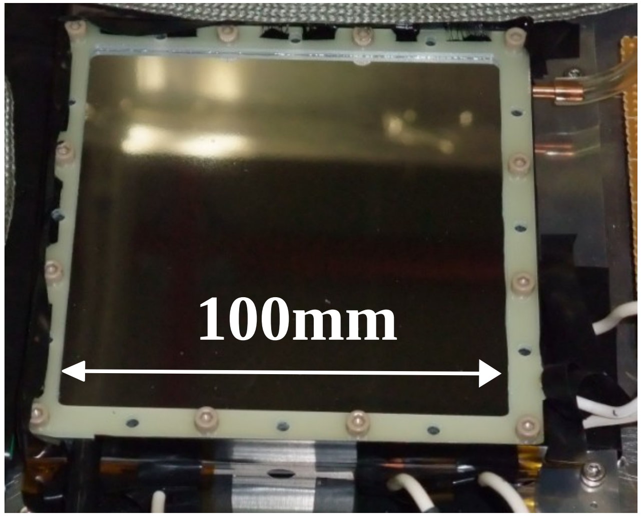


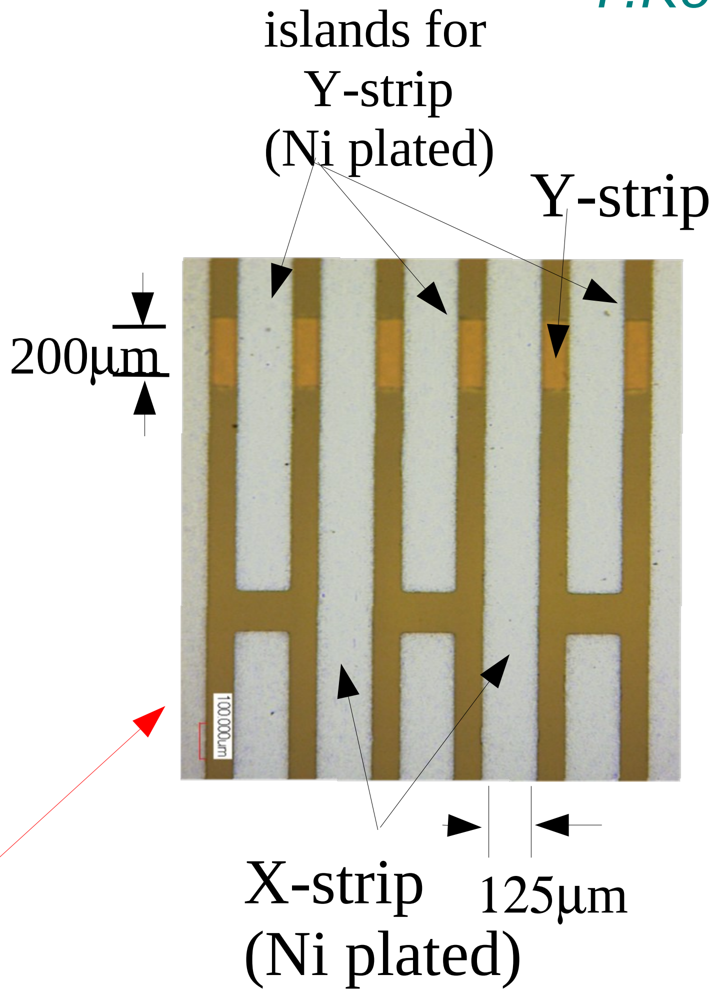


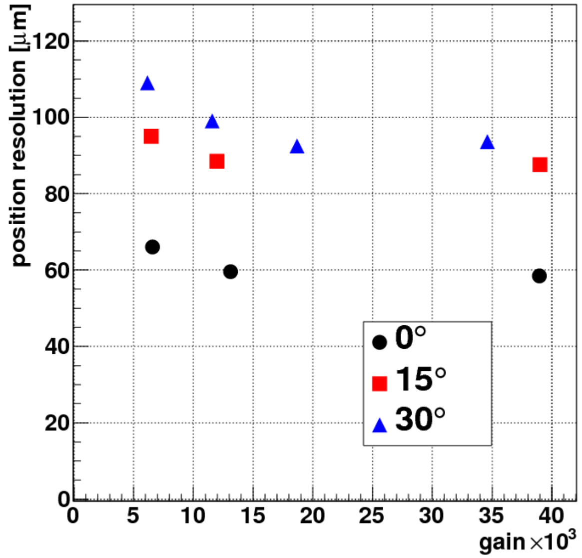


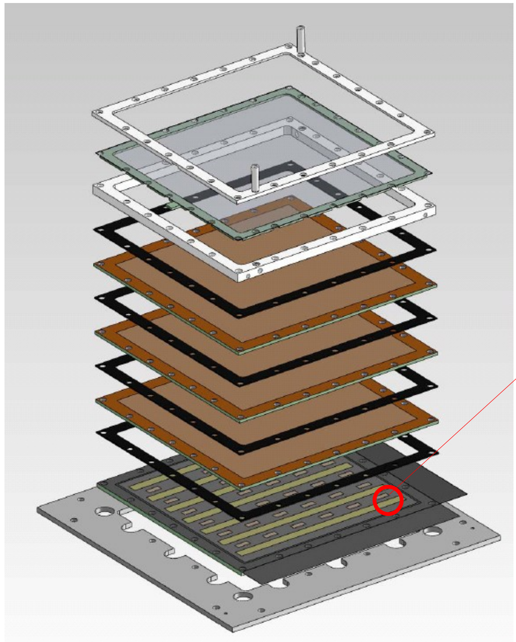
GEM Tracker : first prod. type is tested

