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TPC with GEM

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Contents:

1. Development of MSTPC for TRIAC
2. Development of Vertex Chamber for J-PARC
3. TPC with GEM for RIBF

Measurement of RNB reactions near Coulomb Barrier

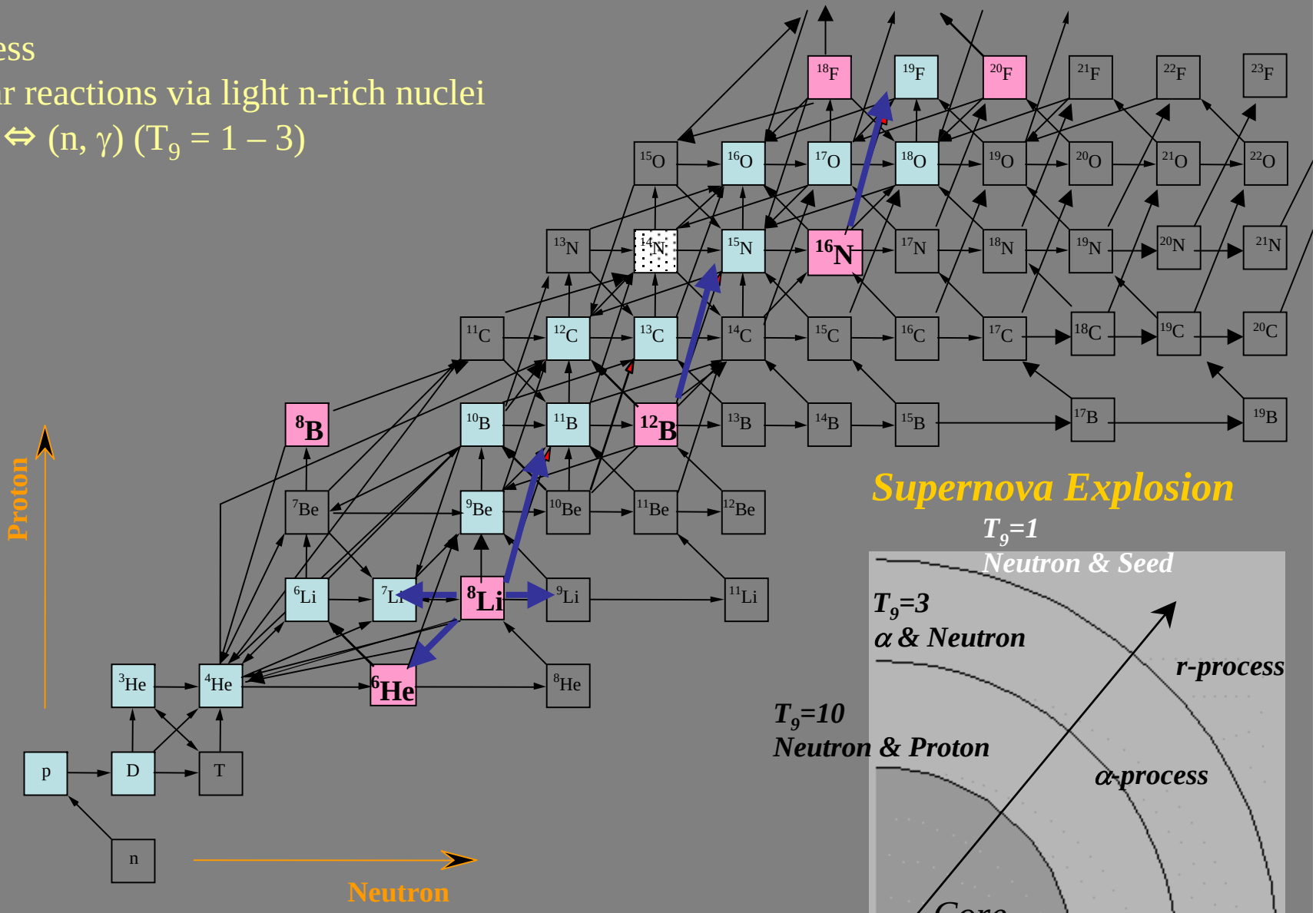
- Astrophysical Nuclear Reactions;
  (α,n), (p,n), (α,p), (p,α), etc
- Sub-barrier Fusion Reactions;
  Super-Heavy-Element Synthesis

Requirements;
Gas Target (He, CH_4, Ar, Xe, ...),
High-Efficient Detector System
(Limited-Intensity and Low-Energy RNB, Neutron Coincidence)

Development of MSTPC !

Cross-section measurements for astrophysical interest

r-process
Nuclear reactions via light n-rich nuclei
$(\alpha, n) \Leftrightarrow (n, \gamma)$ $(T_9 = 1 - 3)$

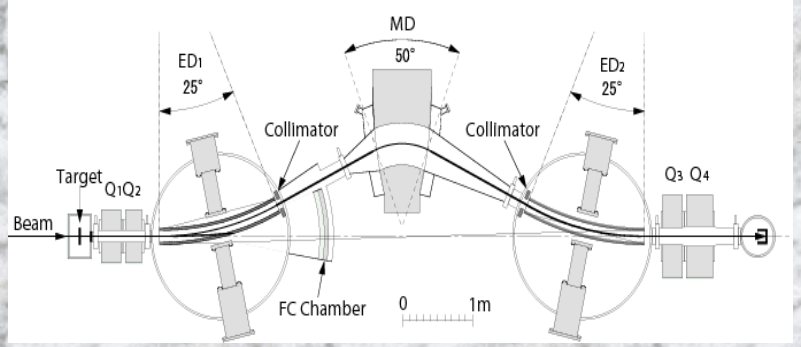


Radioactive Nuclear Beams

Recoil mass separator (RMS) as a in-flight RNB generator

^{8}Li, ^{12}B, ^{16}N(α, n) reactions

RNB	E [MeV]	Primary	Production	Intensity	Purity
^{6}He	10	^{7}Li	^{9}Be(^{7}Li, ^{6}He)	5.9×10^{3}	70%
^{8}Li	14.6	^{7}Li	^{9}Be(^{7}Li, ^{8}Li)	1.4×10^{4}	99%
^{8}B	16, 24	^{6}Li	^{3}He(^{6}Li, ^{8}B)	1.0×10^{4}	99%
^{12}B	24	^{11}B	d(^{11}B, ^{12}B) p	7.8×10^{3}	98%
^{16}N	32	^{18}O	d(^{18}O, ^{16}N)α	4.7×10^{3}	98%



primary beam ⇔ RNB velocity filter(Eρ + Bρ)

