

The SAMURAI TPC: Research goals, Technical design and Schedule*

T. Murakami^a, T. Isobe^b, H. Sakurai^b, A. Taketani^b, M.B. Tsang^c, W. Lynch^c, J. Barney^c, J. Dunn^c, J. Gilbert^c,
Z. Chajecki^c, Fei Lu^c, G. Westfall^c, M. Famiano^d, S. Yennello^e, A. McIntosh^e, R. Lemmon^f, A. Chbihi^g, G.
Verde^h, A. Pagano^h, P. Russotto^h, W. Trautmannⁱ, Y. Leifelsⁱ

^aKyoto University, ^bRIKEN, Japan, ^cNSCL Michigan State University, ^dWestern Michigan University, ^eTexas
A&M University, USA, ^fDaresbury Laboratory, ^gGANIL, France, UK, ^hINFN, CT. Italy, ⁱGSI, Germany

*Talk given by W. Lynch in the SAMURAI International Workshop, March 9-10, RIKEN, Japan

Outline

- Research goals for the TPC
- Technical/Design Questions
- Conceptual design
- Time frame
- Some issues to be considered



U.S. DEPARTMENT OF
ENERGY

Office of
Science

MICHIGAN STATE
UNIVERSITY



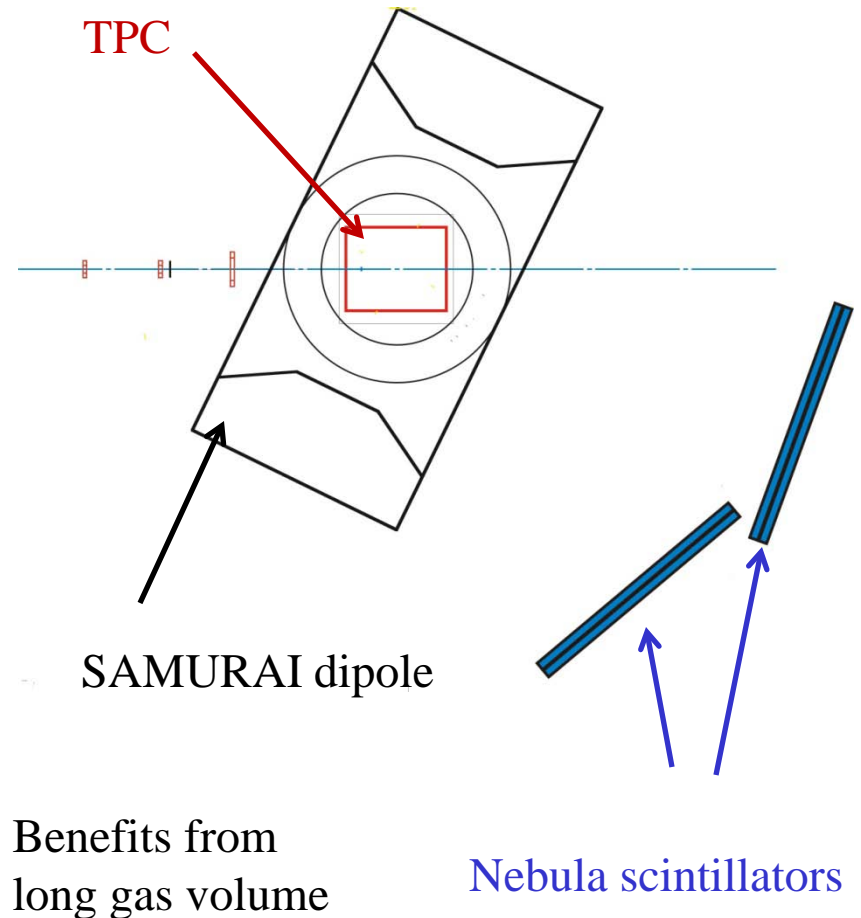
RIKEN Nishina Center
for Accelerator-Based Science



TEXAS A&M
UNIVERSITY

Device: SAMURAI TPC

- Design and build TPC for use within the gap of the SAMURAI dipole.
- The SAMURAI TPC would be used to constrain the density dependence of the symmetry energy at densities greater than saturation density ρ_0 through measurements of:
 - Pion production
 - n, p, t and ^3He flow, including neutron flow measurements with the NEBULA array.
- The TPC may also serve as an active target both in the magnet or as a stand alone device.
 - Asymmetry dependence of fission barriers, extrapolation to r-process. }
 - Giant resonances.
 - ?



EoS Program Measurement Requirements

- The ability to identify both positive and negative pions, as well as the isotopes of hydrogen and helium.
- The ability to separate the tracks of positive pions from the more abundant hydrogen and helium isotopes.
- Measurements of momentum resolutions to about 2%.
- Measurements of momentum and rapidity distributions both in and out of the reaction plane, with impact parameter selection.
- An efficient scintillator wall for trigger purposes.
- The possibility to measure neutrons.
- The possibility to measure heavier isotopes with ancillary detectors placed at forward angles.
 - This requires a thin window in the field cage.