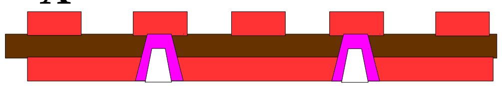
Y.Komatsu, to appear in NIM A



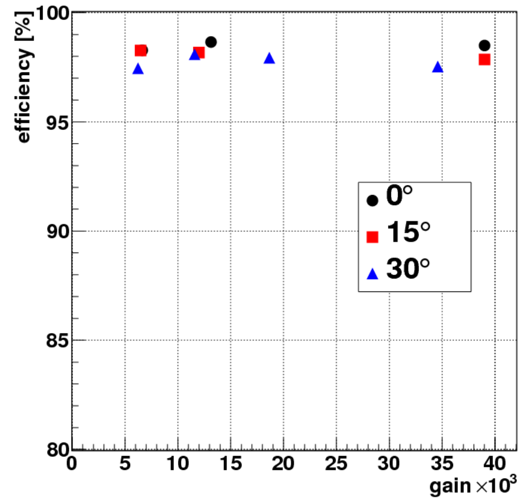








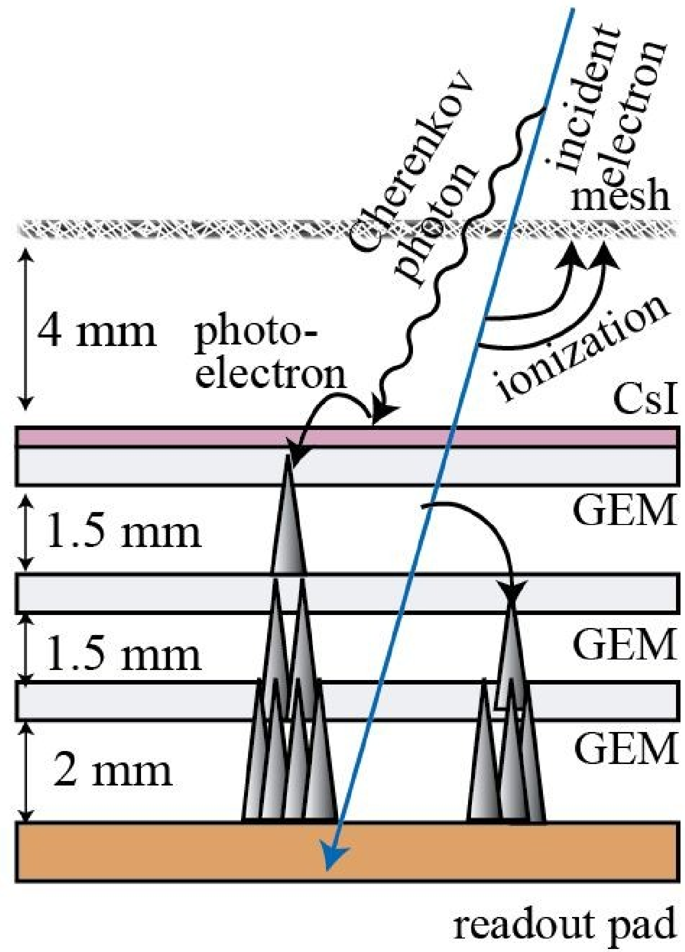
BVH type 2D R/O PCB



HBD (Hadron Blind Detector)

- Threshold type Gas Cherenkov, using CF_4
  - developed thanks to Weizmann/Stony Brook
  - Ionized electrons are collected by mesh
    - photoelectrons are amplified by 3 stages
    - ionized electrons are amp. by only last 2 stages

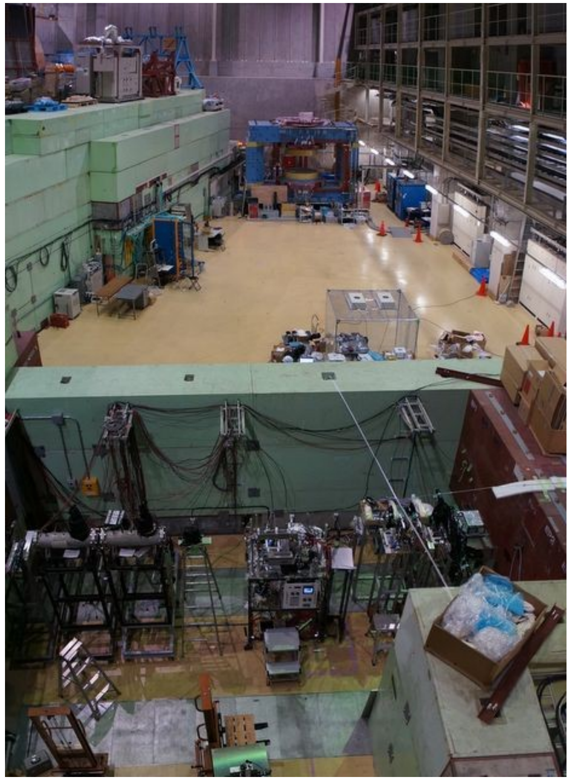
      → can detect only particles with cherenkov photons.
    - (1/100 of pion rejection)
  - GEM : LCP t=100um double stack
  - CsI evaporation by Hamamatsu & RIKEN
  - QE improved at RIKEN
    - 10 photoelectrons detected (cf. PHENIX ~20 p.e.) as of 2011
- Test @ J-PARC in 2012: w/ pion beam
  - pion rejection factor measured for the first time
  - stability for the hadron-beam environment