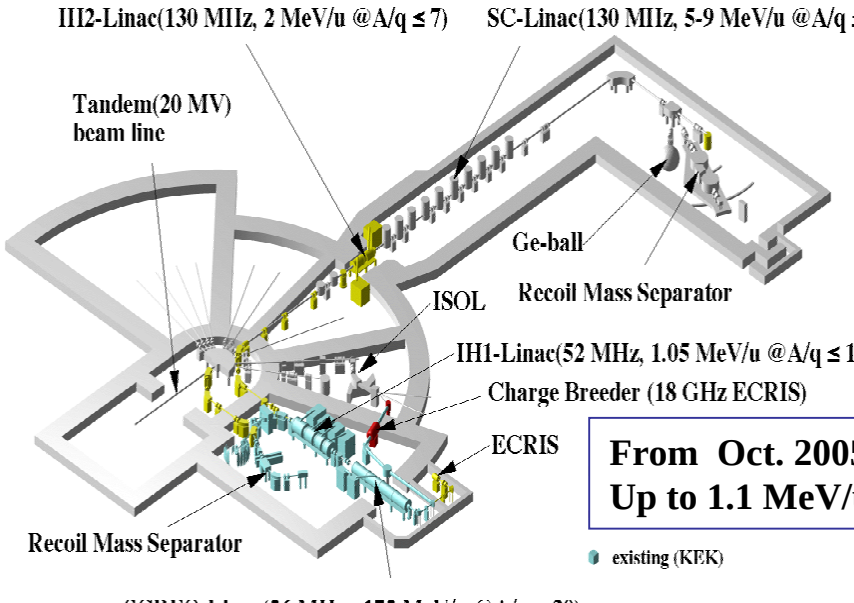
NIM A560(2006)366

Tokai Radioactive Ion Accelerator Complex (TRIAC) ISOL based RNB facility

^{8}Li(α, n) at Ecm < 1.0 MeV

^{8}Li : I ~ 10^{6} Hz, dE/E = 2%, purity = 100%

KEK-JAEA joint project



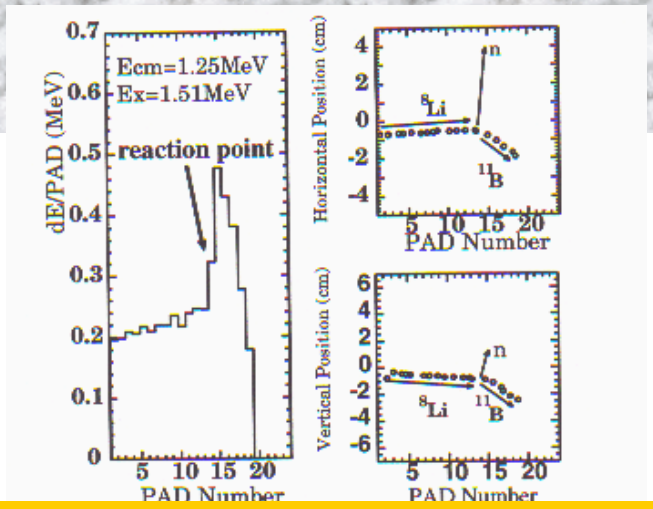
From Oct. 2005
Up to 1.1 MeV/u

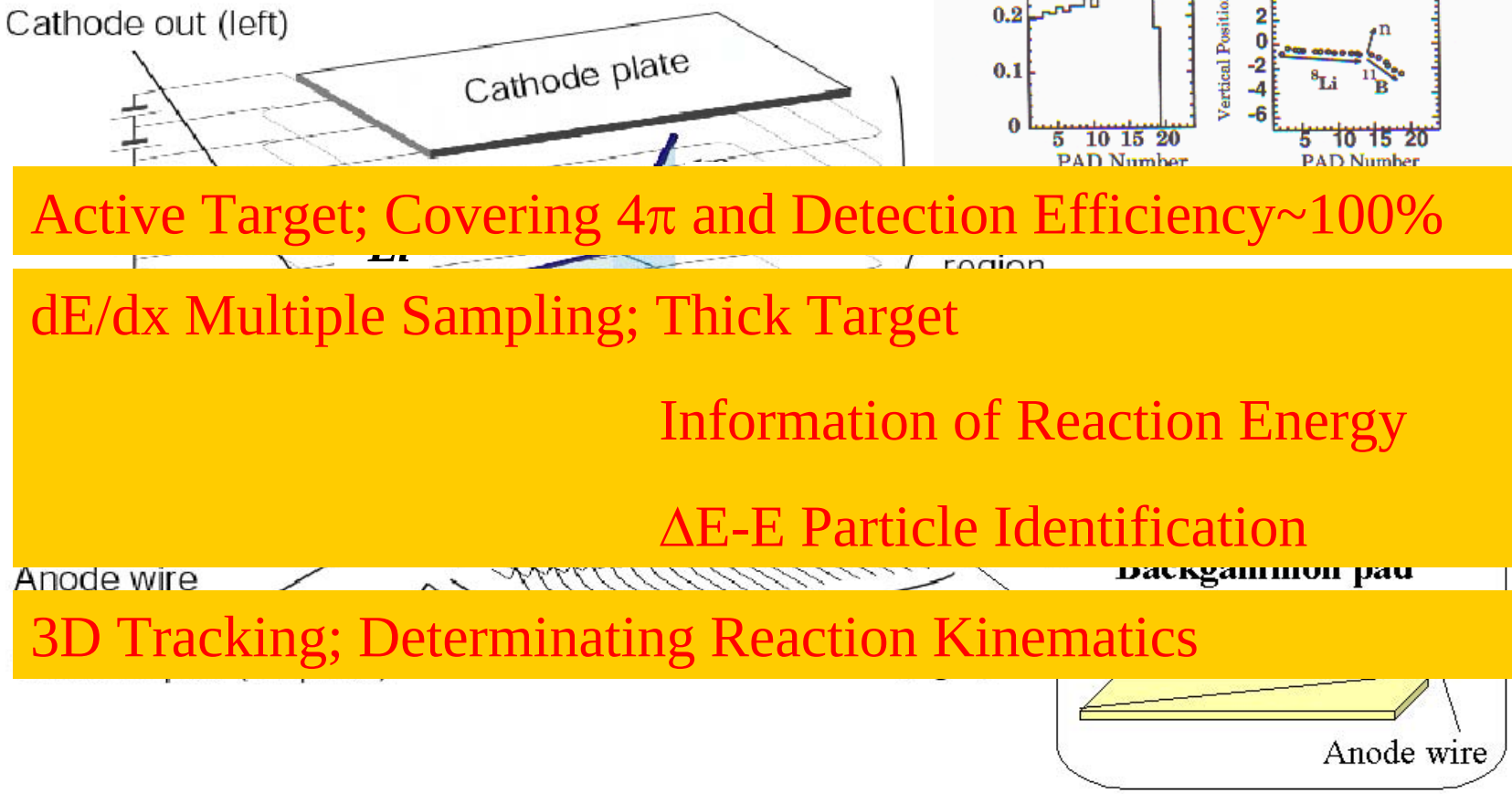
http://triac.kek.jp/

Multiple Sampling and Tracking Proportional Chamber
MSTPC

He gas + ^{8}Li beam

[Ex. He +CO_2(10%) @ 120 Torr]





Active Target; Covering 4π and Detection Efficiency~100%

dE/dx Multiple Sampling; Thick Target

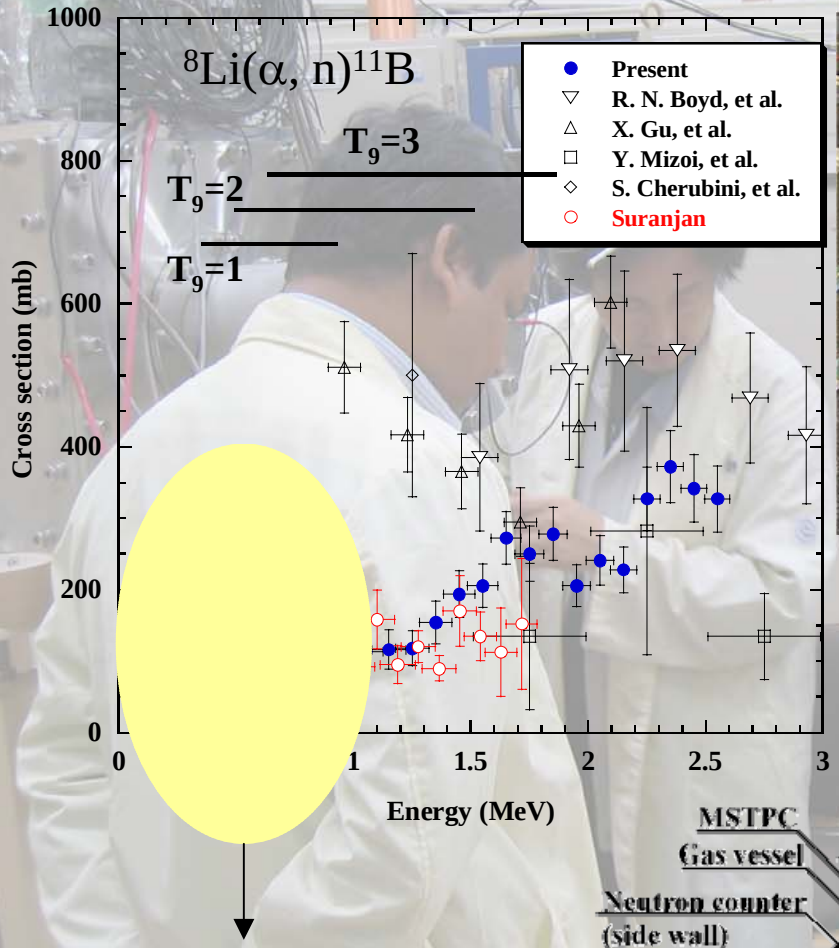
Information of Reaction Energy

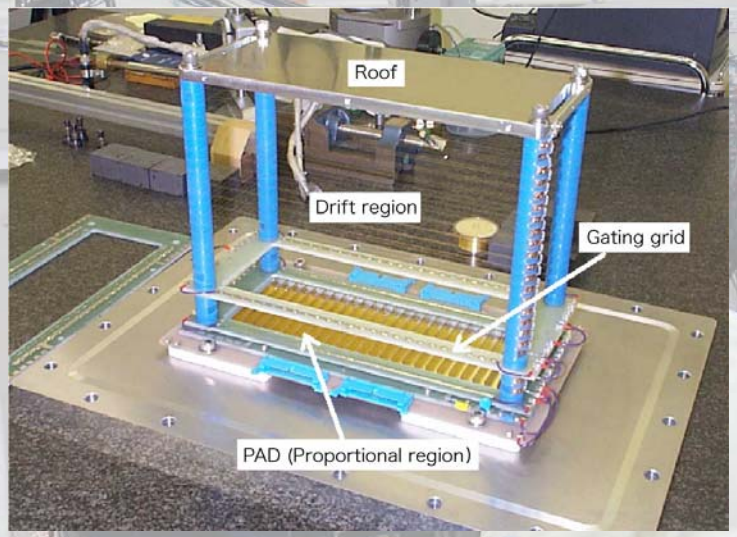
ΔE-E Particle Identification

3D Tracking; Determinating Reaction Kinematics

NIM A431(1999)112, NIM A556(2006)339

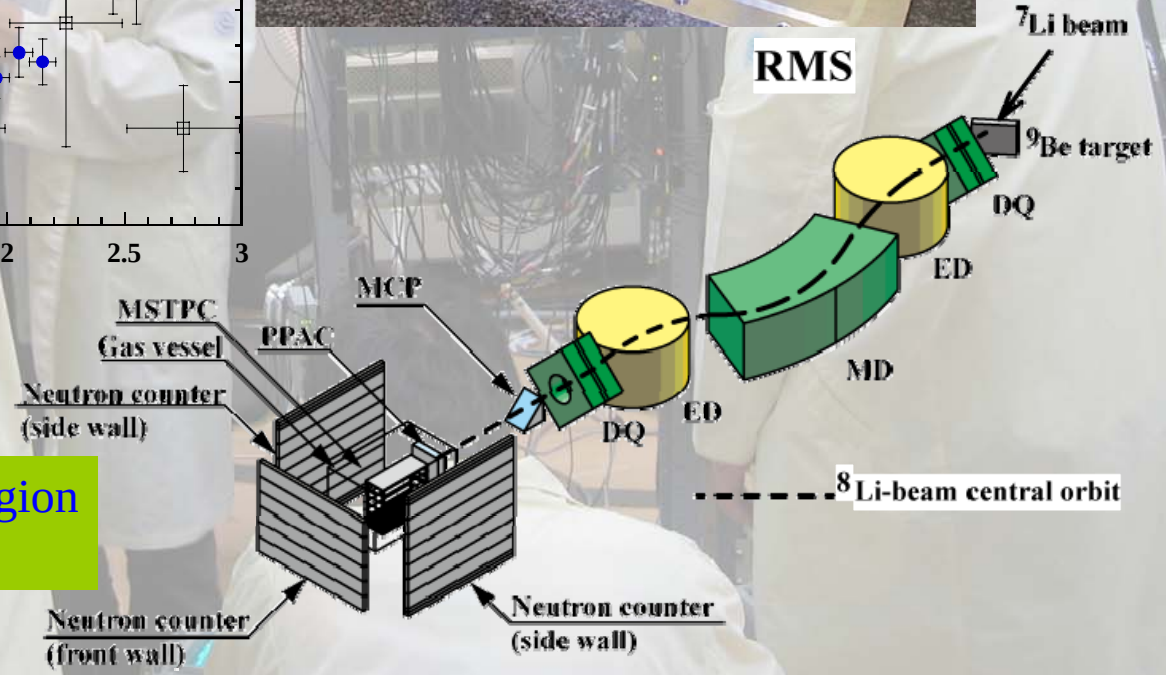
Experimental Setup and Results





MSTPC
Gated-Grid

NIMA556
(2006)339



Down to sub-mille barn region
with over 1 MHz RNB !

