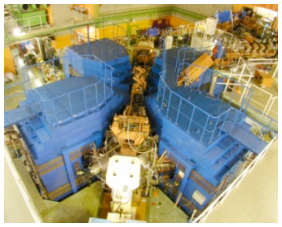
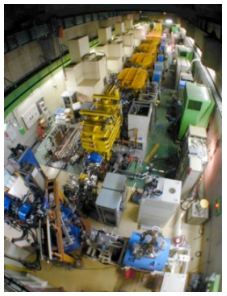
SAMURAI-TPC AND POSSIBLE PHYSICS USING IT

Tetsuya MURAKAMI

Kyoto Univ/RIBF

Layout of RIKEN RI beam factory (RIBF)

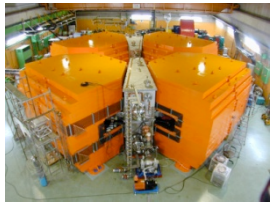




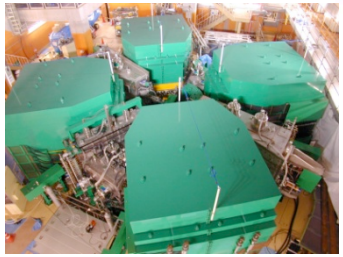
ZeroDegree

RIBF

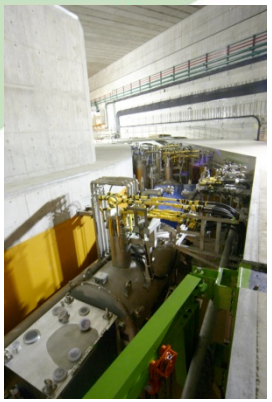
fRC



IRC



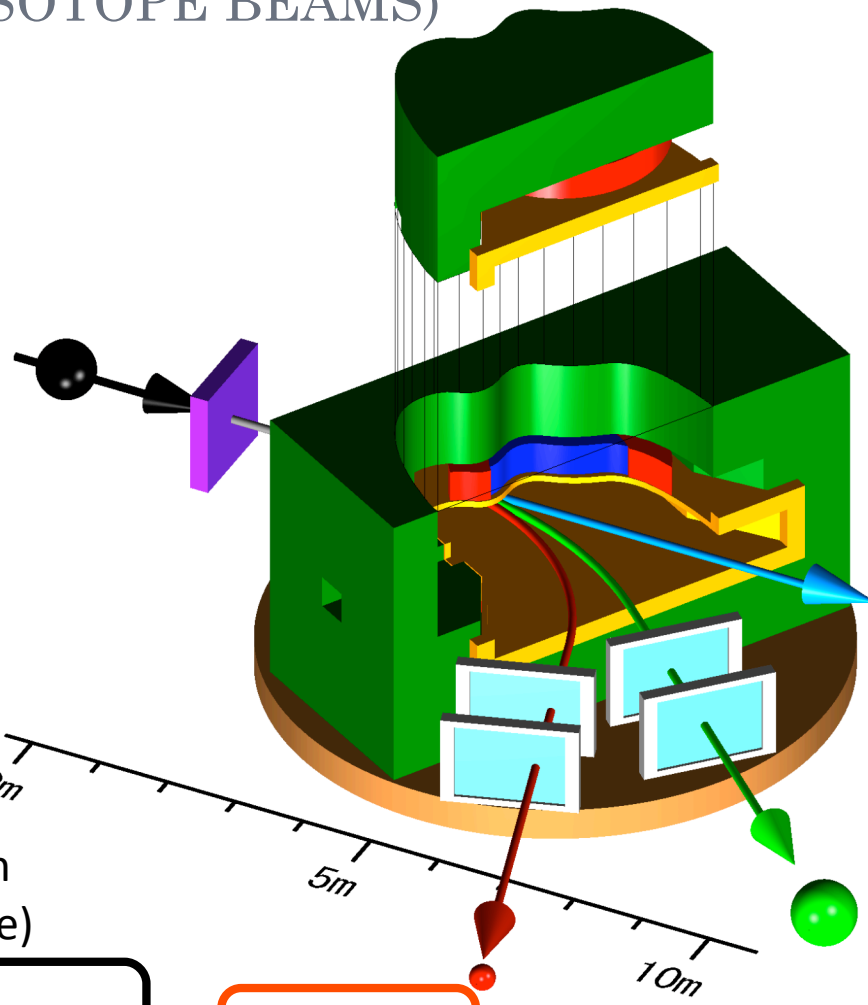
SRC



BigRIPS

SAMURAI (7)

(SUPERCONDUCTING ANALYZER FOR MULTI-PARTICLES WITH RADIO-ISOTOPE BEAMS)



Bending Magnet
- Superconducting
- Large B·L (7Tm)
- Large pole gap (80cm)
- Weight ~ 630 ton

Neutron

(not shown in picture)
Deuteron

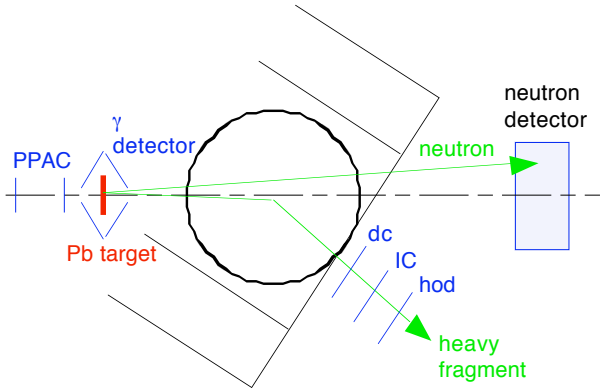
Proton

Heavy Ion

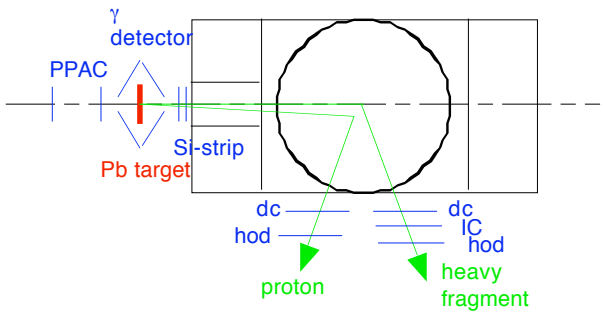
(not shown in picture)
TPC

WHAT KIND OF EXPERIMENT ?