managed by K. Aoki & K.Kanno

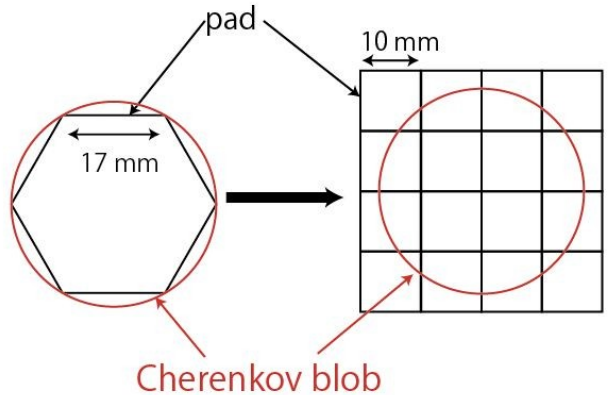
HBD (Hadron Blind Detector)

- Test @ J-PARC K1.1BR in 2012/Jun (T43)
  - #p.e. improvement : 10 → 13
    - QE , gas purity and HV config. optimization
    - however, still less than that of PHENIX (20 p.e.)
  - 300mm LCP-GEM double stack was unstable in the hadron beam environment : breakdown in an hour



- Test @ J-PARC K1.1BR in 2013/Jan (T47)
  - 100mm/50mm PI-GEM triple stack were stable, even for CF_4
  - pion rejection is improved with a higher gain of new PI-GEM and smaller-size readout pad
    - measure the distributed charge

  → pion rejection factor 100 with e-efficiency 70% achieved, same level as PHENIX, in spite of the less #p.e.



- Test using 300mm PI-GEM in 2013/June: canceled
  - stability is checked at RIKEN

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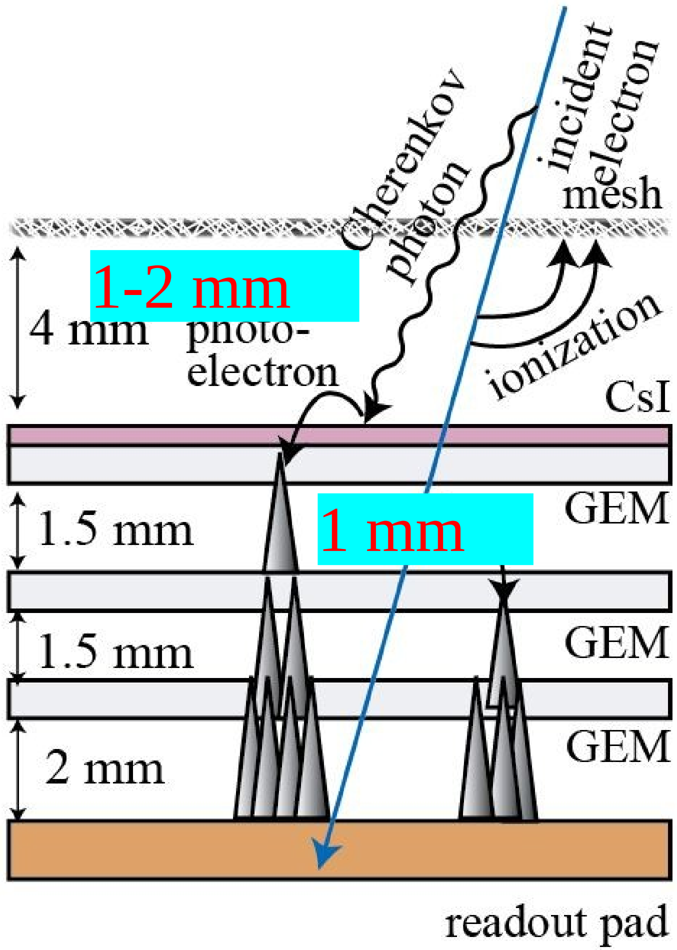
HBD : New configuration

- gap length, gain, pad size...
  - PI-GEM (t=50um), triple stack
  - drift gap : 4mm to 1-2mm
  - 1st gap : 1.5 mm to 1 mm : to reduce the ionization by pion
  - 1st gap gain : 20 to 40 : to enhance the p.e. signal
  - readout pad size : a=16mm → 10mm
  - then we can expect
    - pion rejection 40 or more at 80% electron efficiency at online
    - pion rejection 400 or more at 70% electron efficiency at offline.