Design requirements for active target

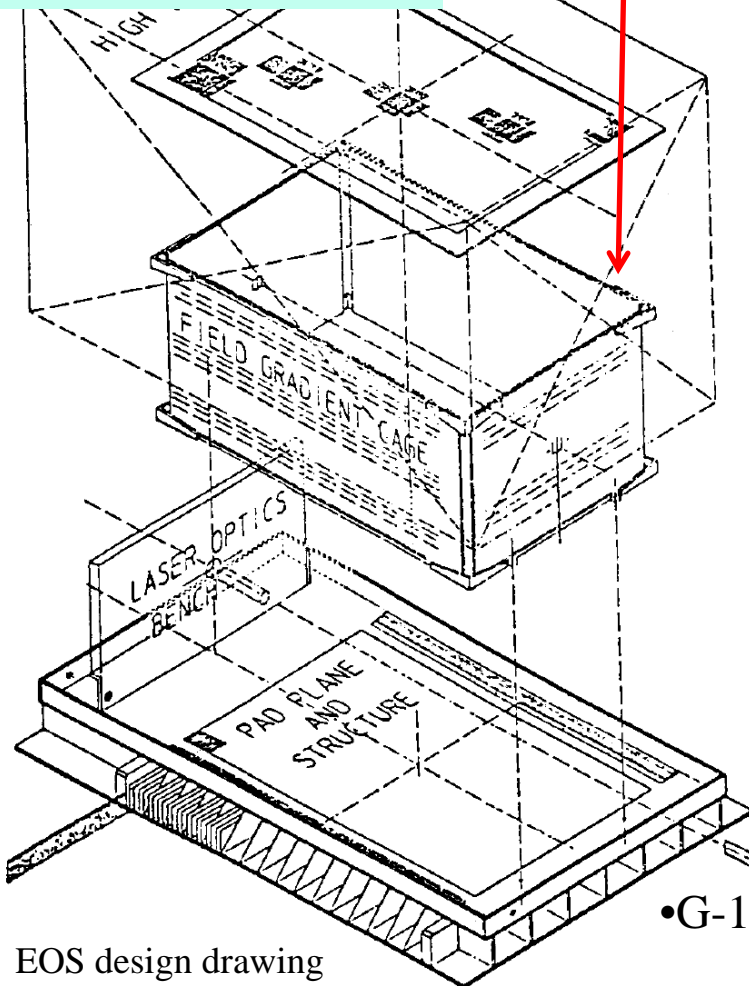
- The ability to run non-standard gases; e.g. H_2 , D_2 , He. Separate detector and insulation gas volumes
 - The drift velocities in pure H_2 , D_2 and He gases are low.
 - The dielectric strengths of pure H_2 , D_2 and He gases are not that high.
 - The lack of UV photon suppression (He) which leads to continuous discharge can be a problem.
 - H_2 and D_2 can be a safety concern.
- The ability to position ancillary detectors at forward angles.
 - This requires a thin window in the field cage.

Motivates
separate
insulation
and
detector
gases

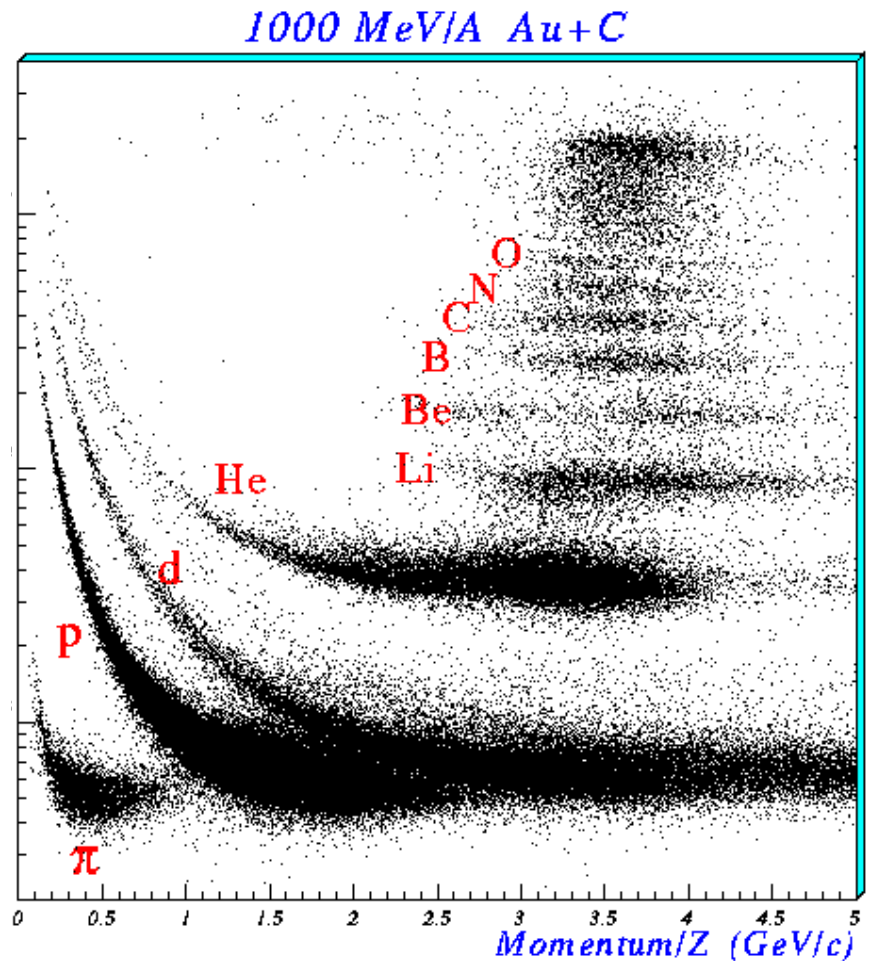
SAMURAI requires a dipole design e.g. EOS TPC

Q in pads, and time of arrival yields x, y, z, dE/dx for each particle.