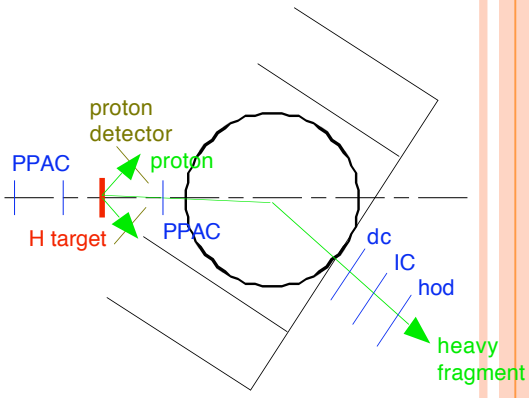
(γ,n) reaction: neutron-rich side



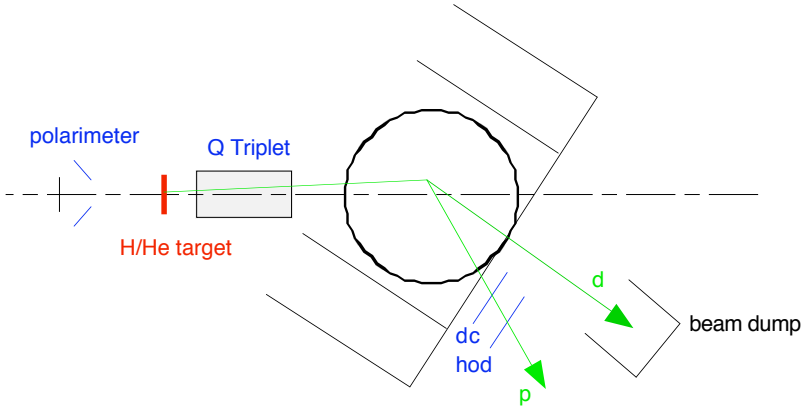
(γ,p) reaction: proton-rich side



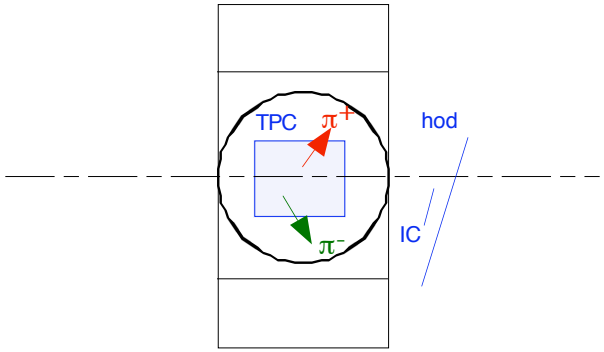
(p,p'), (p,2p) etc.



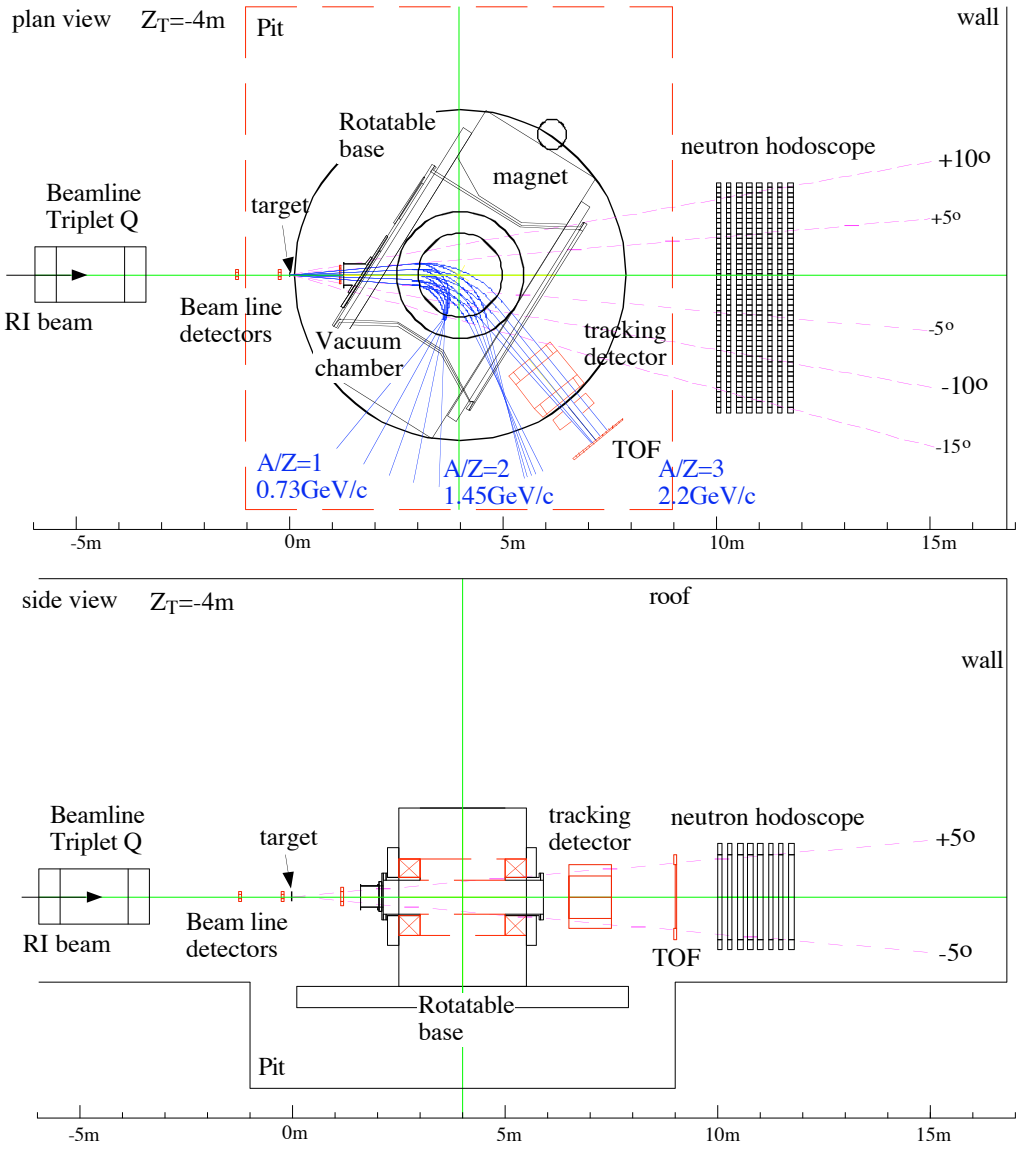
Pol. d-induced reaction



EOS measurement



LARGE ACCEPTANCE



Large momentum byte

R_{max} / R_{min} ~ 2 – 3

(magnet rotatable)