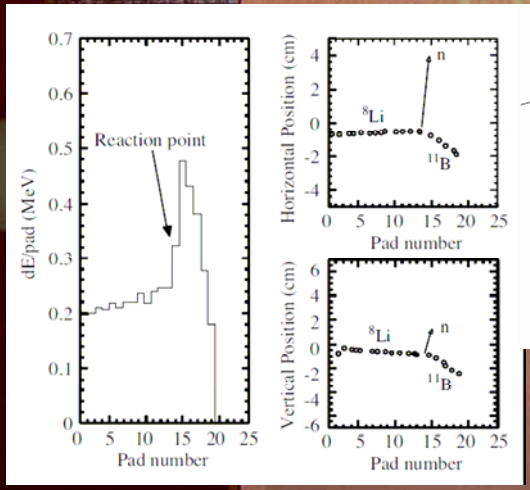
GEM-MSTPC

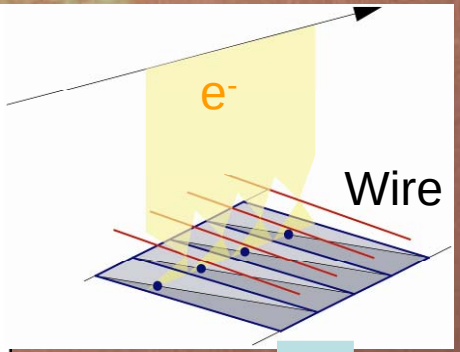
Multiple-Sampling and Tracking Proportional Chamber

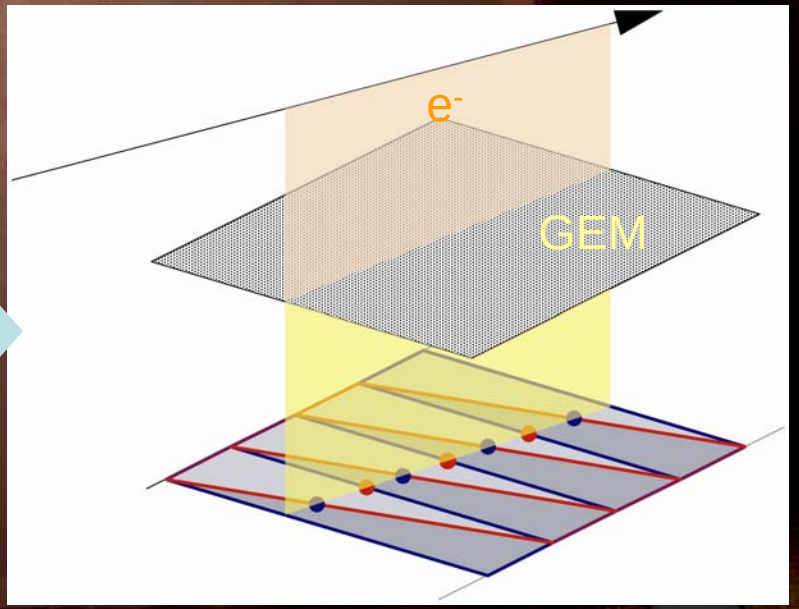
- Gas target
- dE/dx multiple sampling (MUSIC)
- 3D tracking (TPC)

→

- High detection efficiency (~100%)
- Excitation function in the wide energy range





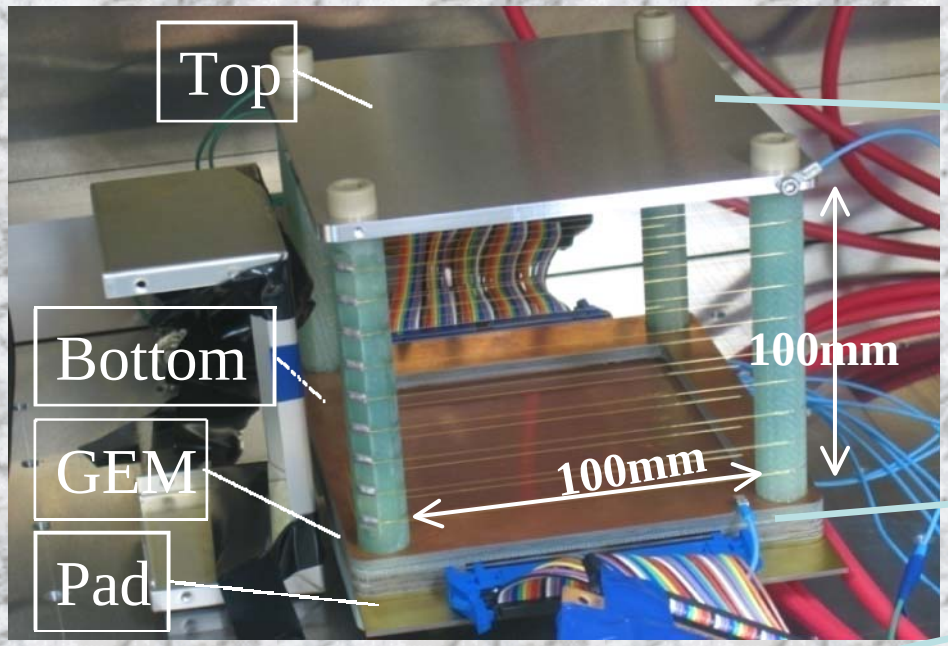


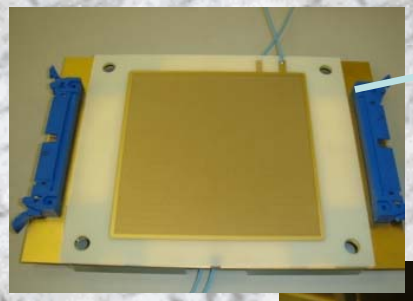
10 years ago, RNB intensity was up to 10kHz,
but now, it becomes to be more than 1MHz.

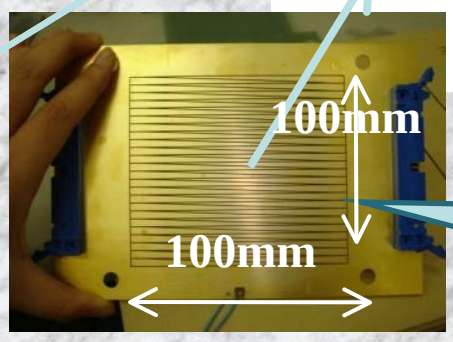
Anode wire → GEM

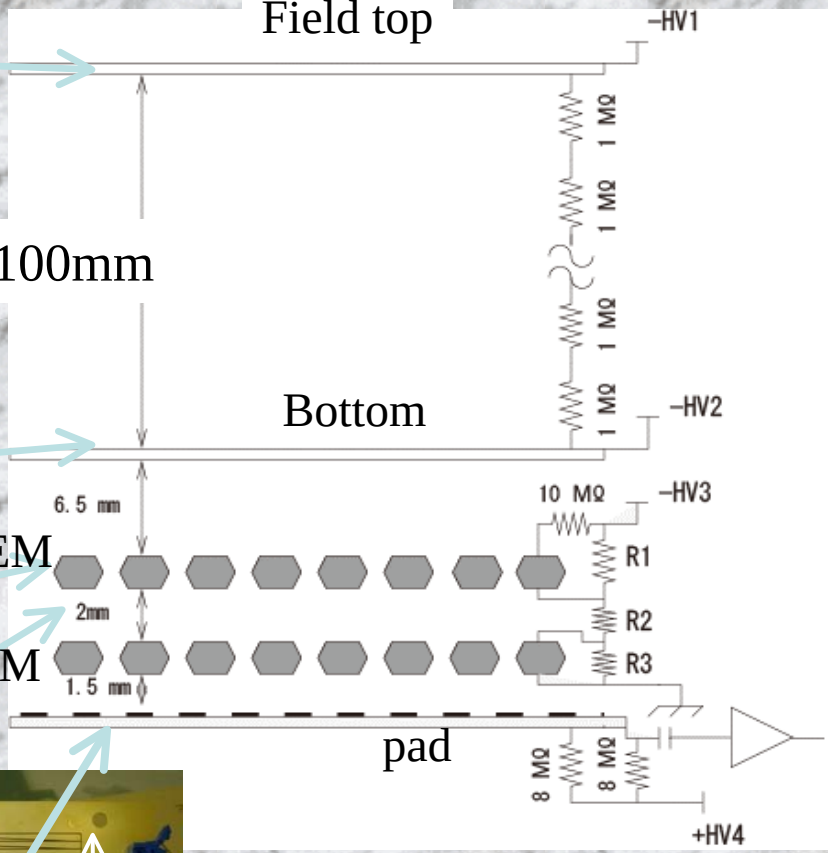
GEM-MSTPC

(Gas Electron Multiplier - Multiple Sampling Tracking Proportional Chamber)