Rohacell (plastic closed cell material, mostly gas)



EOS design drawing

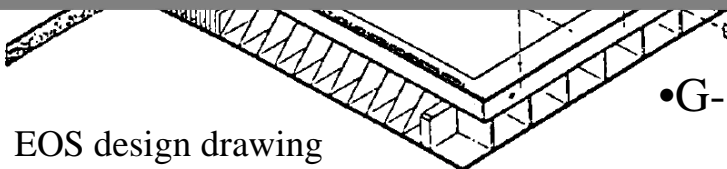
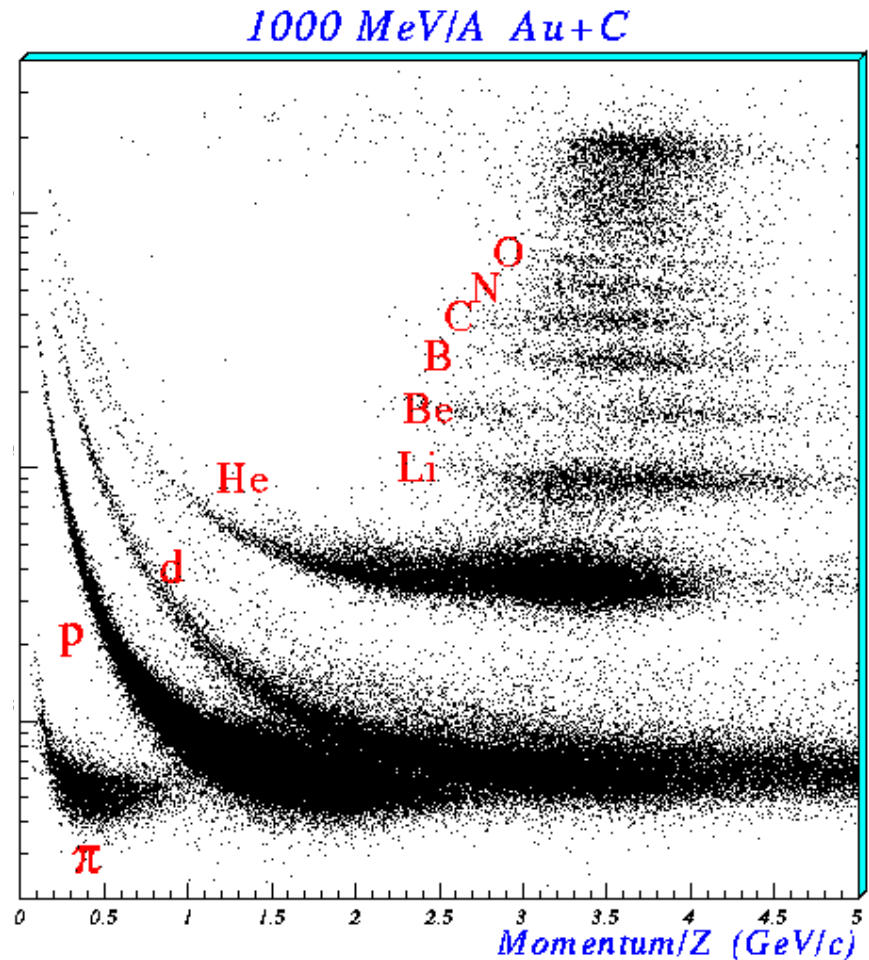


•G-10 (copper pads) Pad plane and electronics structure

Dipole design e.g. EOS TPC

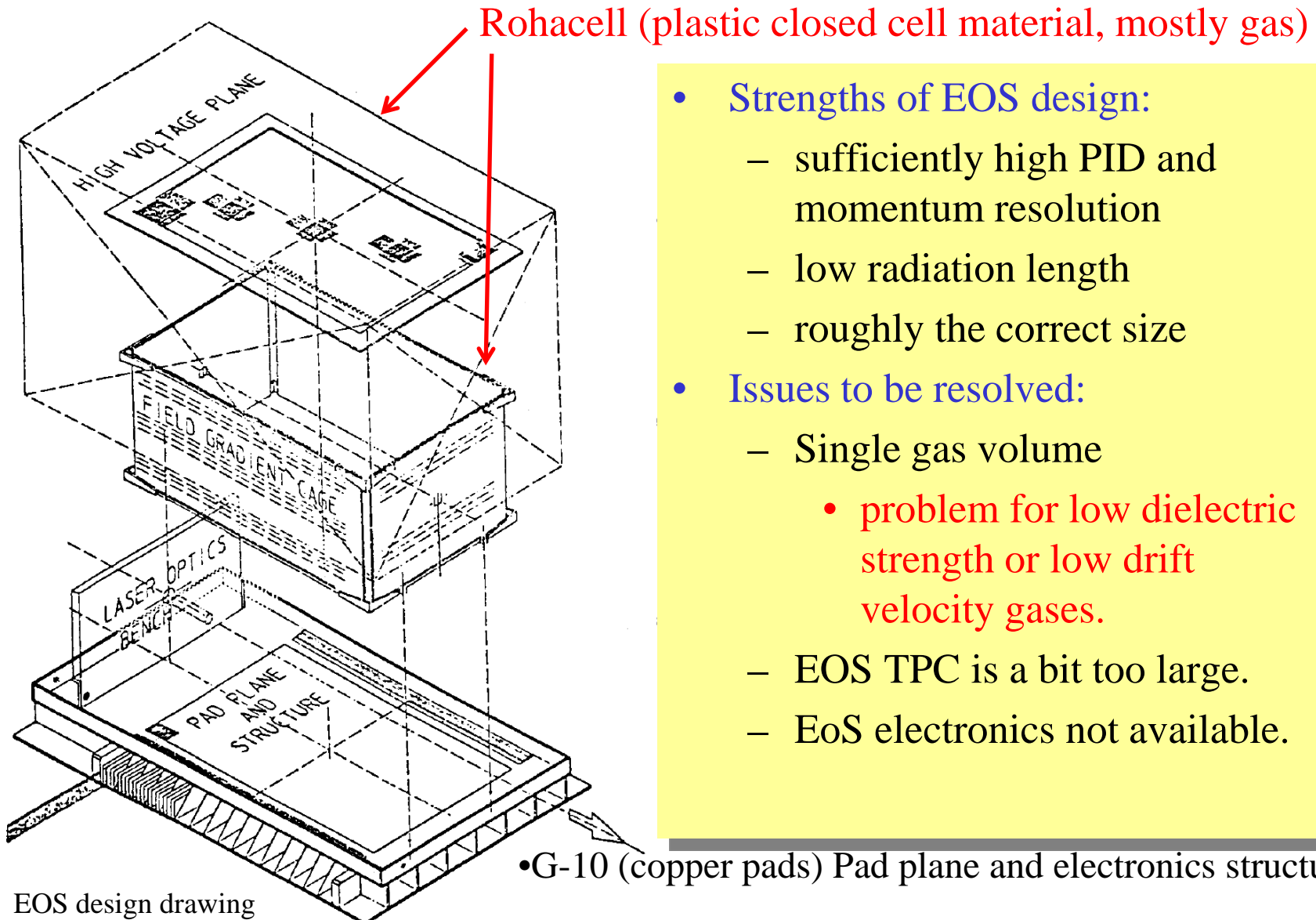
Rohacell (plastic closed cell material, mostly gas)