Large angular acceptance

for neutron,

vertical – 5 degrees

horizontal – 10 degrees

(~100% coverage

up to E_{rel} ~ 3MeV,

~ 50% coverage

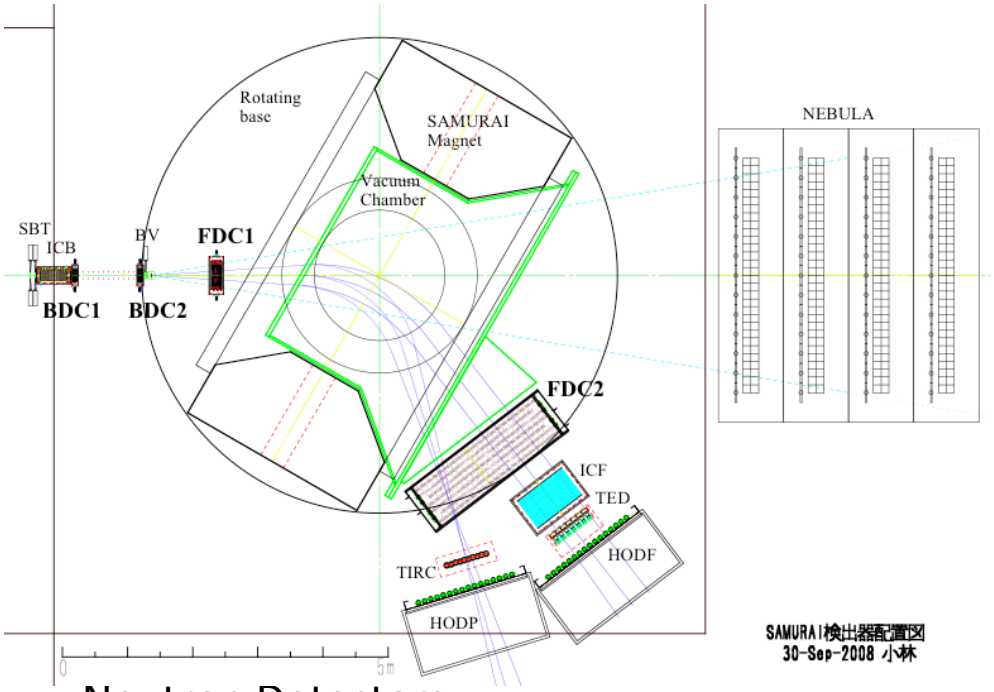
at E_{rel} ~ 10 MeV)

CURRENT STATUS

- Budget approved 1.5BJPY in FY2008 – 2011
- All the contracts have been made in FY 2008
  -- all the specifications are fixed
- Contracts done for
  - Superconducting dipole magnet
  - Almost full set of HI detector
  - Almost half volume of the neutron detector
  - Proton detectors
  - Triplet quadrupole magnet for beam transmission
  - Peripherals (vacuum pumps, circuit modules,…)
- START EXPERIMENTS IN SUMMER 2011

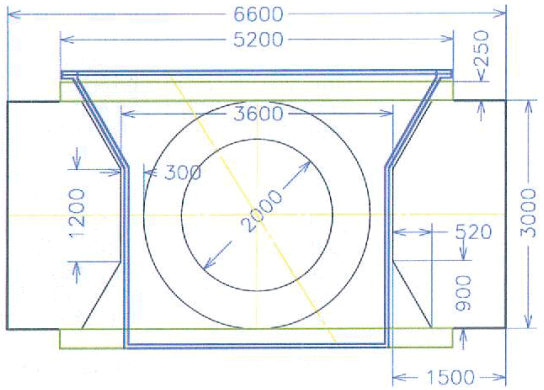
DETECTORS

- Heavy Ion Detectors
  - Beam chamber
    - Chamber/case/feedthru
    - Electronics
    - Gas handling
  - Upstream chamber
    - Chamber/case
    - Electronics
    - Gas handling
  - Downstream
    - Chamber/case/feedthru
    - Electronics
    - Gas handling
  - Charge measurement
    - Ion chamber
    - Electronics
  - Velocity measurement
    - Plastic hodoscope
    - Cherenkov
  - Total E (pure CsI)
    - Detector
    - Electronics



- Neutron Detectors
  - Scintillator, PMT, Electronics
- Proton Detectors
  - Microstrip Silicon
  - Readout circuit
  - Proton Drift chamber
  - Hodoscope + elec.
- Polarized Deuteron Experiments
  - MWDC – Hodoscope
  - Z=1 detector – Beam dump
  - Polarimeter
- TPC

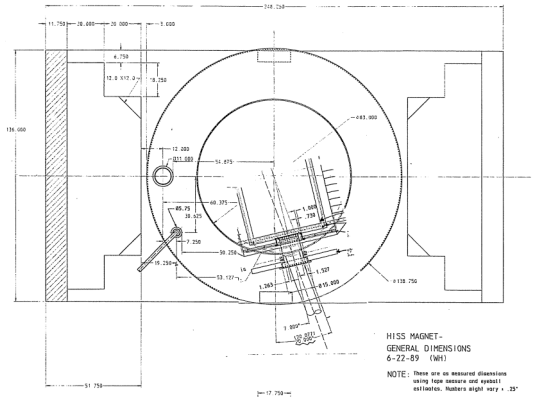
COMPARISON OF SAMURAI WITH EOS(HISS)

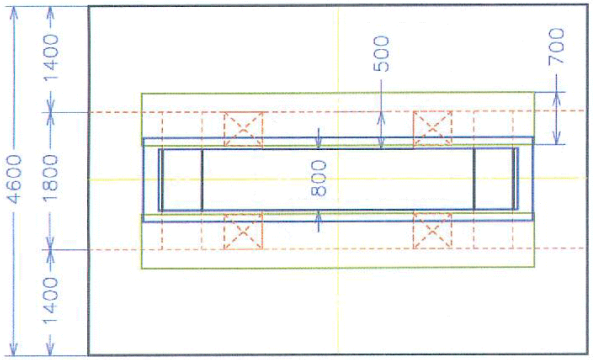


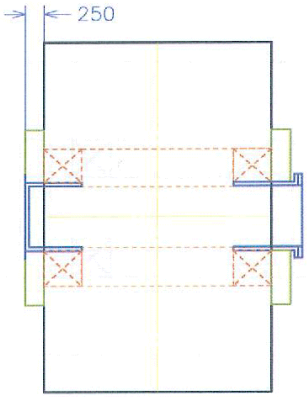
Cross section
pole: 3.14m↑2
side yoke: 4.03
u/d yoke: 4.20
assume : coil=0.5x0.5m↑2

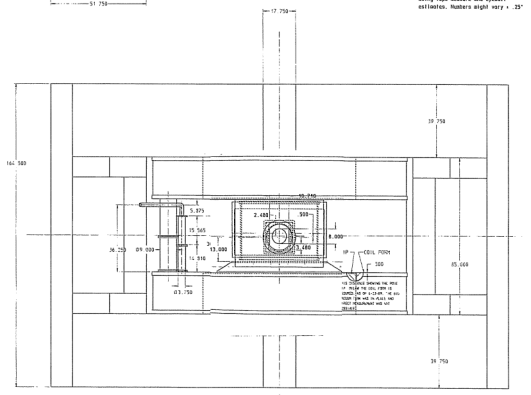
volume
pole: 3.14 m↑3
side yoke: 14.42
u/d yoke: 55.44
cramp: 3.64
sum: 76.74m↑3
weight: 603.9 t (7.87t/m↑3)

22−May−2008 Kobayashi T.