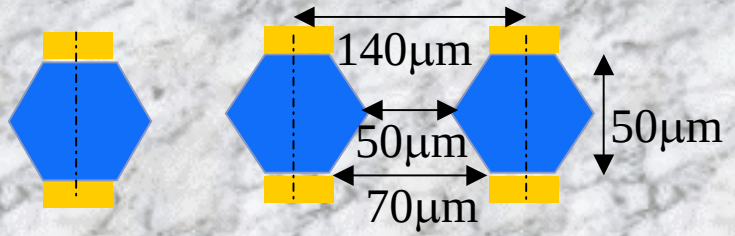


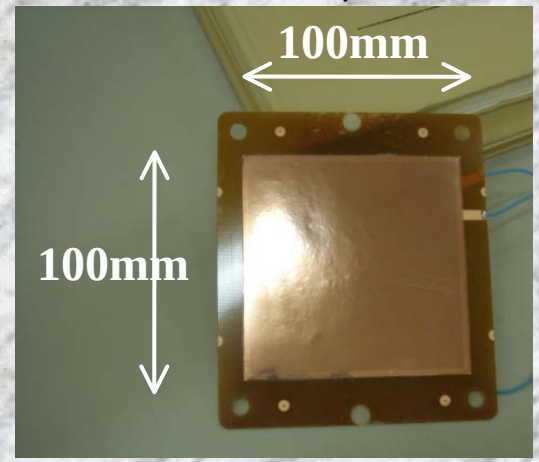
24 Backgammon pads

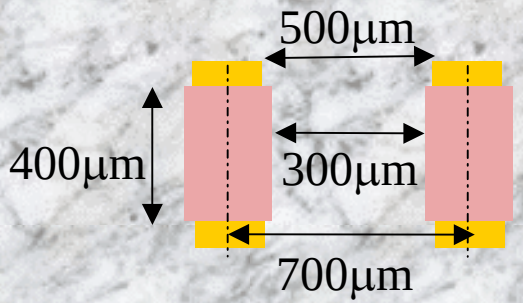
Two types of GEM

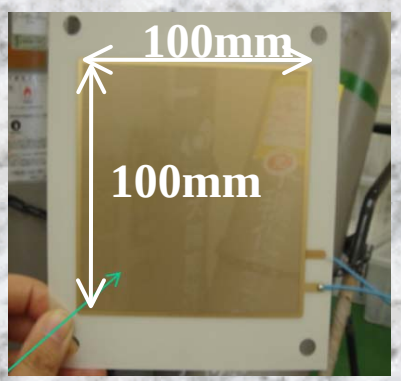
Thin GEM; CERN standard
thickness: Kapton 50 μm
Cu 5μm x 2
hole: process chemical etching
diameter 50 μm - 70 μm
pitch 140 μm

Thick GEM; REPIC
thickness: FR-4 400 μm
Cu 10 μm x 2
hole: process drill machine &
chemical etching
diameter 500 μm - 300 μm
pitch 700 μm

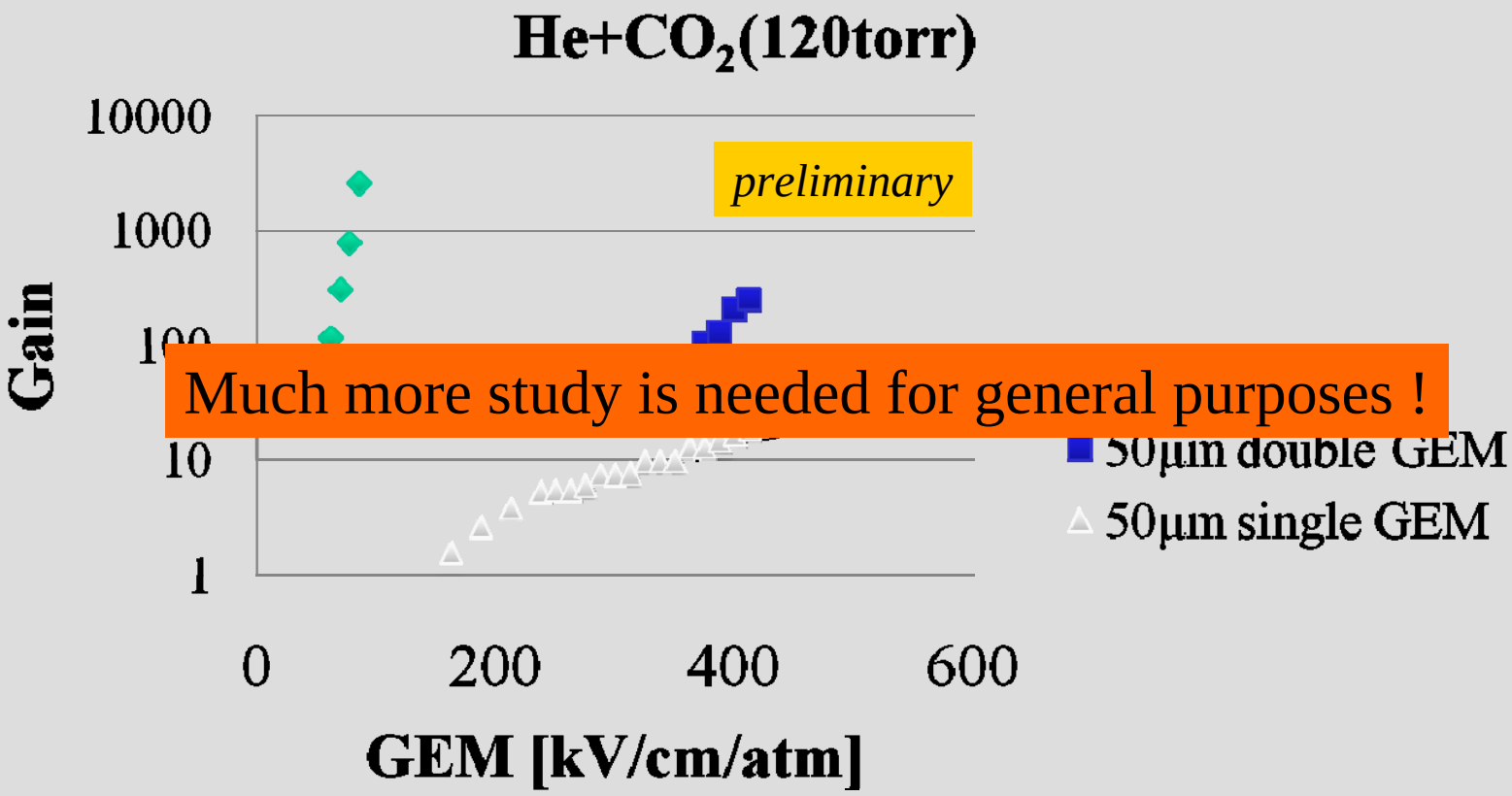








Gas-gain study



The present thick GEM is suitable for;

He-base gas	more than 90% He
low pressure	less than 1 atm
limited gas gain	less than 10^5