- Strengths of EOS design:
 - sufficiently high PID resolution



•G-10 (copper pads) Pad plane and electronics structure

Dipole design e.g. EOS TPC



EOS design drawing

- Strengths of EOS design:
 - sufficiently high PID and momentum resolution
 - low radiation length
 - roughly the correct size
- Issues to be resolved:
 - Single gas volume
 - problem for low dielectric strength or low drift velocity gases.
 - EOS TPC is a bit too large.
 - EoS electronics not available.

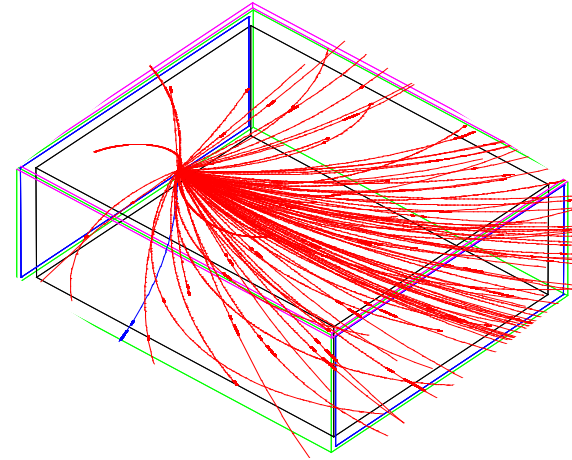
•G-10 (copper pads) Pad plane and electronics structure

Proposed SAMURAI TPC properties

(DOE FOA awarded Oct 2010)

SAMURAI TPC proposed design parameters

Pad plane area	130 cm x 86 cm
Number of pads	11664 (108 x 108)
Pad size	12 mm x 8 mm
Momentum resolution (Isobe)	2%
Drift distance	55 cm
Pressure	1 atmosphere
dE/dx range	Z=1-3 (Star El.), 1-8 (Get El.)
Two track resolution	2.5 cm
Multiplicity limit	200 (may impact absolute pion eff. in large systems.)



GEANT simulation

$^{132}\text{Sn}+^{124}\text{Sn}$ collisions at $E/A=300$ MeV

- Good efficiency for pion track reconstruction is essential.
- Initial design is based upon EOS TPC, whose properties are well documented.

SAMURAI TPC Design Issues

- The choice of electronics readout and the associated mechanics of pad plane and electronics readout (RIKEN/MSU)
- The gas amplification scheme (MSU)
- The overall size and placement within SAMURAI magnet (RIKEN)
- The mechanics for chamber, field cage, target (MSU, TAMU)
 - Ancillary detectors in gas volume?
 - Use of difficult counter gases?
 - Separate insulation gas? (useful for helium or hydrogen)
- The laser system (WMU, RIKEN)

The Electronics Decision

- EoS had a 12 bit ADC. This provides a dynamic range that extends from pions to oxygen.
- STAR (new and old) and ALICE electronics have 10 bit digitization, which reduces the dynamic range
- AGET (SACLAY active target electronics) has a 12 bit ADC, and will be in production in 2012-2013.
- This new electronics has a higher rate capability.
- We proposed to use STAR electronics initially and upgrade to the AGET electronics at the end of 2014.
 - This rules out MICROMEAS, which cannot use STAR electronics (polarity is wrong).