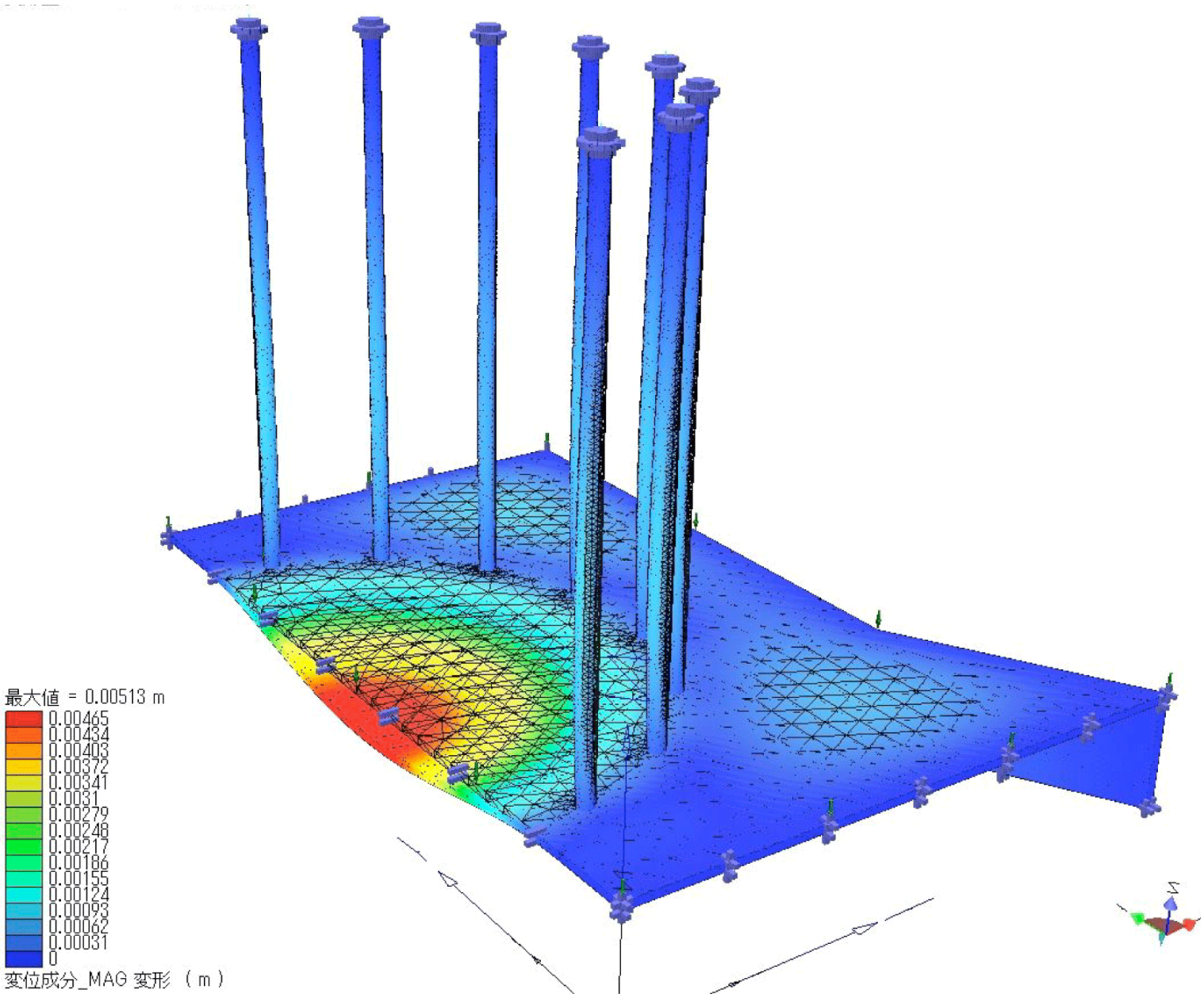




Gap ~80 cm(expected)