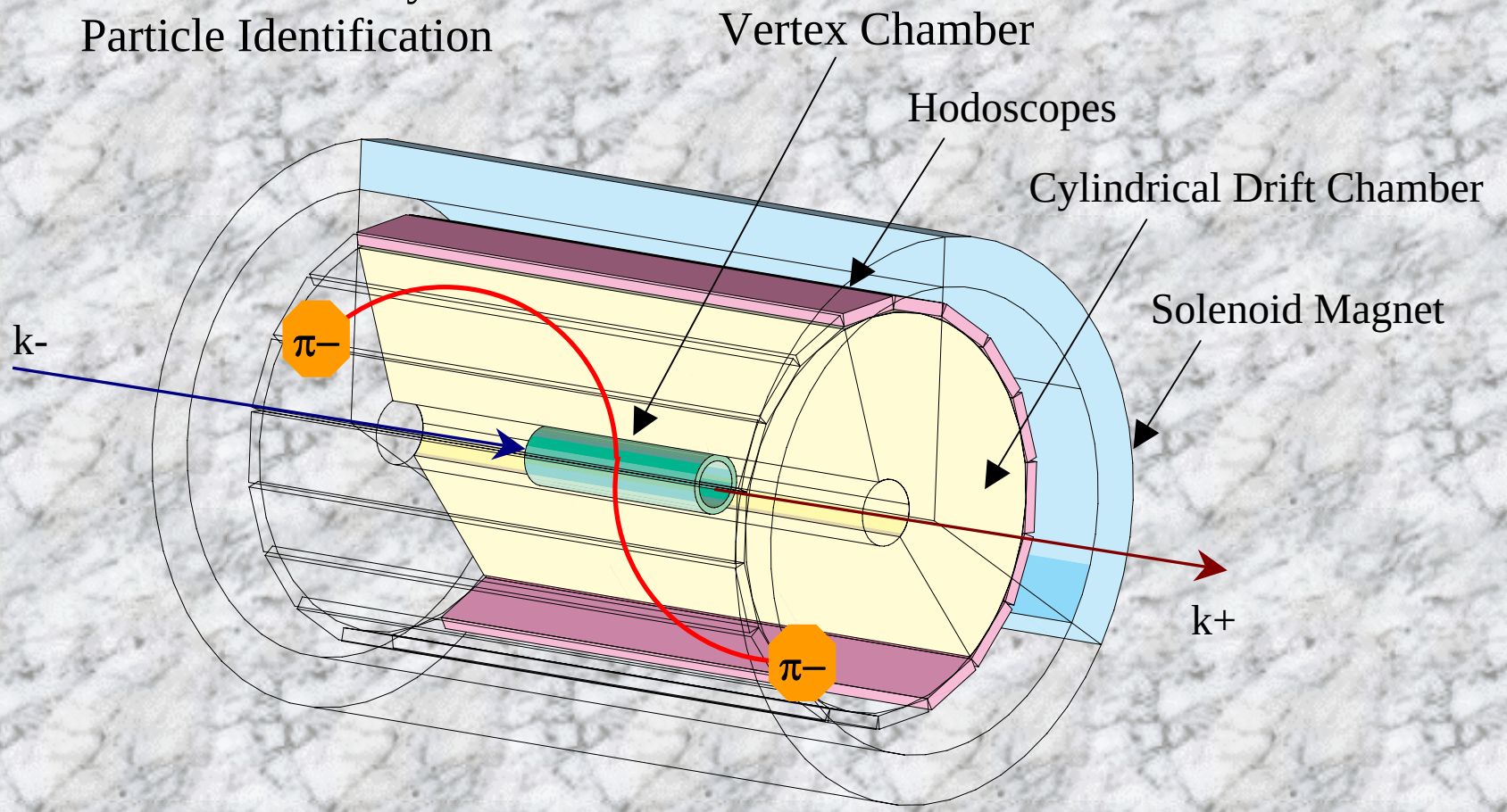
Vertex chamber inside CDS for J-PARC

Search for double-Λ hyper nuclei

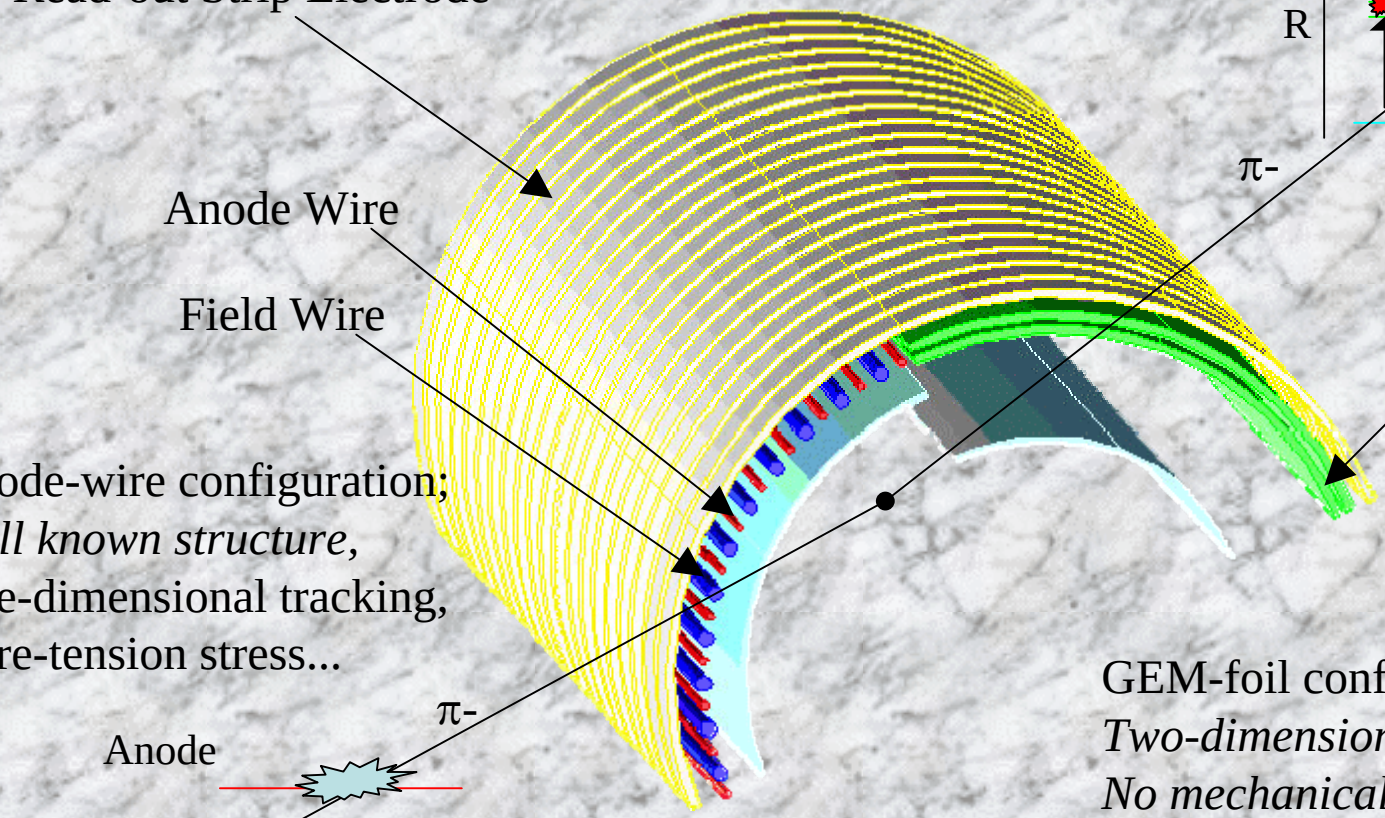
Vertex Determination
Momentum Analysis
Particle Identification

Ex. ${}^{5}_{\Lambda\Lambda}\mathrm{H} \rightarrow {}^{5}_{\Lambda}\mathrm{He} + \pi^{-}$ ($p_{\pi^-} \sim 134$MeV/c)

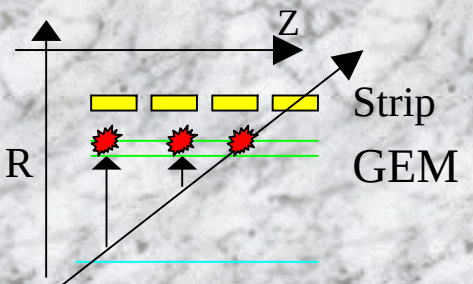
${}^{5}_{\Lambda}\mathrm{He} \rightarrow {}^{4}\mathrm{He} + \mathrm{p} + \pi^{-}$ ($p_{\pi^-} \sim 99$MeV/c)



Two Promising Designs - Anode wire or GEM ?



Radial TPC



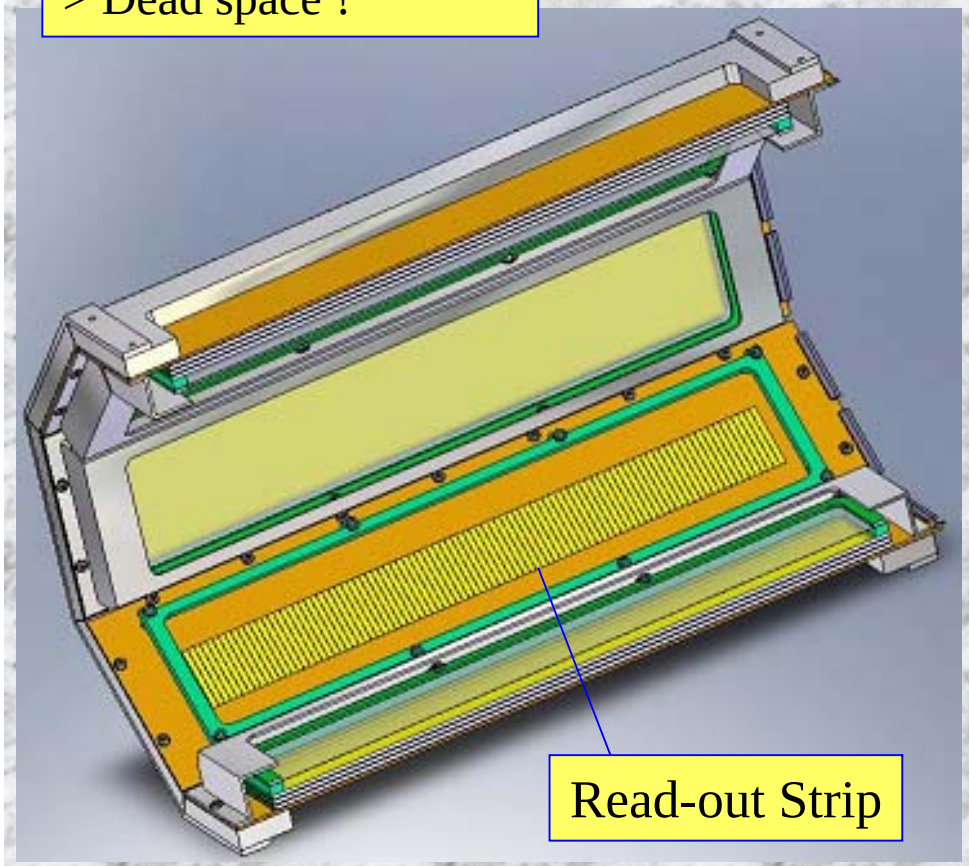
GEM foil x 2~3

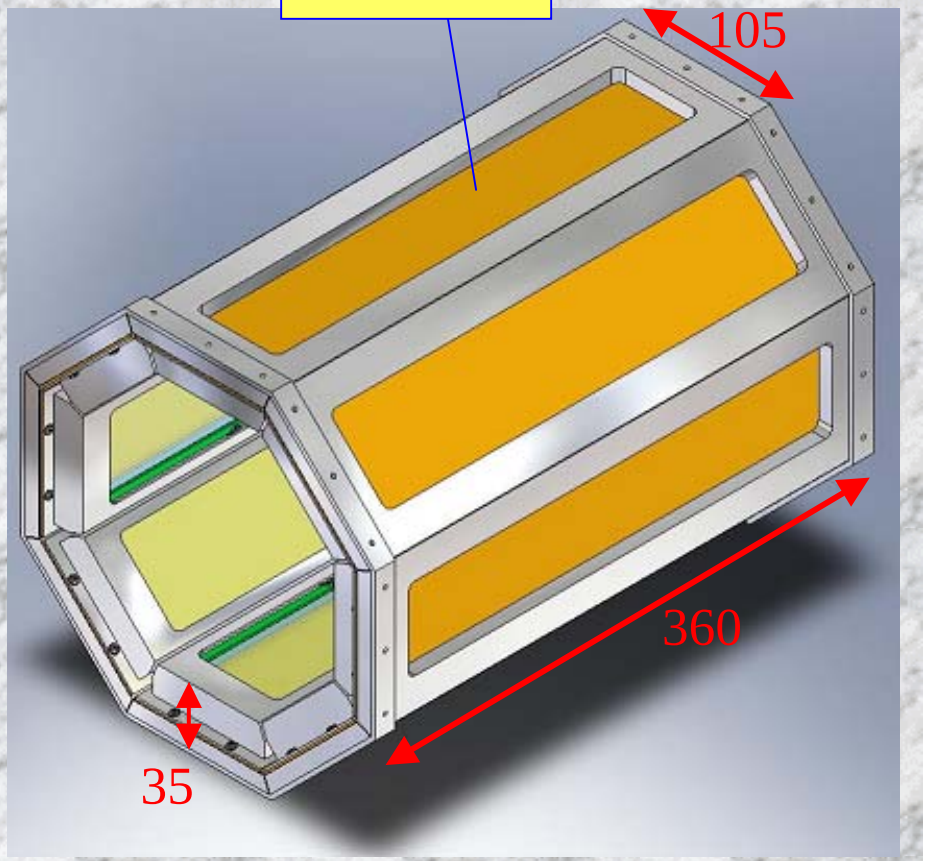
Anode-wire configuration;
Well known structure,
One-dimensional tracking,
Wire-tension stress...