- required performance is almost achieved
  - move to mass-production in this year

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Schedule

- 2007: stage1 approval
- 2008-2011 : detector R&D
- JFY2012 :
  - Test exp (T43/T47) at J-PARC
    - GEM stabilty and HBD response for pion beam
    - GEM R/O electronics
- 2013 Jan : High-p construction budget is approved
- 2013 Sep : start the mass production (GEM, tracker R/O board, etc.)
- In the Hadron hall schedule table, we are assigned
  - 2014 Nov-2015 Jan : magnet reconstruction
  - 2015 Feb-Aug : detector installation in the magnet
  - 2016 Jan-Mar : detector commissioning w/ beam
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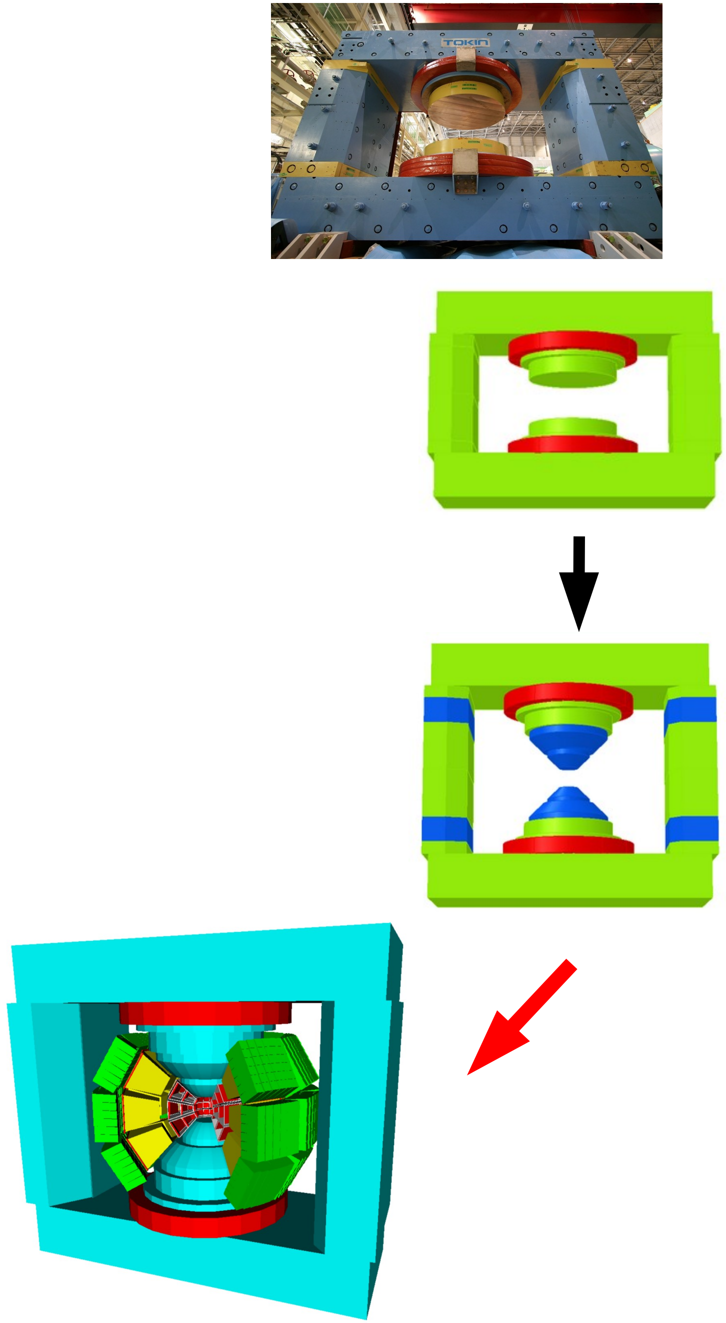

Summary

- Investigation of the hadron spectral modification in the nuclear matter is a study of the nature of QCD vacuum and its excitation.
  - major origin of hadron mass is the spontaneous breaking of chiral symmetry and the spectral modification could be a signal of the chiral restoration.
  - Spectral modification of hadrons is observed in the hot (HI collisions) and dense (nuclei) matter in the dilepton invariant mass spectra.
  - modification of narrow resonances are only observed by KEK-PS E325.
  - discussion is not converged : chiral restoration or not
- J-PARC E16 will measure the vector meson modification in nuclei with the ee decay channel, using 30GeV primary proton beam.
  - confirm the observation by E325 and provide more precise information of the mass modification to clarify the chiral symmetry in the finite density matter.
  - preparation is underway with the Grant-in-Aid on Innovative Areas ("New hadrons") . Detector mass-production is just started.
  - Staged Goal of construction : 8 modules out of 26, by Jan 2016.
  - TDR will be prepared by the next PAC to obtain the stage-2 approval.

Backup slides...