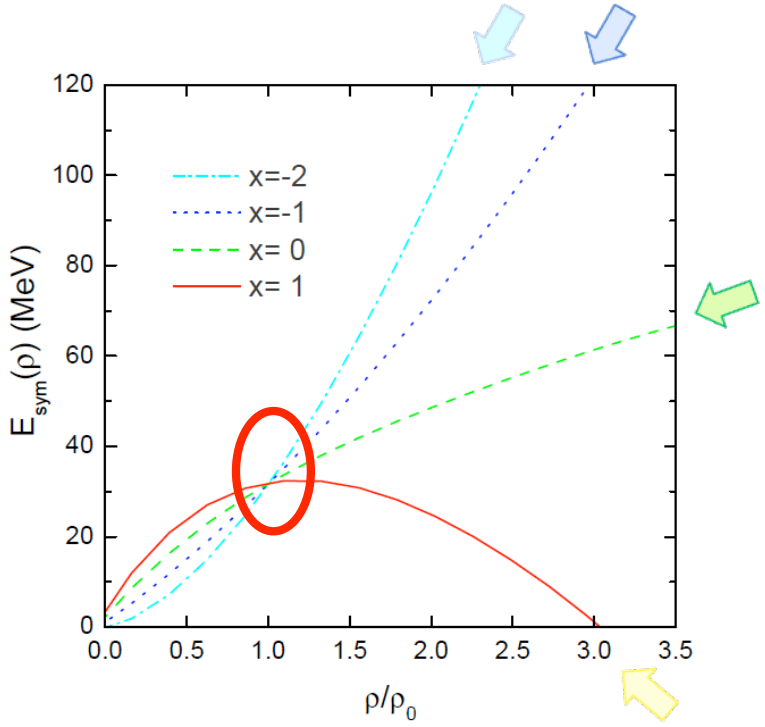
Gap=100 cm

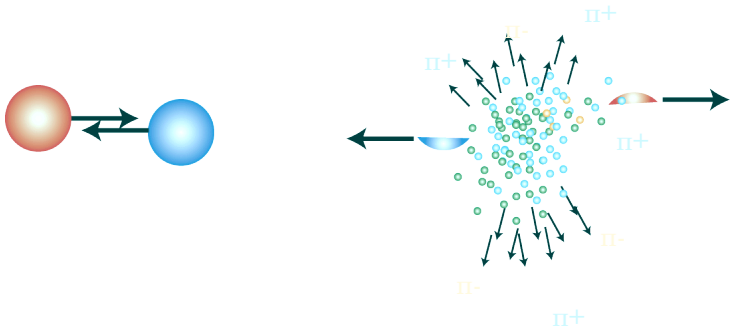
POSSIBLE STRUCTURE OF VACUUM CHAMBER



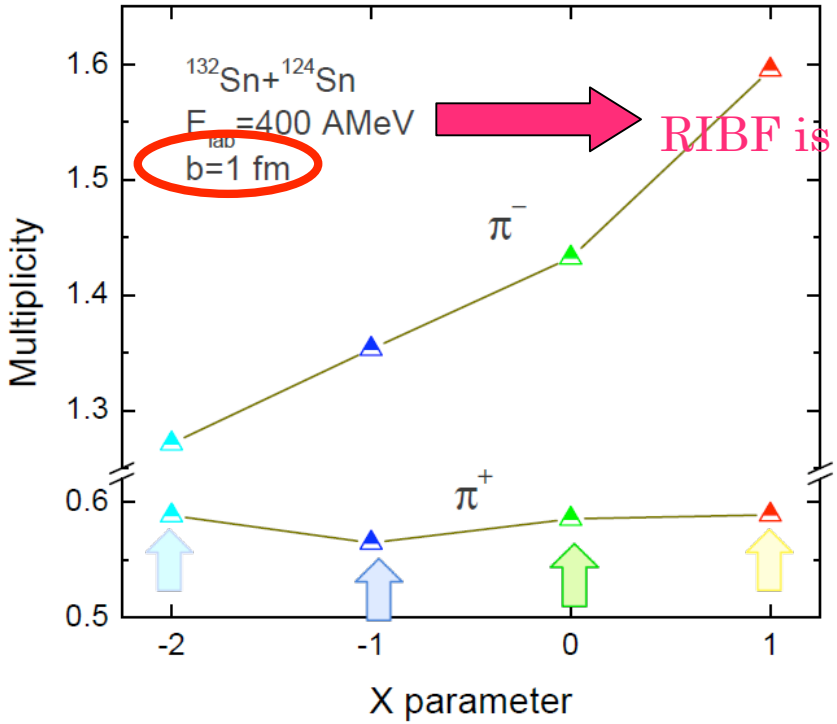
FIRST EXPERIMENT WITH TPC

Bao-An Li, Phys. Rev. C71 014608 (2005)





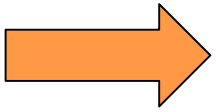
$\pi^{\pm}$ ratio as a good probe of E



RIBF is ideal

REQUIREMENT OF TPC FOR PION RATIO MEASUREMENT

- TPC must measure MIPs in the presence of heavy particles
- Associated charged-particle multiplicity for Sn+Sn reactions (Typical combination) around 350 MeV/A ~80 or more



Need two-track resolution ~4 cm or better

- EOS TPC had already shown such capabilities.

TEST OF PARAMETERS IN+^{132}XE @400 MEV/U AT HIMAC

- Centrality Filter

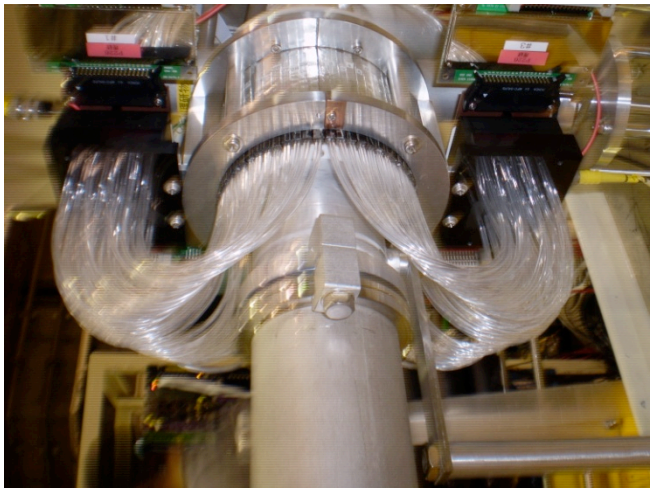
  Slabs of plastics
  (60 elements)
  +optical fiber
  +Flat Panel PMT
  +ASD chip board
  + multihit TDC
  Coverage:27.2°<θ_{lab}<57.5°

