"Development of the SpiRIT TPC for probing the symmetry energy"

Jonathan Barney

NuSYM16

June 13, 2016

千里之行，始於足下

A journey of a thousand mile begins with a single step

WiFi

- Network: Physics-5G (or Physics-2G)
- Password: Tsinghua

How can we study neutron stars?

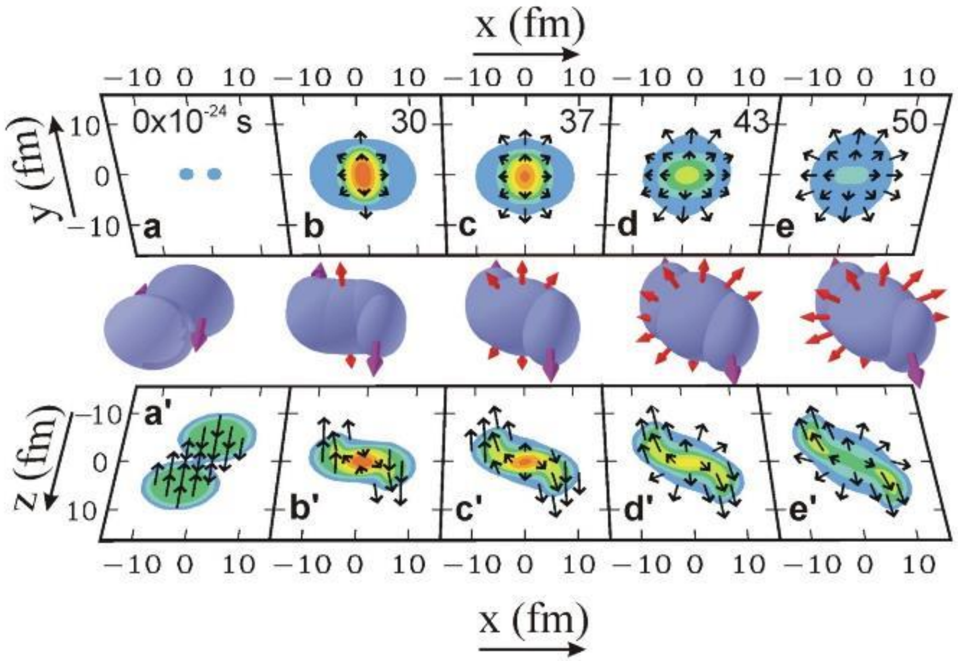
There are some limits to what we can explore firsthand

Image - @KawikaSingsonPhotography

Heavy ion collisions

- Heavy ion collisions provide a short lived, dense environment to study
- Rare isotopes provide systems with high asymmetry

- Heavy ion collisions
  <u>+ rare isotopes</u>
  = neutron star laboratory



Danielewicz, P. et al. Science. 298 pp. 1592-1596 (2002)

Time Projection Chamber – our camera for collisions

- Time projection chamber is ideally suited for identifying particles in magnetic field