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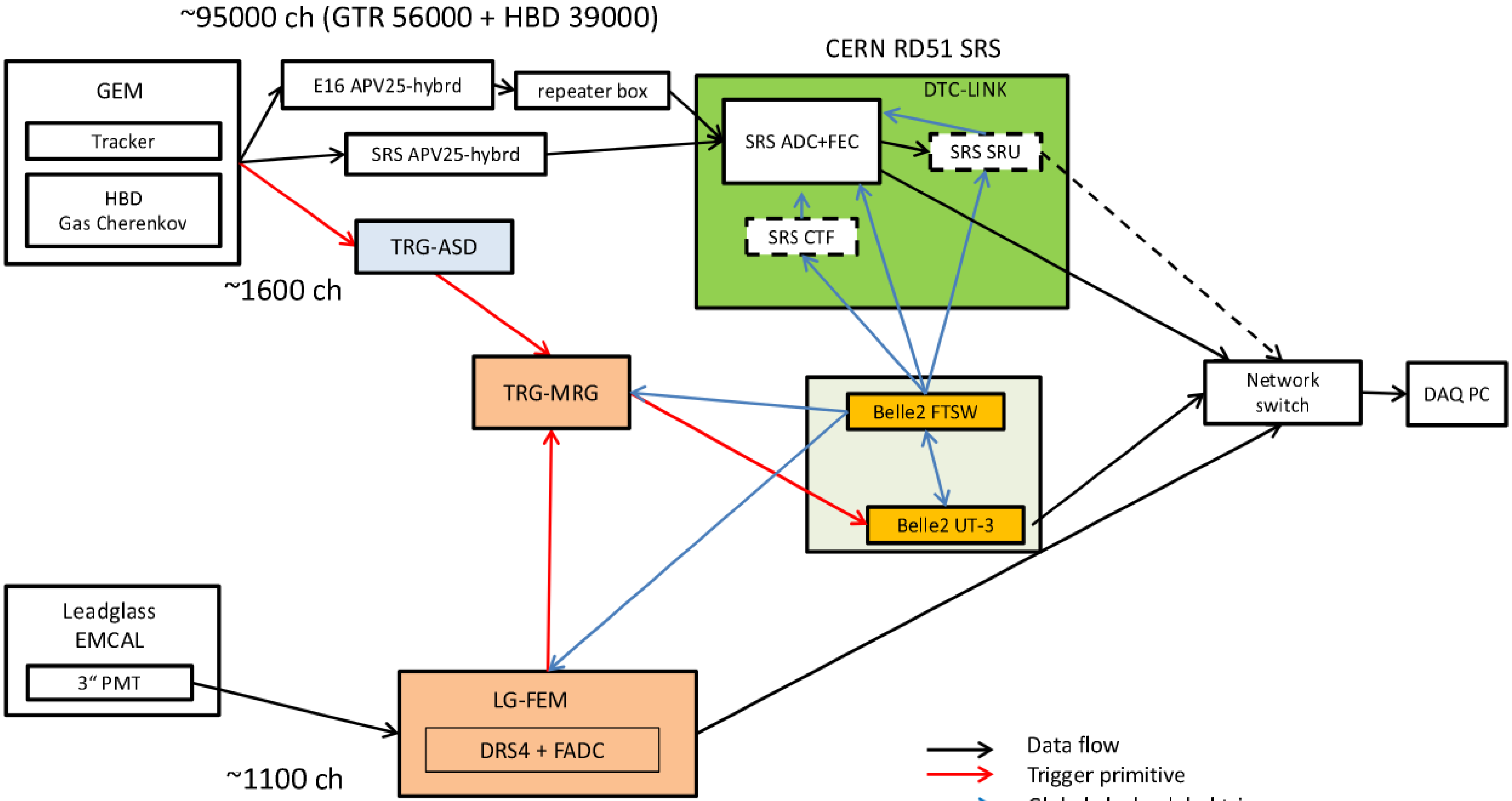
Readout electronics