GEM-foil configuration;
Two-dimensional tracking,
No mechanical Stress,
High counting rate,
Unknown structure,
Mass density.....

Design study

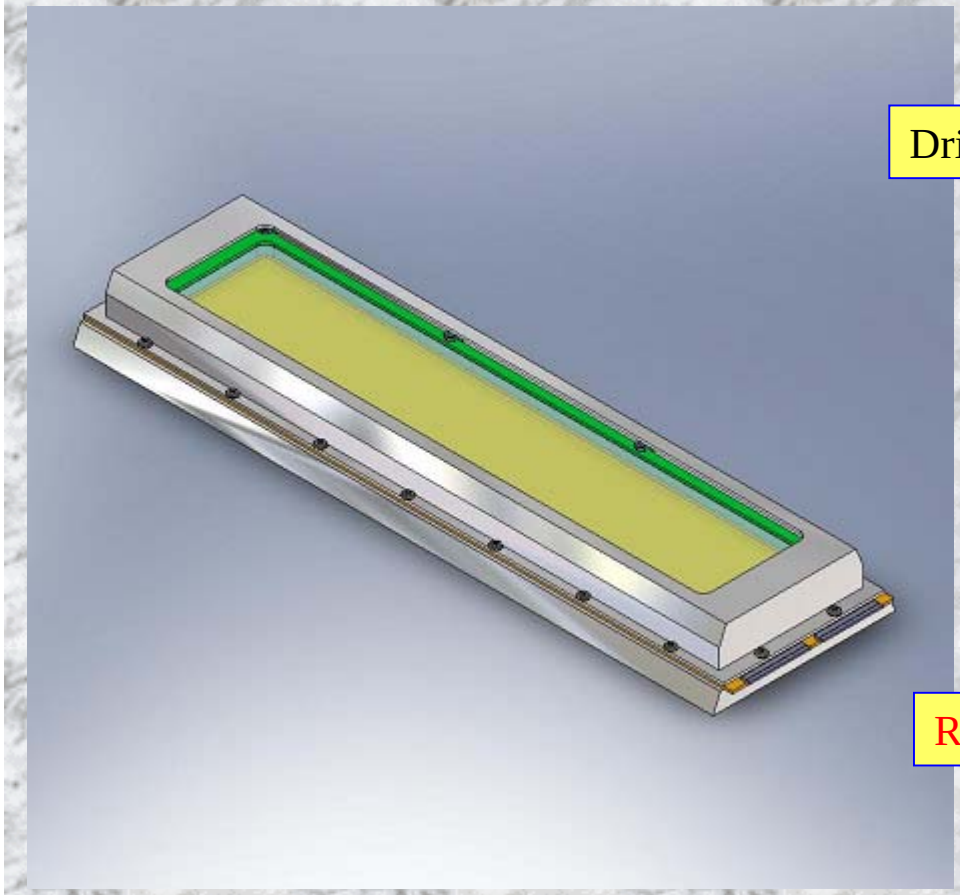
> 8 sectors
> No mechanical Stress
> Dead space ?

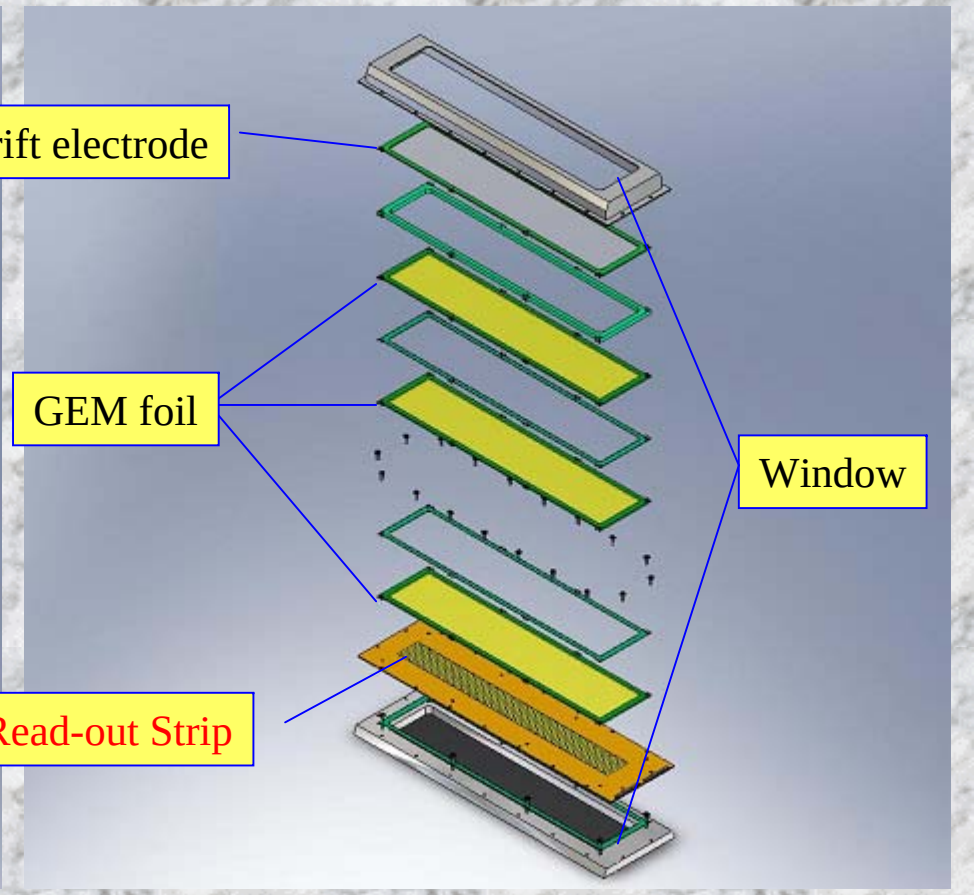




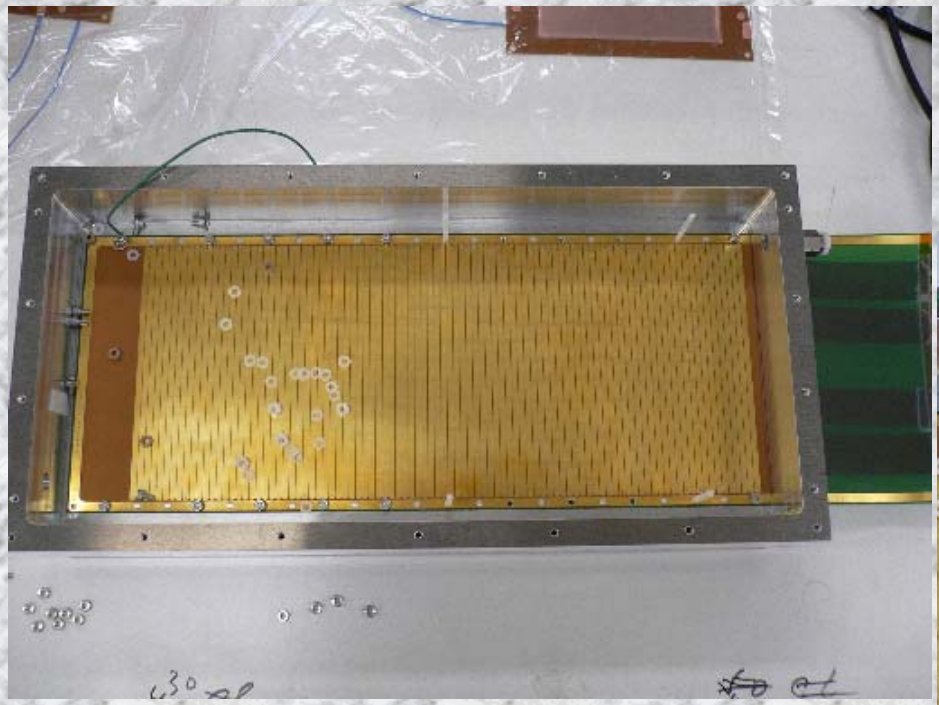
Cylindrical or Polygonal, that is a question.