Figures adapted from Rai et al.,

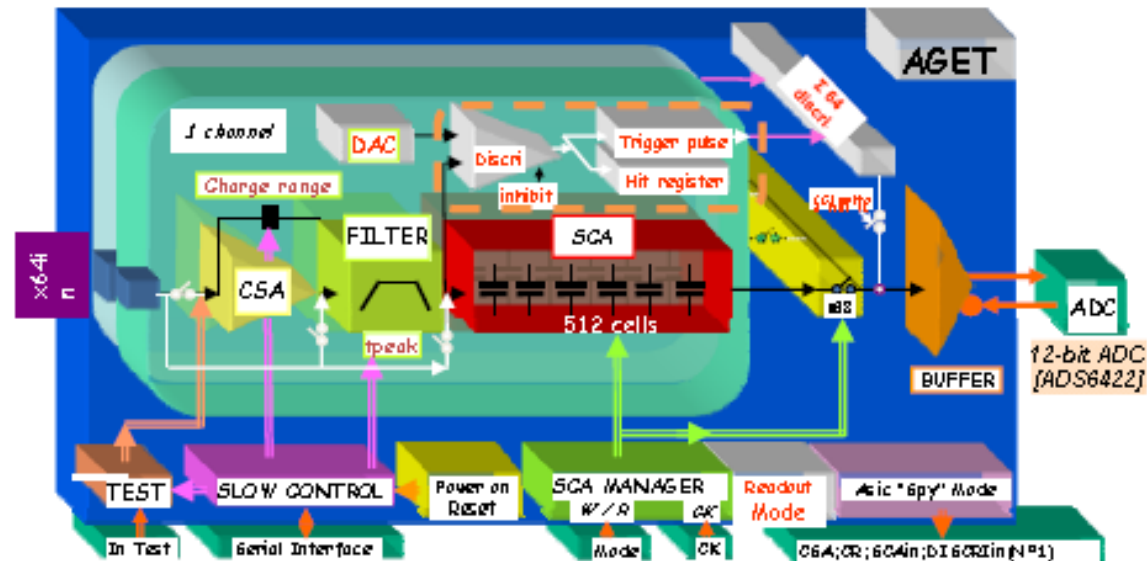
EOS pad signal for centered minimum ionizing particle (in P10)	
dE/dx (eV/cm)	1250
Pad Length (cm)	1.2
Electrons/eV loss	26
Gas Gain	2400
Pad signal (e's)	8800
channel (EoS)	40

Electronics	bits	noise (e's)	Dynamic range	ch/ noise	M.I. ch #	max charge at $y_b/2$	max charge at y_b	max rate(s^{-1})
EOS	12	700	150 fC	3	40	~5	8	20
STAR	10	600	125 fC	.77	40	2-3	4	100
AGET	12	850	120 fC	4.5	40	~5	8	1000

AGET: Planned final SAMURAI electronics

AGET ASIC design: incorporates aspects of the T2K ASIC design

Collaborators from IRFU, GANIL, CENBG, NSCL, RIKEN, U. Kyoto ...



New features

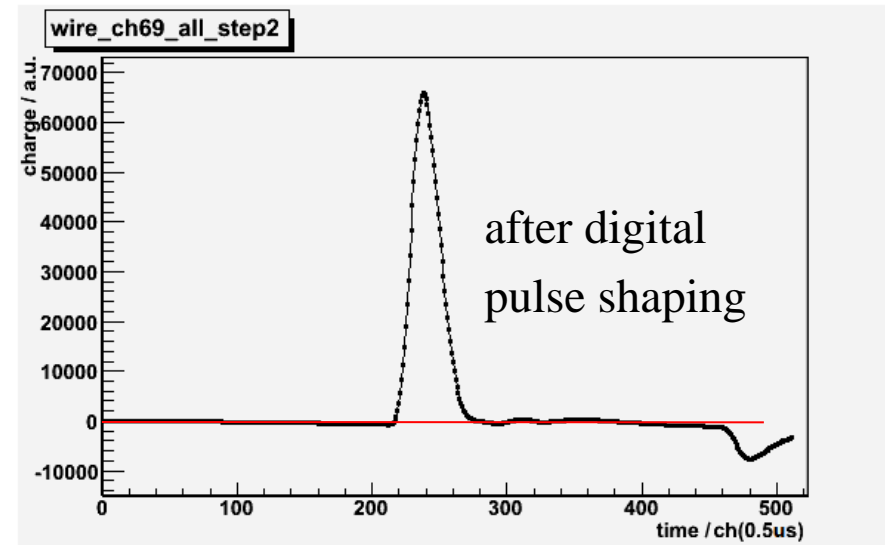
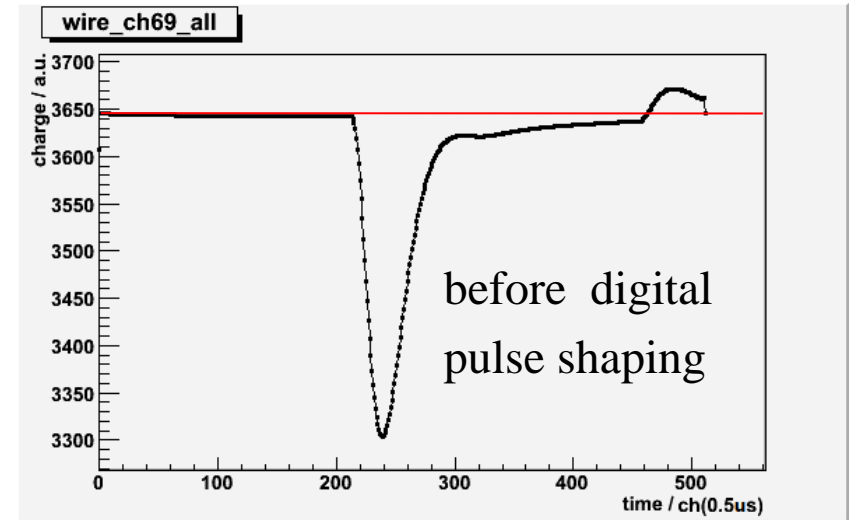
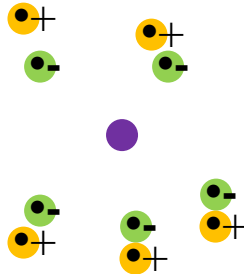
- Discriminator -> 'Hit' channel
- Internal trigger
 - Level 1; hit-pad multiplicity, Level 2; hit pattern analysis
- Trigger rate $\sim 1,000$ Hz (\leftarrow Selective SCA readout)
- Data compression, Timestamp

- Prototype is being tested now.