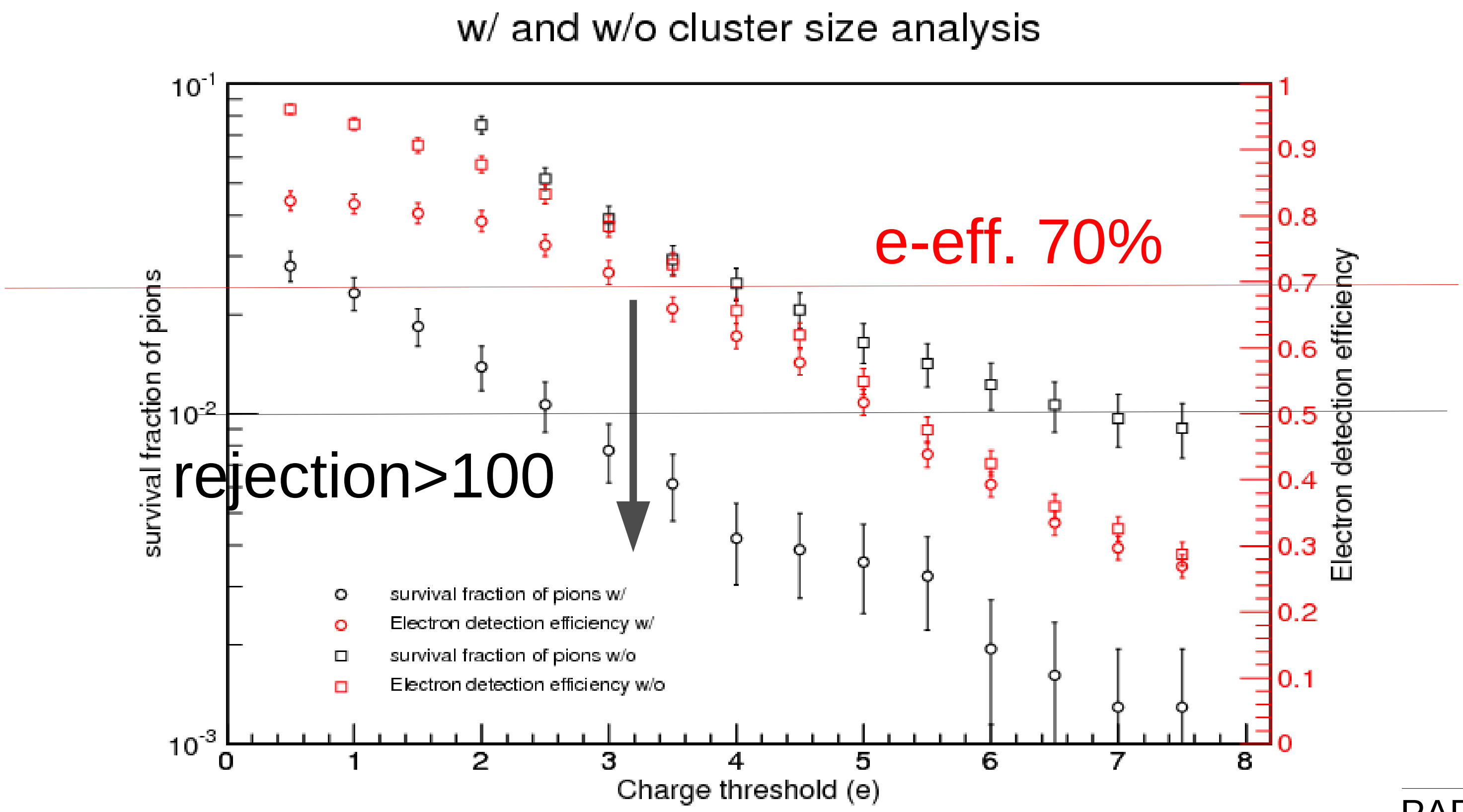


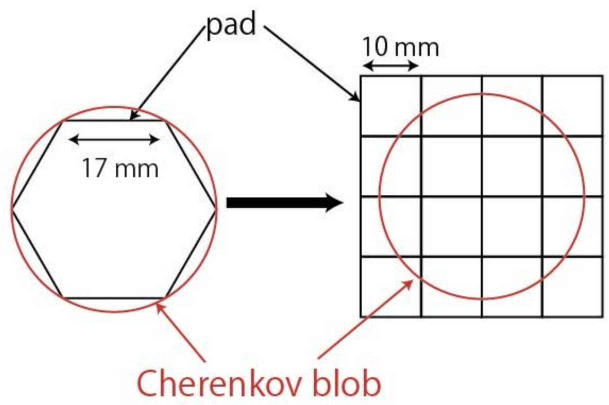
- APV25 chip and SRS are used for GEM readout
  - collaborating with CERN RD51

HBD (Hadron Blind Detector)

- Test @ J-PARC K1.1BR in 2013/Jan (T47)
  - pion rejection is improved with a higher gain of new PI-GEM and smaller-size readout pad
    - measure the distributed charge: selecting 3 fired pads or more

→ pion rejection factor 100 with e-efficiency 70% achieved, same level as PHENIX, in spite of the less #p.e.