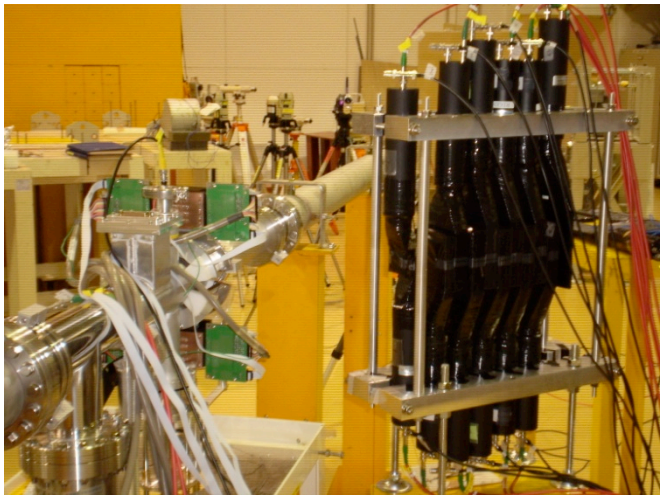
- Pion range counter

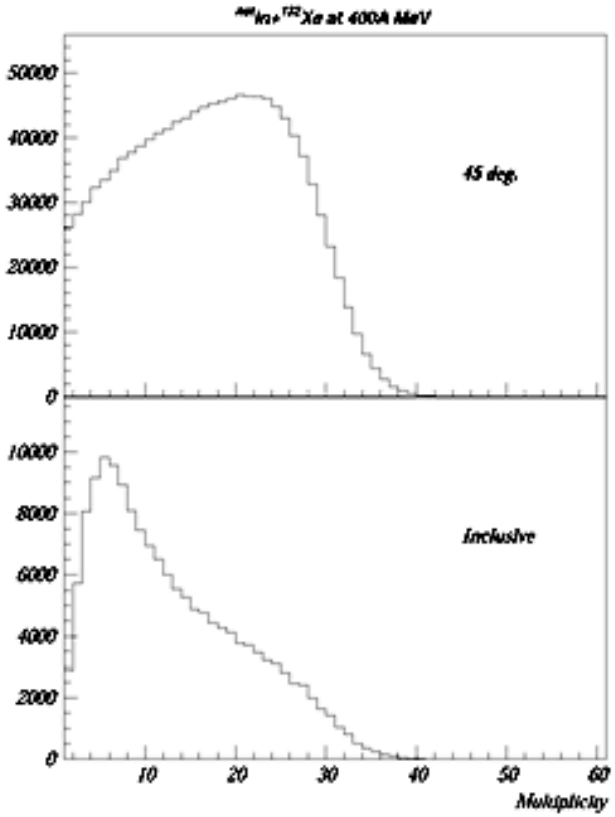
  2mm×2+15mm+30mm×8 stacks+5mm(veto)

  Coverage: 10msr

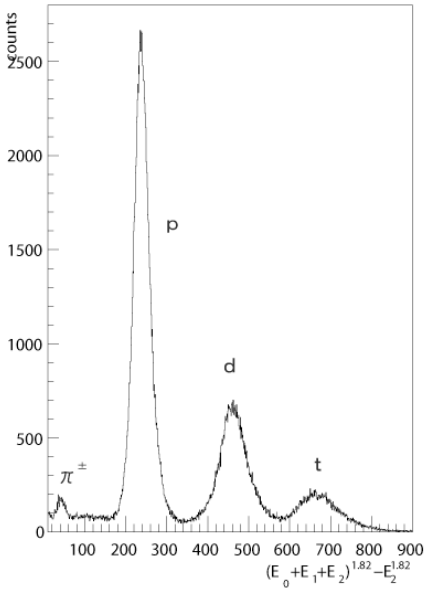
  $\pi^+ \rightarrow \mu^+ + \nu_\mu$ (life: 26 ns)





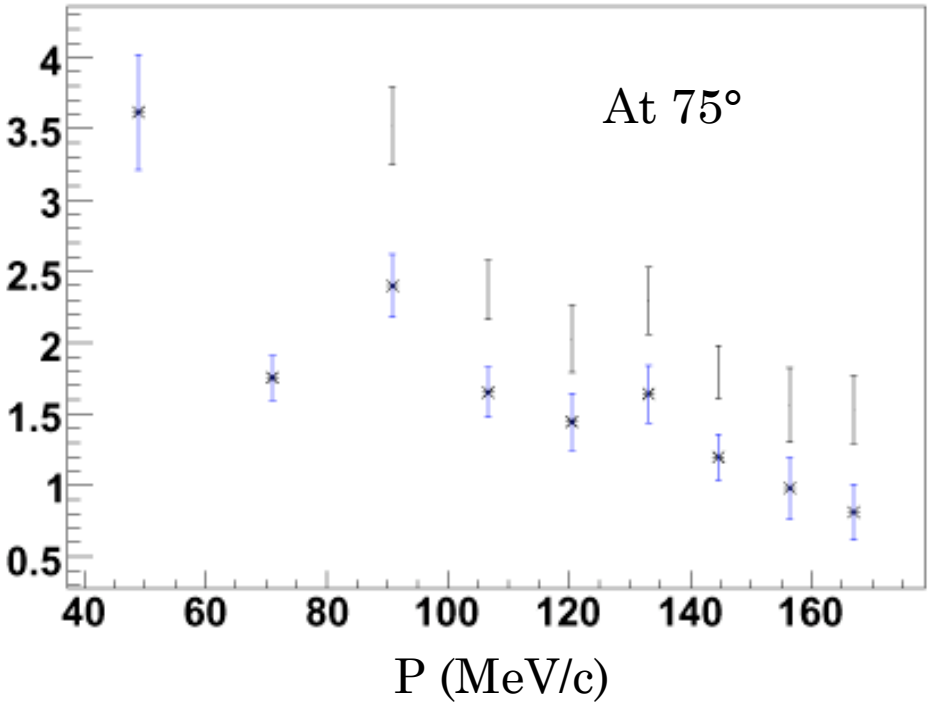


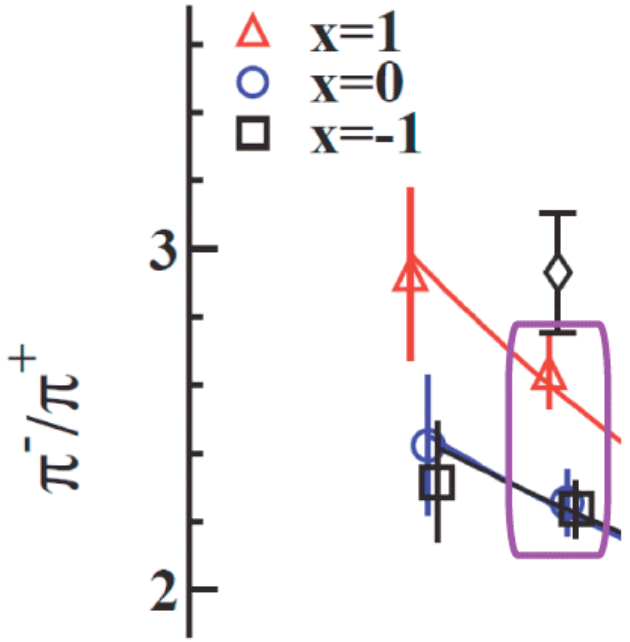
12kHz@Beam 3×10^{6}pps
with 328.5 mg/cm^2 target