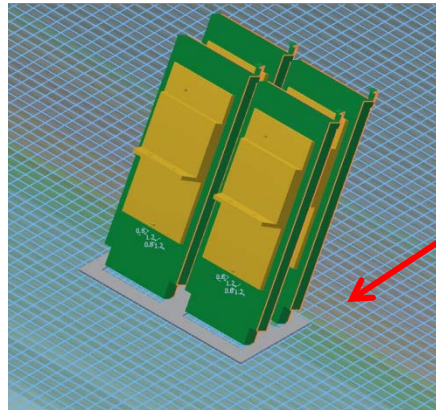
AGET is designed for Micromegas

Can we use AGET electronics with wires?

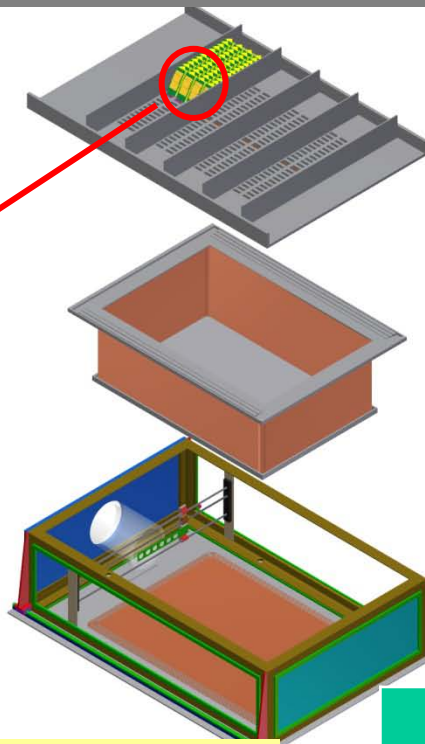
- The AGET and T2K electronics have no pole-zero circuit to compensate for slow ion drift.
- We have observed the slow ion drift in a test of wire readout technology using the T2K readout board.
- We have removed the slow ion drift tail by digital pulse shaping techniques.



Samurai TPC conceptual design features



FEE card from
STAR electronics
sitting on pad plane



Pad plane and electronics

Field cage

TPC chamber

Figure by McIntosh, Dunn, Barney, Gilbert

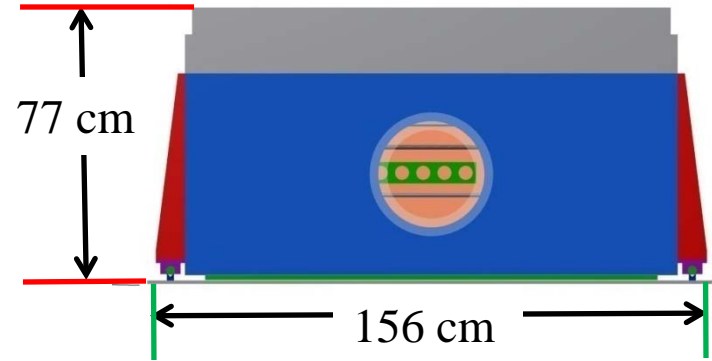
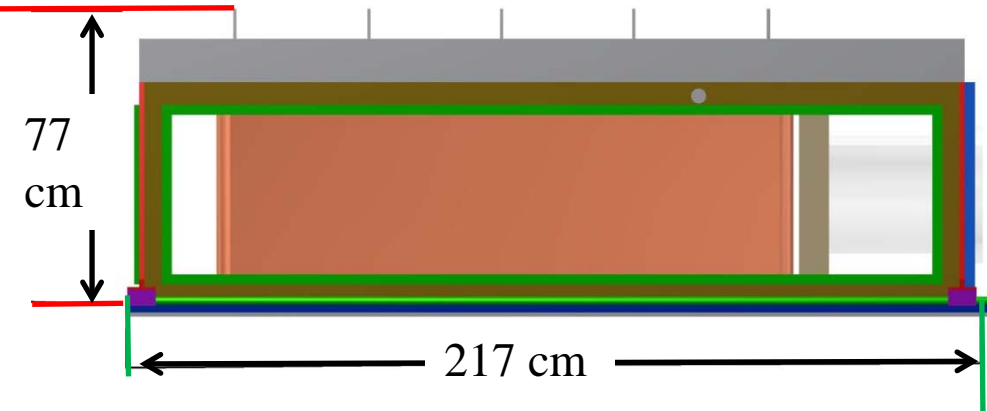
- Separate detector and insulation gas volumes.
- Very thin field cage and chamber walls to allow measurements of fragments and neutrons.
- A pad plane design that allows switch from STAR to AGET electronics.