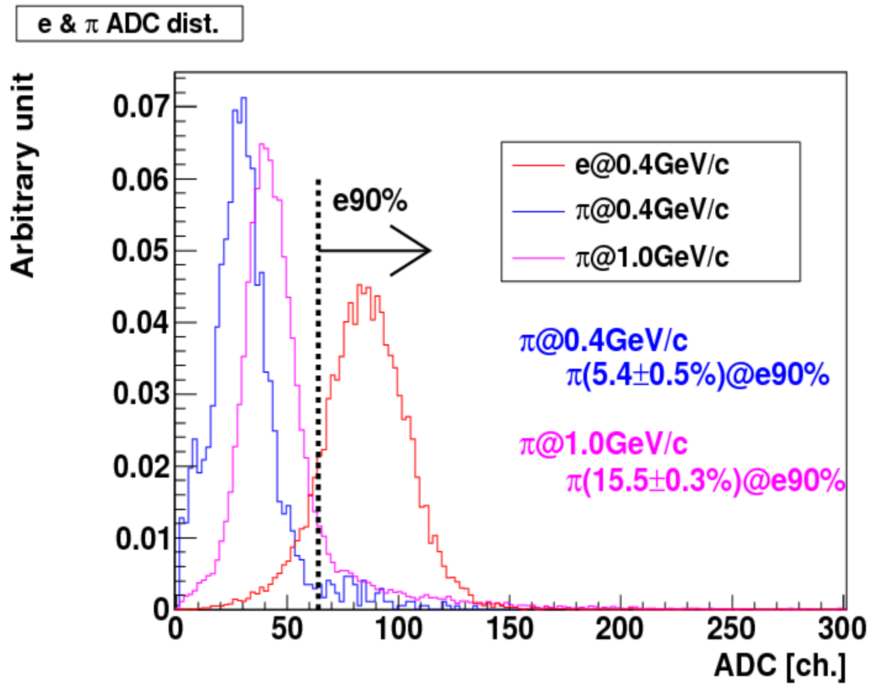


Lead Glass from TOPAZ / E362

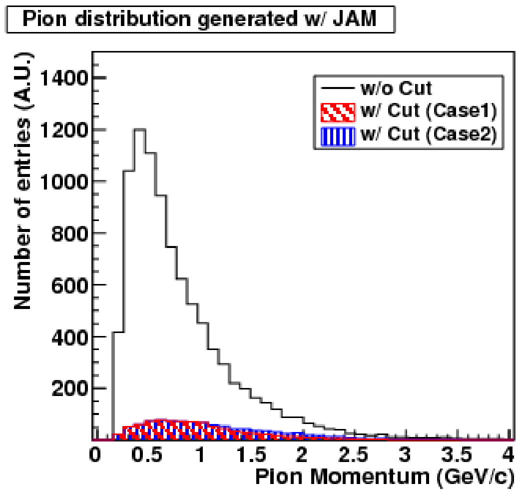
17 frames were decomposed
at KEK warehouse

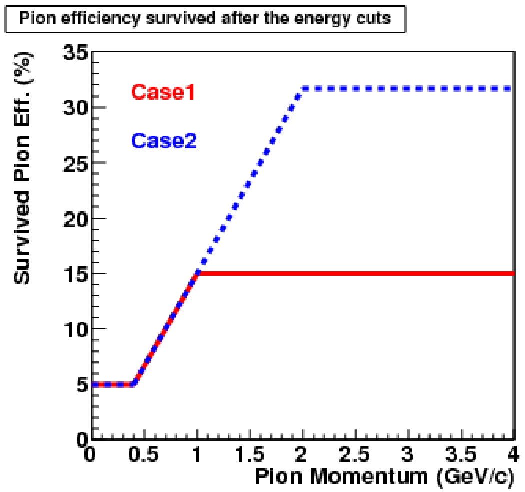
by Y. Aramaki & S. Sekimoto

Lead Glass



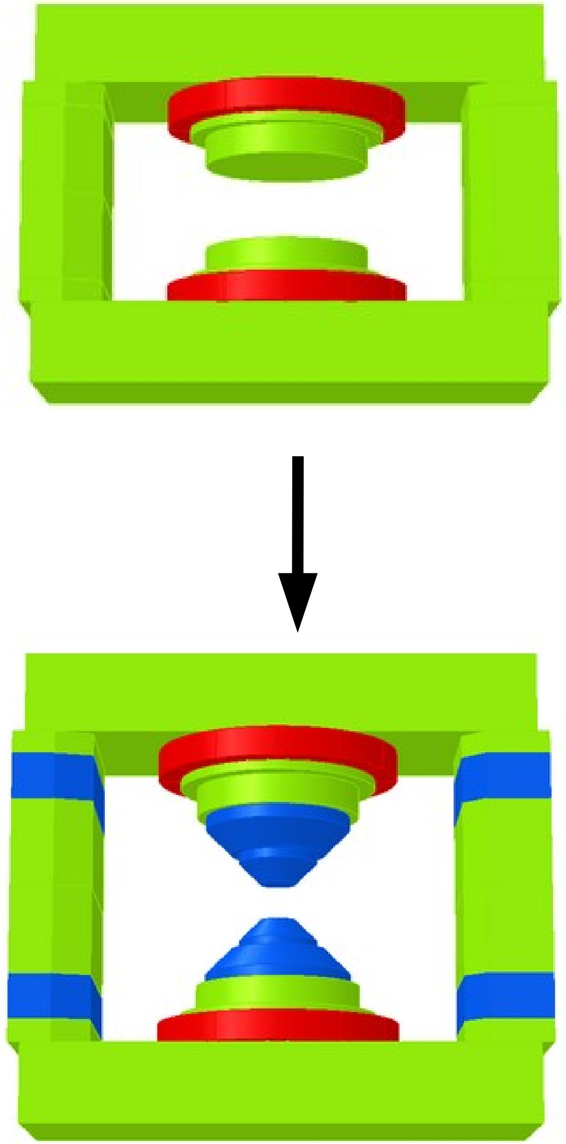
- Online
  - pion suppression down to 10% w/ the trigger threshold which keeps 90% of electron efficiency at 0.4GeV/c
- Offline
  - pion suppresion down to 5% (2%) at 0.4(1.0) GeV/c w/ 90% electron efficiency