Trigger rate:173Hz
@75°
Beam 3×10^{6}pps
with 328.5 mg/cm^2
target

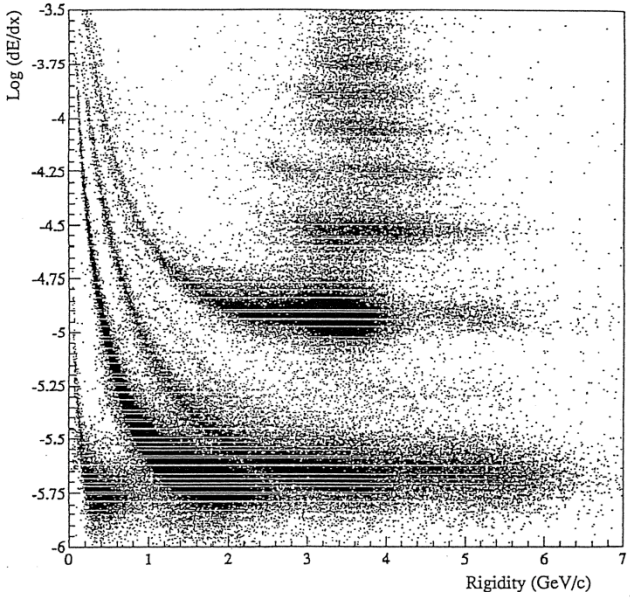
Π^-/Π^+

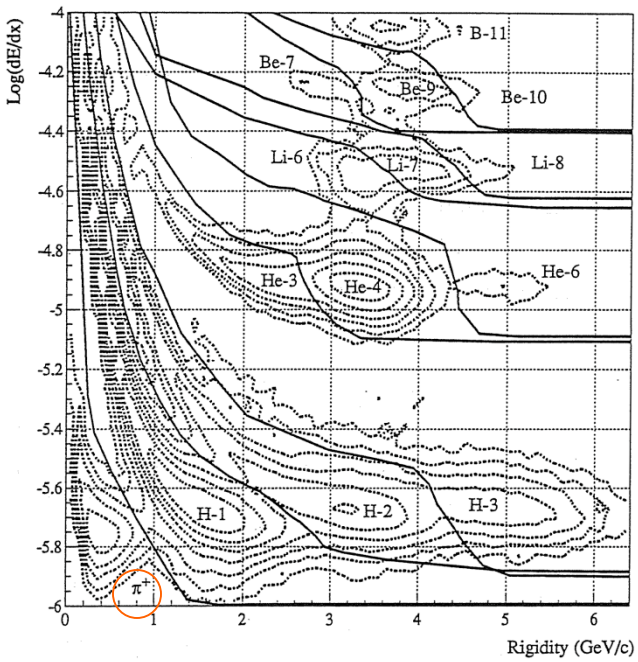

At 75°
4
3.5
3
2.5
2
1.5
1
0.5
40
60
80
100
120
140
160
P (MeV/c)


x=1
x=0
x=-1
π^-/π^+
3
2

PERFORMANCE OF EOS-TPC

HISS TPC Characteristics	
Pad Plane Area	1.5m × 1.0m
Number of Pads	15360 (120 × 128)
Pad Size	12mm × 8mm
Drift Distance	75 cm
Time Sampling Freq.	10 MHz
Signal Shaping Time	250 ns
Electronic Noise	700 e
Gas Gain	3000
Gas Composition	$90\%Ar + 10\%CH_4$
Pressure	1 Atmosphere
B Field	13 kG
E Field	120 V/cm
Drift Velocity	5cm/μ s
Event Rate	10-80 events/ 1 sec spill
dE/dx range	Z = 1-8, $\Lambda, \pi, p, d, t, He, Li - O$
Two Track Resolution	2.5cm
Multiplicity Limit	$\approx$ 200





Pad Signal for a Centered Minimum Ionizing Particle	
dE/dx (eV/cm)	1250
Pad Length (cm)	1.2
Electrons/eV loss	26
Gas Gain	3000
Efficiency of charge collection due to the integration time	0.4
Wire-Pad Coupling	0.16
Pad Signal (e)	11000

Electronics Specifications							
Device	Gain	Device Noise	Cumulative Noise		Min I Signal	Device Maximum	
			e	mV	mV	mV	Min I's
Preamp	0.32 μV/e	600 e	600	0.192	3.5	2000	570
Shaper Amp	6.5	0.5 mV		1.3	23	2000	90
CCD	1.0	0.6 mV	700	1.4	23	2000	90

Table 2: Operating parameters and electronic specifications

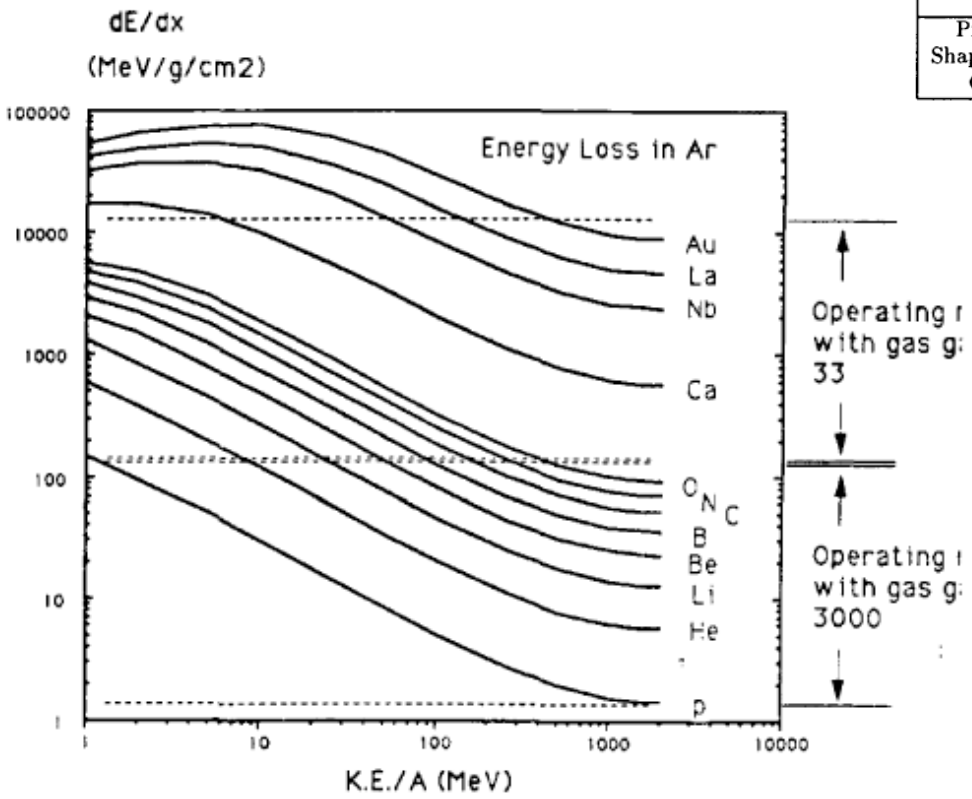


Figure 3: dE/dx versus kinetic energy per nucleon for a variety of ions. The dynamic range of the TPC electronics is shown for two different gas gains

OUR CONSERVATIVE WISH LIST(NOT YET FIXED)