SAMURAI TPC conceptual design parameters

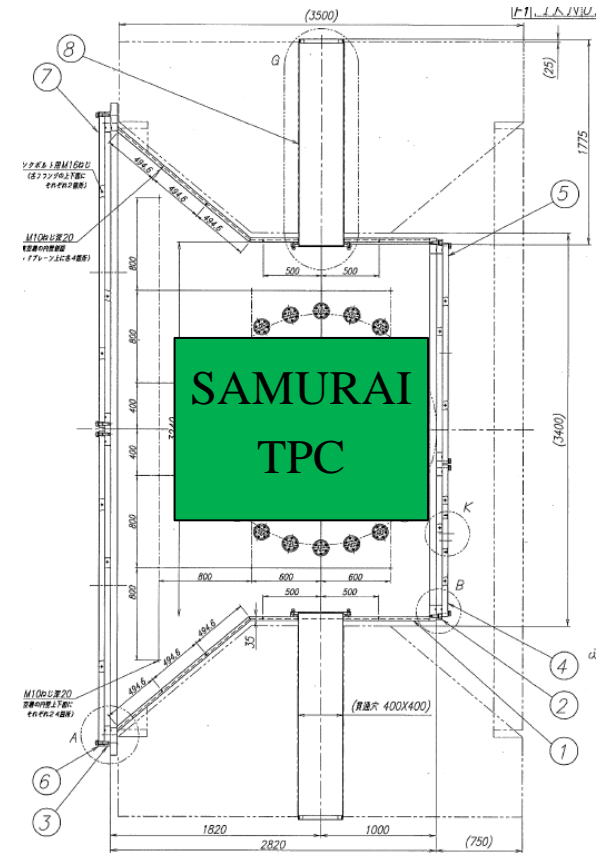
Pad plane area	130 cm x 86 cm
Number of pads	11664 (108 x 108)
Pad size	12 mm x 8 mm
Drift distance	53 cm
Pressure	1 atmosphere

TPC chamber dimensions (not final)

Figures by McIntosh, Dunn, Barney, Gilbert



- Design has reentrant beam line with window just before the target ladder and field cage window.
- Right section in the “side view” figure above contains the reentrant window, the target ladder and an optical bench for calibration laser system.
- Upper right figure shows the rail mounts that will allow the TPC to slide inside the chamber. The rails bolt to existing holes in the chamber



Present status of SAMURAI TPC project

- Conceptual design will be completed this month.
 - followed by design review and costing.
- STAR electronics is packed and will be shipped to Michigan soon.
- Detailed design of the chamber will be completed by the end of summer.
- Construction and assembly will be completed by end of 2012.
- Testing will be completed by summer 2013
- Installation in RIKEN is planned for 2014.

Star electronics before packing

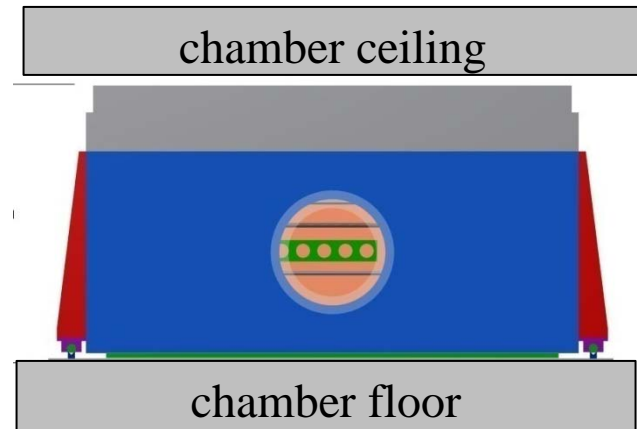


Photos by Chajecski, et al.

Issues for discussion

(What we presently know. It is not a complete list)

- Water cooling:
 - Need to remove ~ 2 kW of power dissipated in FEE and RDO cards
- Clean power: $\sim 4-5$ kW?
- Installation:
 - rails bolted to chamber floor
 - Access for insertion
- Electronics location
- gas handling
- laser
- alignment
- clean room



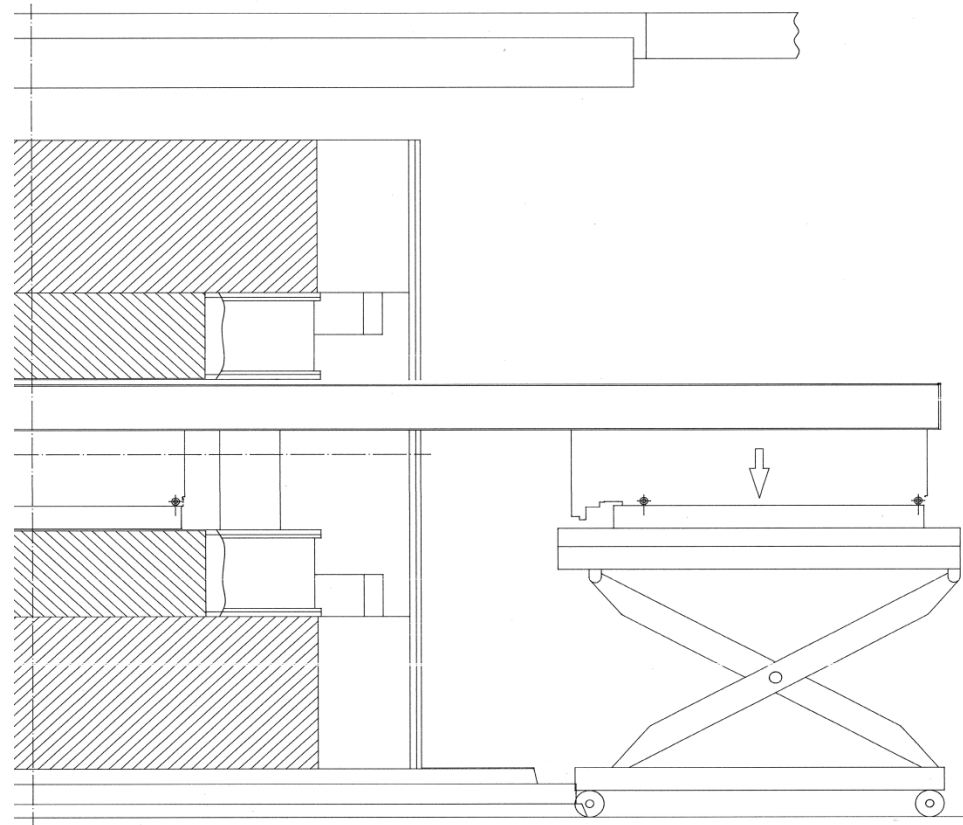
mass ~ 500 kg

Figure by McIntosh, Dunn, Barney, Gilbert

Issues for discussion

(What we presently know. It is not a complete list)