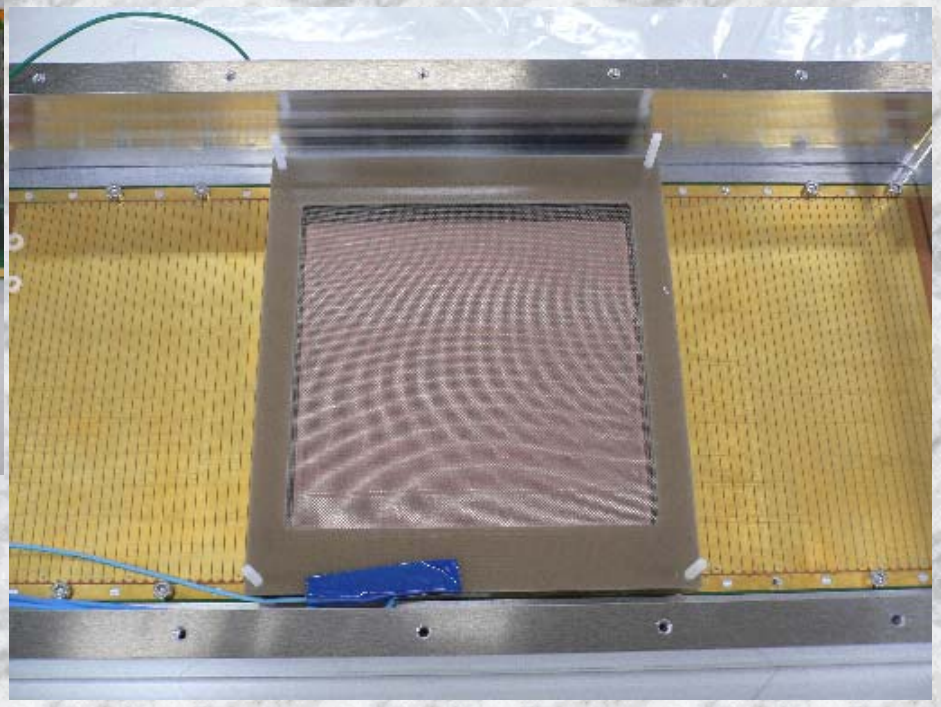
Structure of one sector



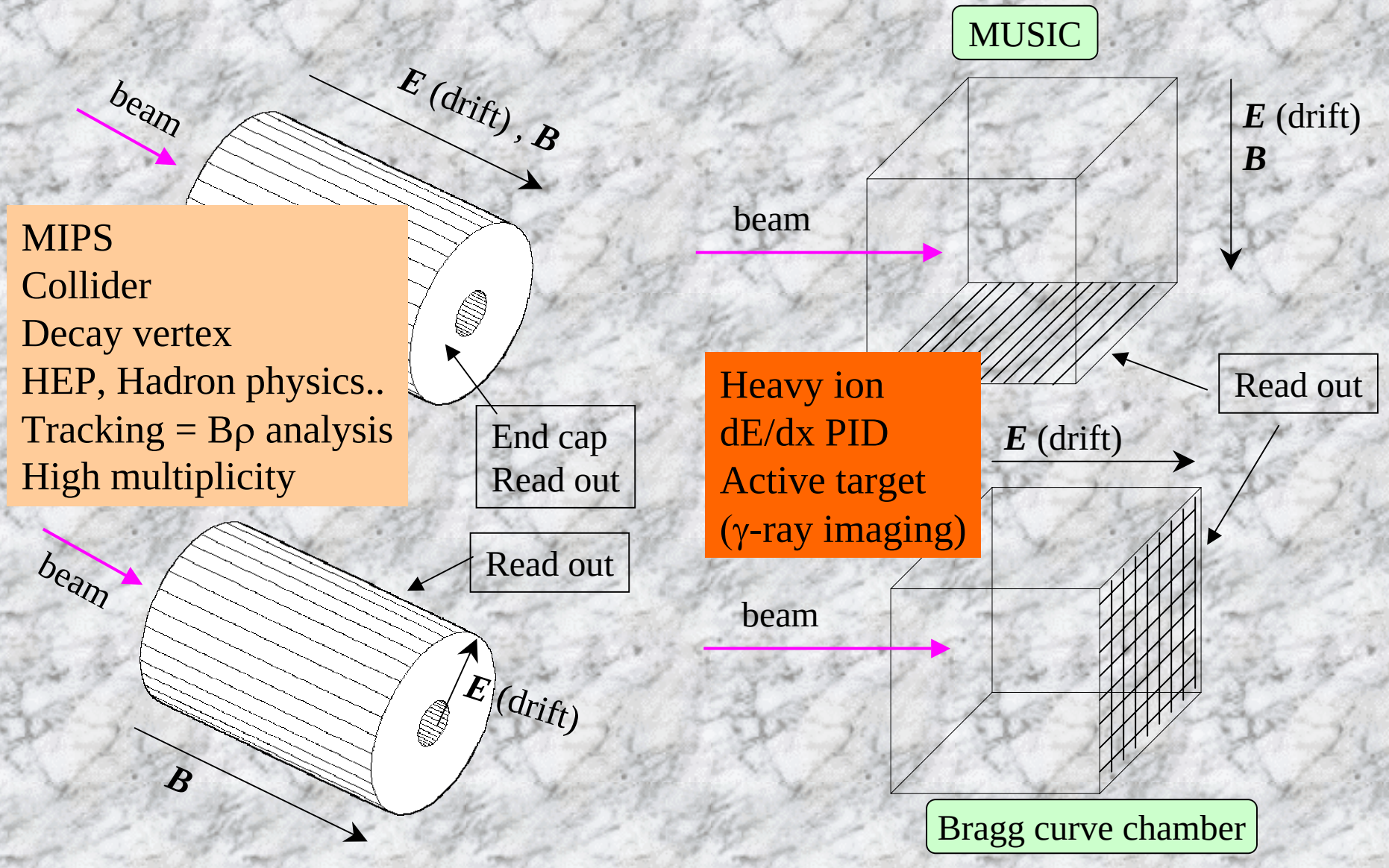


Prototype



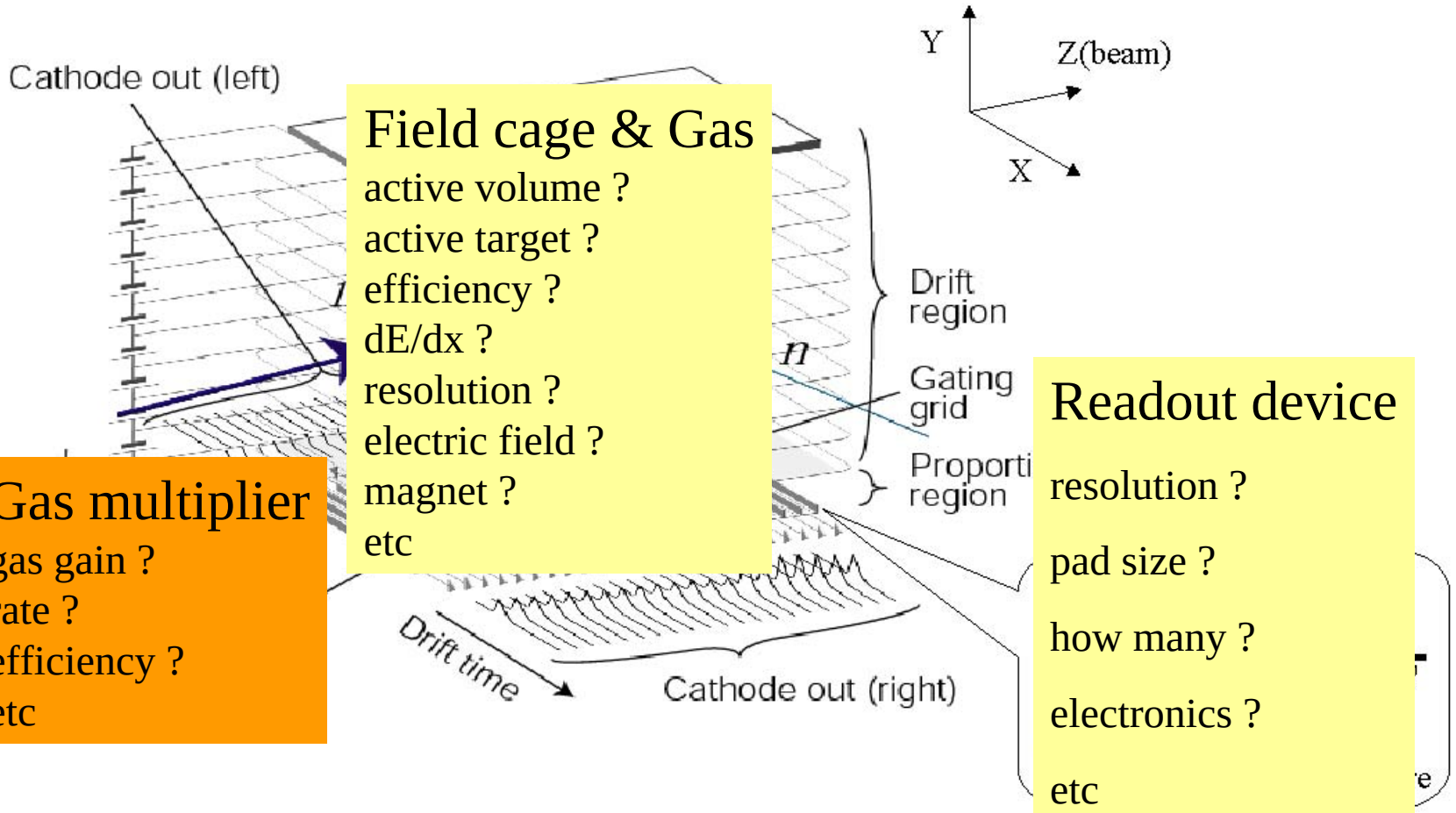


Time Projection Chambers



TPC with GEM for RIBF

What kind of Experiment ?