- Pad Plane Area 1.3m x 0.9m
- #Pad ~12,096 (108x112)
- Pad size 12mmx8mm
- Drift Distance >55 cm
- Time Sampling Freq. 20 MHz
- Time buckets >256
- Dynamic range at least 12bits

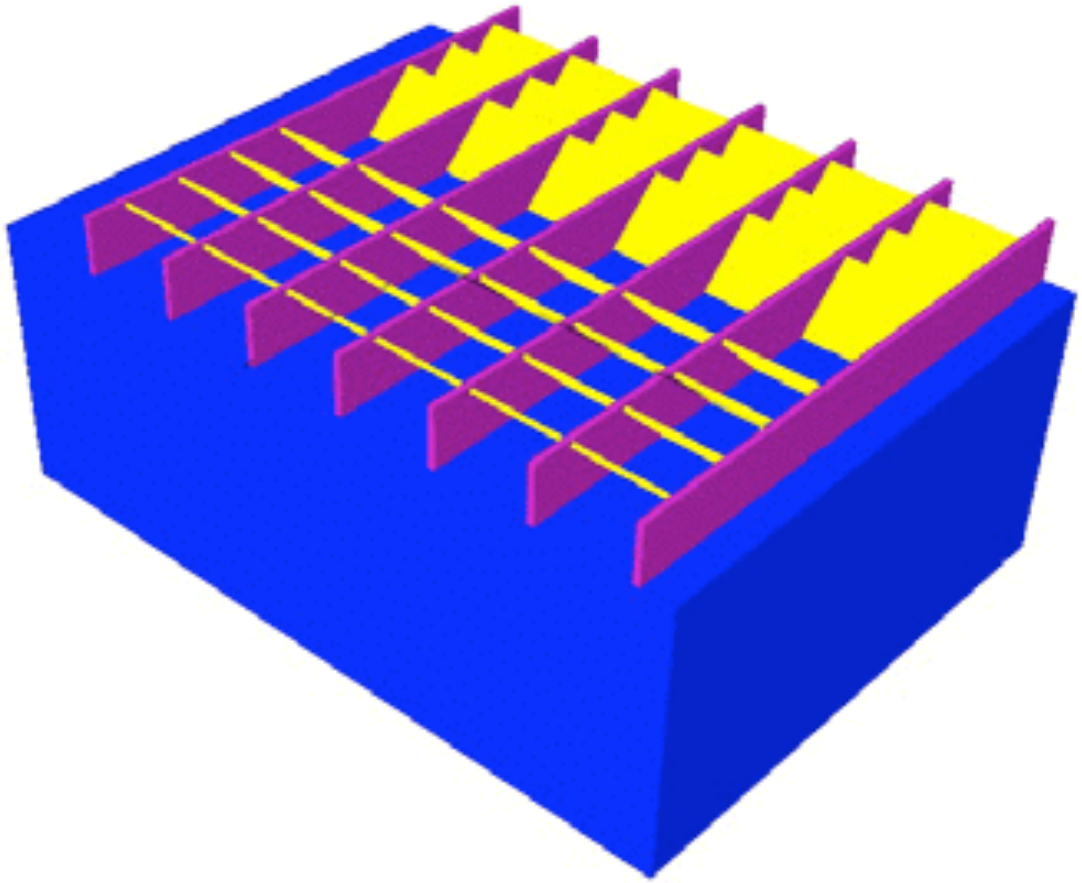
proportional

- Multiplicity Limit ~100 (→200??)
- Event Rate ~a few100 events/sec
- Two Track Resolution <4 cm (→2 cm??)

3 million pixel volume→occupancy less than 10 %
typically a few%

Charged particle Multiplicity (External)

Gated wire



TRADITIONAL EOS STUDY

- Multifragmentation of Participant Zone

  TPC is ideal 4π detector.

  Good acceptance for all Z

  Coherent analysis of numerous observables

  Fix A_{tot}, Plot vs. E/A -- Minimize finite-size effects

  Can be used as a replacement of well used 4π Detector like INDRA, ISiS and so on.

EOS TPC has already shown the capability.

SYMMETRY ENERGY

Besides π-/π+ ratios

- Pion flow
- Neutrons & Protons

Relative energy spectra

Differential flow

Balance energy

- Charged Fragments

t/^{3}He ratio, ^{3}He/^{4}He ratios,

^{6}Li/^{7}Li ratios, ^{6}He/^{6}Li flow

FISSION

- Active target –plan @ GSI, 1 GeV/nucleon fission following Coulomb excitation – track to know which foil

- Using H, He gas in TPC

Track to find interaction point (*E*). *Get the entire* excitation function at one bombarding energy

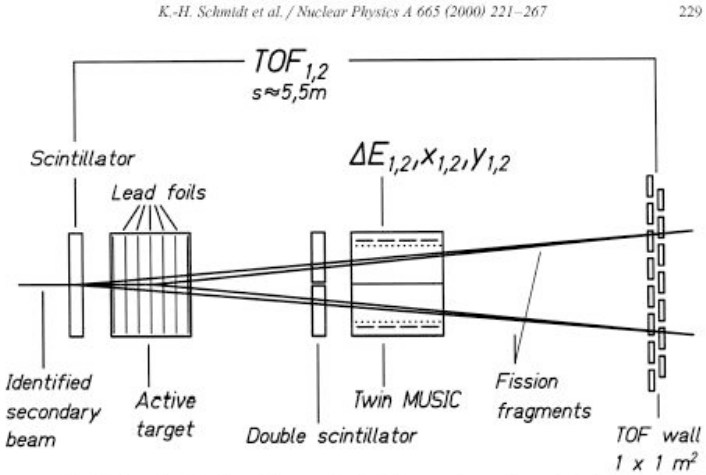


Fig. 4. Schematical drawing of the set-up for the fission experiment with secondary beams.

MULTI-PARTICLE FINAL STATE

- Looking for New kinds of Cluster states
  like $^{12}Be \rightarrow {}^{6}He + {}^{6}He$

- Coulomb dissociation into p+HI(neutron-rich)

Large relative energy can be covered by TPC.

NUCLEAR STRUCTURE EXPERIMENTS - (ACTIVE TARGET)

- Inelastic Scattering at intermediate enegies
- (p,p') or (α,α') inverse kinematics, 100-200MeV/n
  precise information on decay branch.
- Giant resonance studies to access nuclear compressibility

  We cannot use higher energy beam!!

  <100 MeV/nucleon

- Charge Exchange Reactions
- AZ(p,n)A(Z+1), AZ(3He,t)A(Z+1) AZ(d,2He)A(Z-1)