- Water cooling:
 - Need to remove ~ 2 kW of power dissipated in FEE and RDO cards
- Clean power: $\sim 4-5$ kW?
- Installation:
 - rails bolted to chamber floor
 - Access for insertion
- Electronics location
- gas handling
- laser
- alignment
- clean room

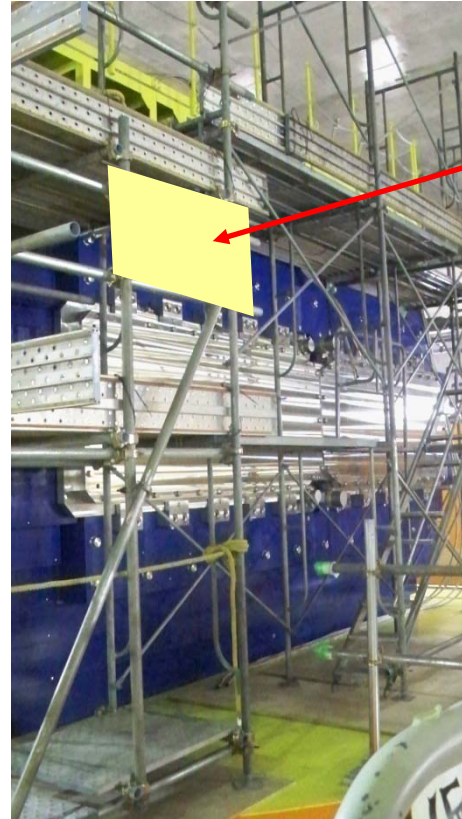


EoS TPC insertion design

Issues for discussion

(What we presently know. It is not a complete list)

- Water cooling:
- Clean power: ~ 4-5 kW?
- Installation:
- Electronics location
 - location of RDO cards near the TPC
 - location of VME crate and power supplies
- gas handling
- laser
- alignment
- clean room

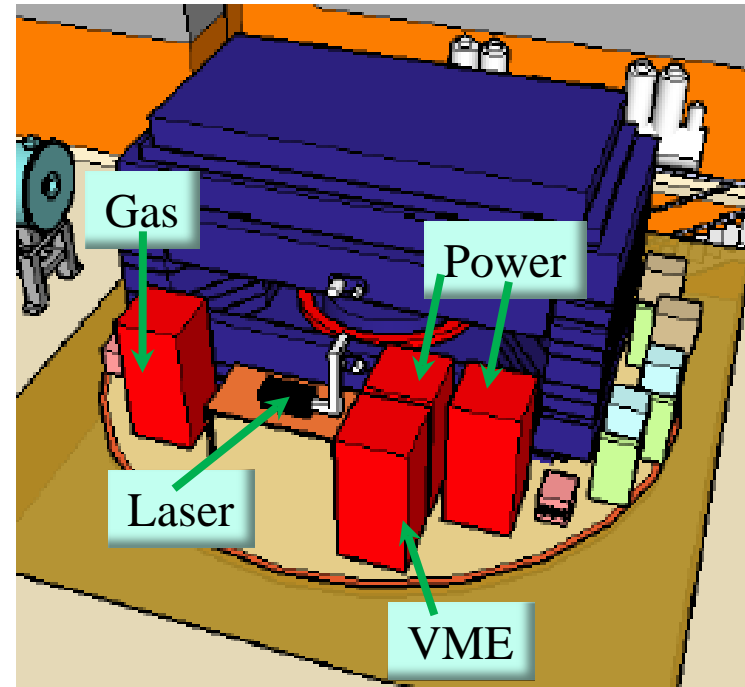


- RDO cards
 - Need to be within 2 m of TPC
 - Can be removed when TPC not in use.

Issues for discussion

(What we presently know. It is not a complete list)

- Water cooling:
- Clean power: ~ 4-5 kW?
- Installation:
- Electronics location
 - location of RDO cards near the TPC
 - location of VME crate and power supplies
⇒ 2-3 racks
- gas handling: 1 rack
- laser
- alignment: want $\vec{E} \perp \vec{B}$ and knowledge of location.
- clean room: class 10000 with access to crane



- Laser positioning is critical
- Positioning of VME, gas controller and power supplies is not critically important.

Summary and acknowledgements

- The RIBF facility is the most suitable accelerator facility for many of these measurements.
- The SAMURAI magnet is well suited for a TPC designed for nucleus-nucleus collisions.
 - We would appreciate having a web site where drawings and other documentation about the SAMURAI dipole and its associated devices, including the SAMURAI TPC, could be stored and retrieved.
- We appreciate the support of the RIBF facility and the SAMURAI collaboration for this program.
- I would like to acknowledge the efforts of the SAMURAI TPC collaboration, which provide most of the information presented.
- We also acknowledge funding of the US effort by Department of Energy for 2010 to 2015



U.S. DEPARTMENT OF
ENERGY

Office of
Science

MICHIGAN STATE
UNIVERSITY



RIKEN Nishina Center
for Accelerator-Based Science



TEXAS A&M
UNIVERSITY