Field cage & Gas

active volume ?
active target ?
efficiency ?
dE/dx ?
resolution ?
electric field ?
magnet ?
etc

Gas multiplier

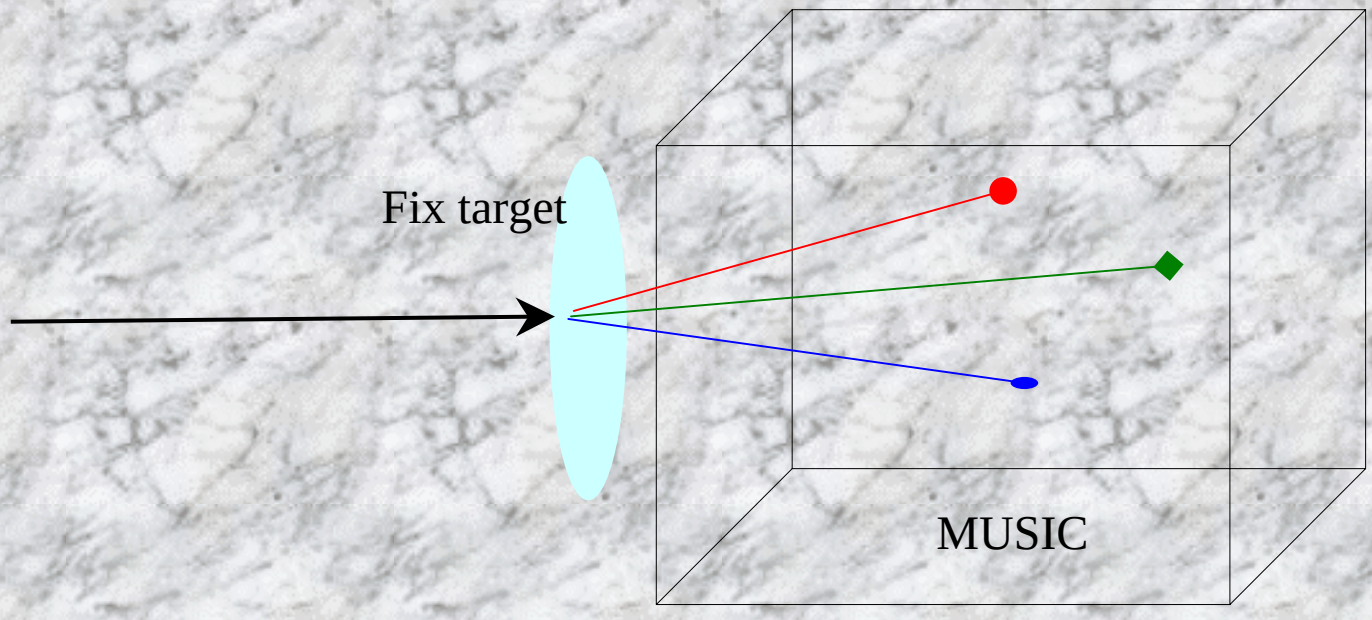
gas gain ?
rate ?
efficiency ?
etc

Readout device

resolution ?
pad size ?
how many ?
electronics ?
etc

Experiments and detector designs

Case 1: Fragmentation-reaction measurement

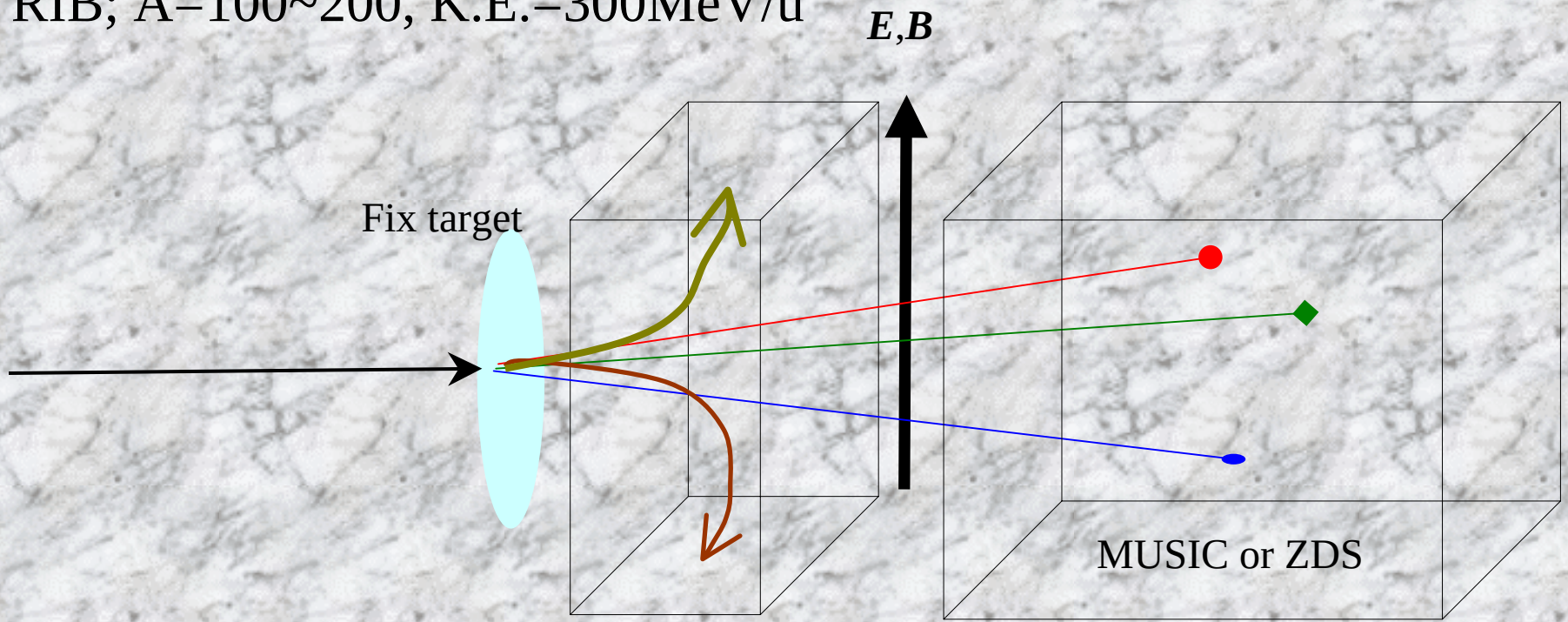


Sufficiently large dE/dx, gas multiplification device never be needed.

We don’t use TPC with GEM.

Experiments and detector designs

Case 2: Fragmentation + Meson (hadron?) production
RIB; A=100~200, K.E.=300MeV/u



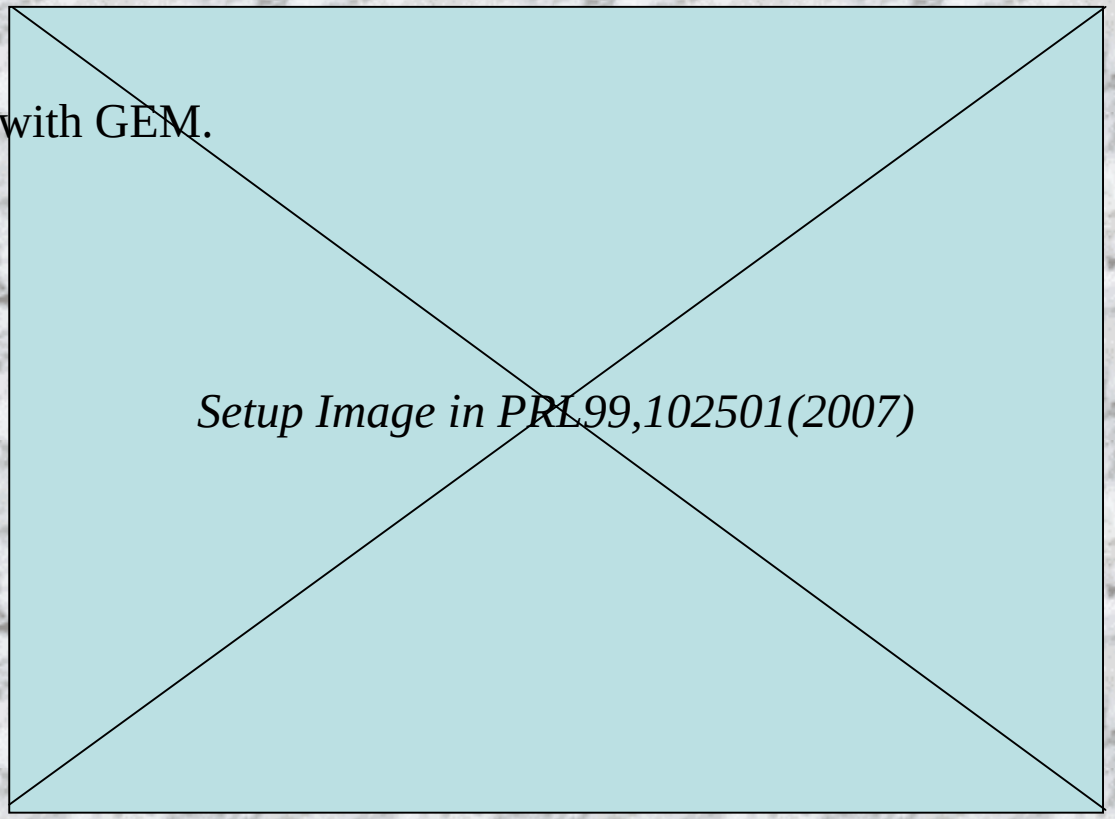
Ex. EOS@Bevalac &AGS

Experiments and detector designs

Case 3: Measurement of exotic radioactive decay

First Direct Observation of Two Protons in the Decay of ^{45}Fe with a Time-Projection Chamber
J. Giovinazzo, et al. PRL **99,** 102501 (2007)

Kinematics of two protons are completely determined by a TPC with GEM.



Experiments and detector designs

Case 4: Reaction measurement with H and He target

RIB; A=100~200, K.E.=300MeV/u

Ex. Inverse-kinematics (p,p'),(p,n),(p,α),(α,α'),(α,n),(α,p), and so on