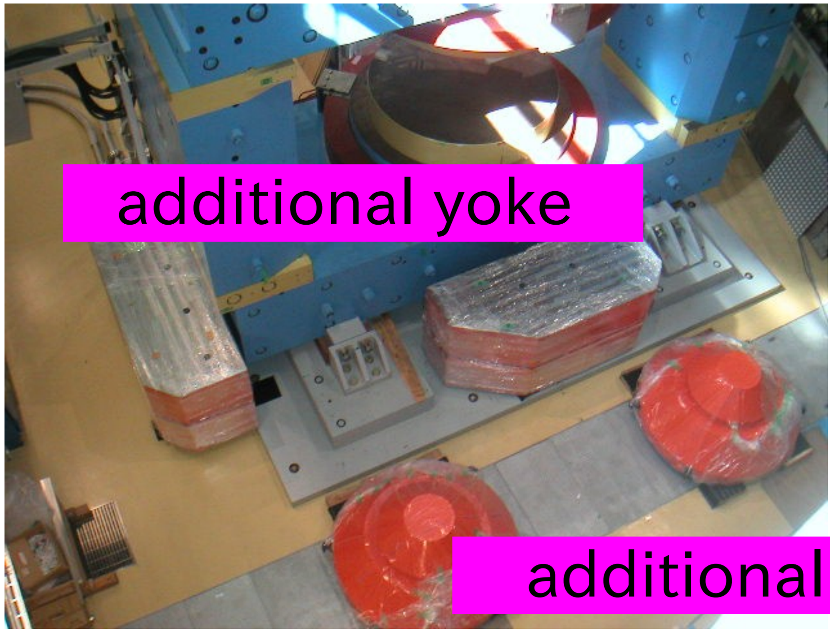




Spectrometer Magnet

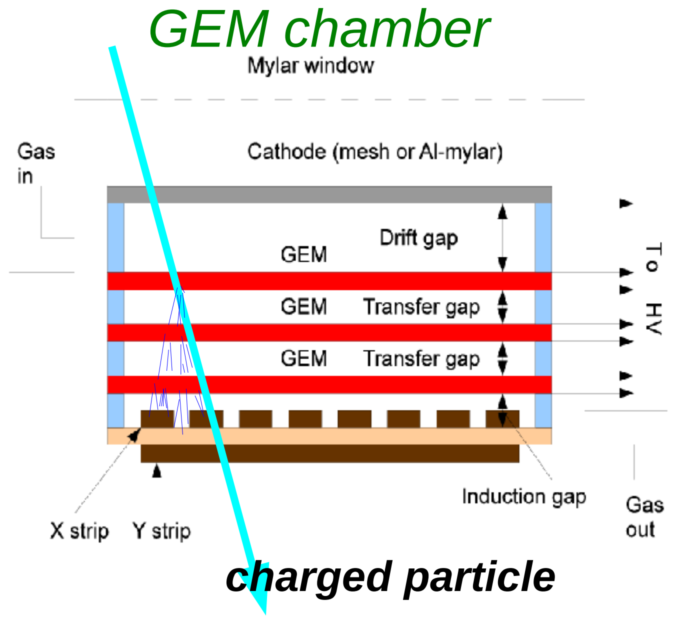
delivered in 2012
(managed by R. Muto)

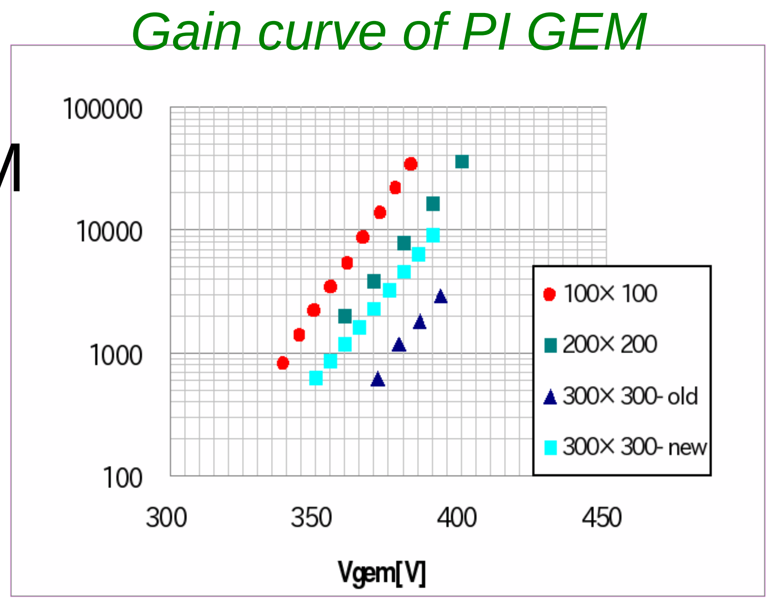


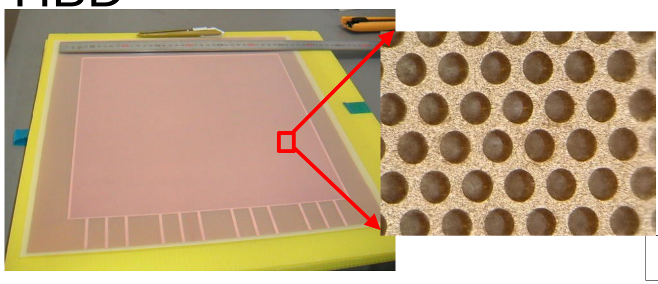


Detector R&D

- GEM Tracker to cope with the high rate
  - $Ar+CO_2$(70:30)
  - angled injection, 2D readout,etc.
  - required position resolution 100um is achieved for angled tracks w/ FADC R/O
- Hadron Blind Detector to trigger the electrons
  - CsI photocathode, CF_4 gas purity, etc.
  -
- Domestic Large size (300mmx300mm) GEM
  - kapton (Polyimide, PI) t=50um for GT
  - LCP , t=100 um for HBD







Spectrometer Magnet re-construction

- FM magnet (used by KEK-PS E325)
  - additional poles and yokes
    - larger acceptance/stronger field
  - decompose -> proper location on the High-p line
    -> re-construction with new parts
  - a pit (digging of the floor concrete) is required
    under the magnet
  - takes 6-8 months
    - scheduling of the area and overhead crane usage
  -