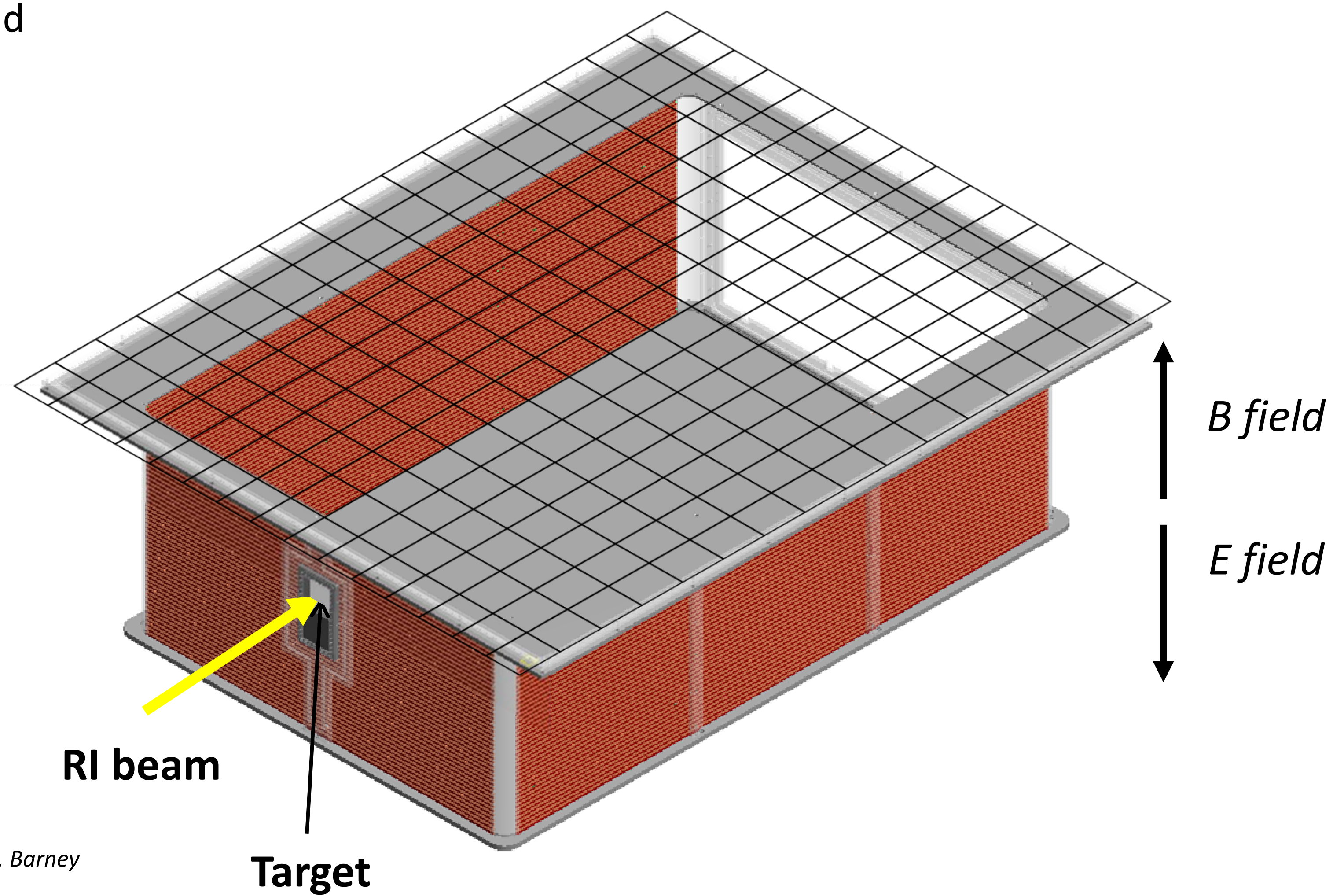


Figure by J. Estee and J. Barney

Time Projection Chamber – our camera for collisions

- Time projection chamber is ideally suited for identifying particles in magnetic field
- Products from reaction ionize detector gas inside a detection volume, called the field cage

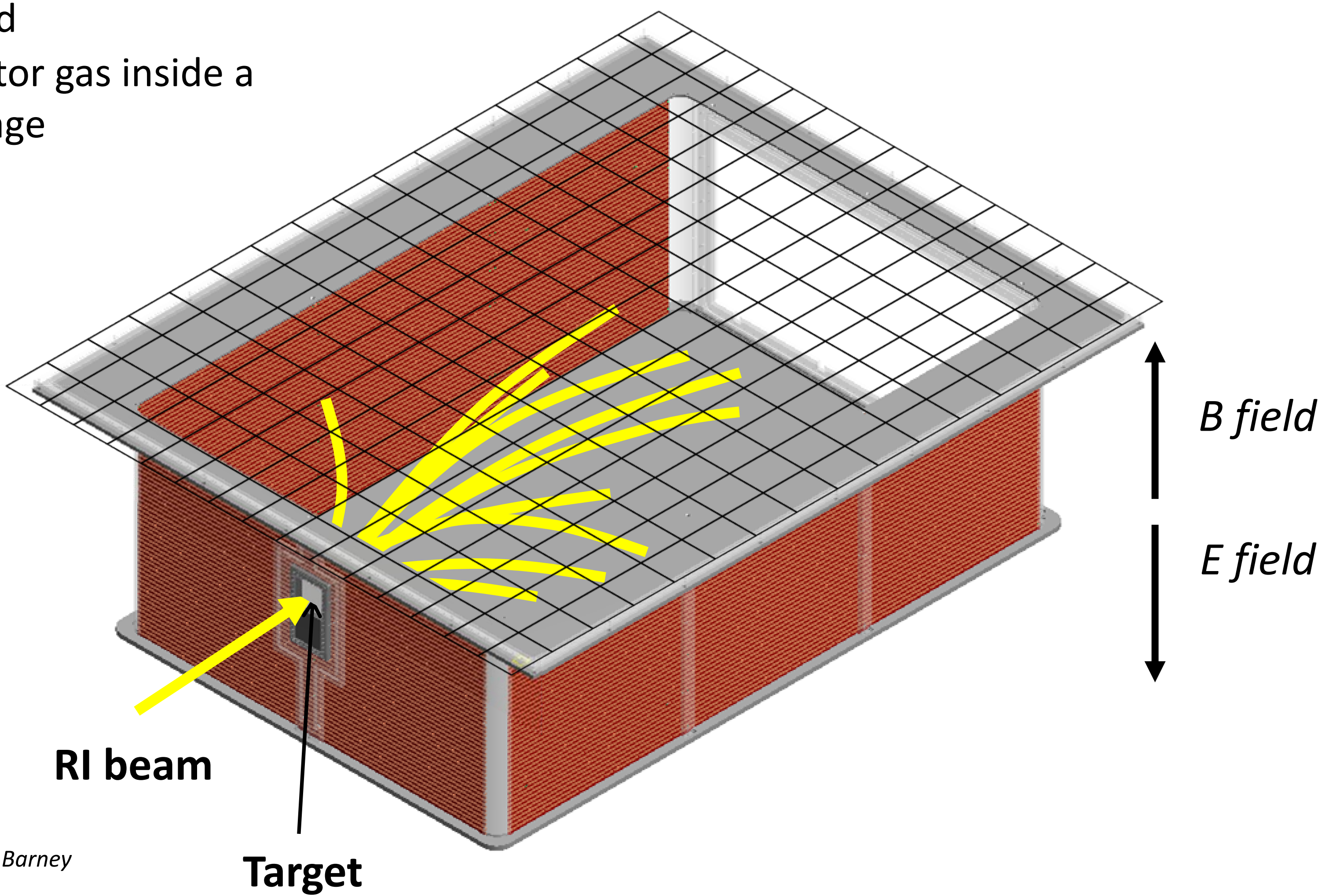


Figure by J. Estee and J. Barney

Time Projection Chamber – our camera for collisions

- Time projection chamber is ideally suited for identifying particles in magnetic field
- Products from reaction ionize detector gas inside a detection volume, called the field cage
- 2-D path traced out on pad plane

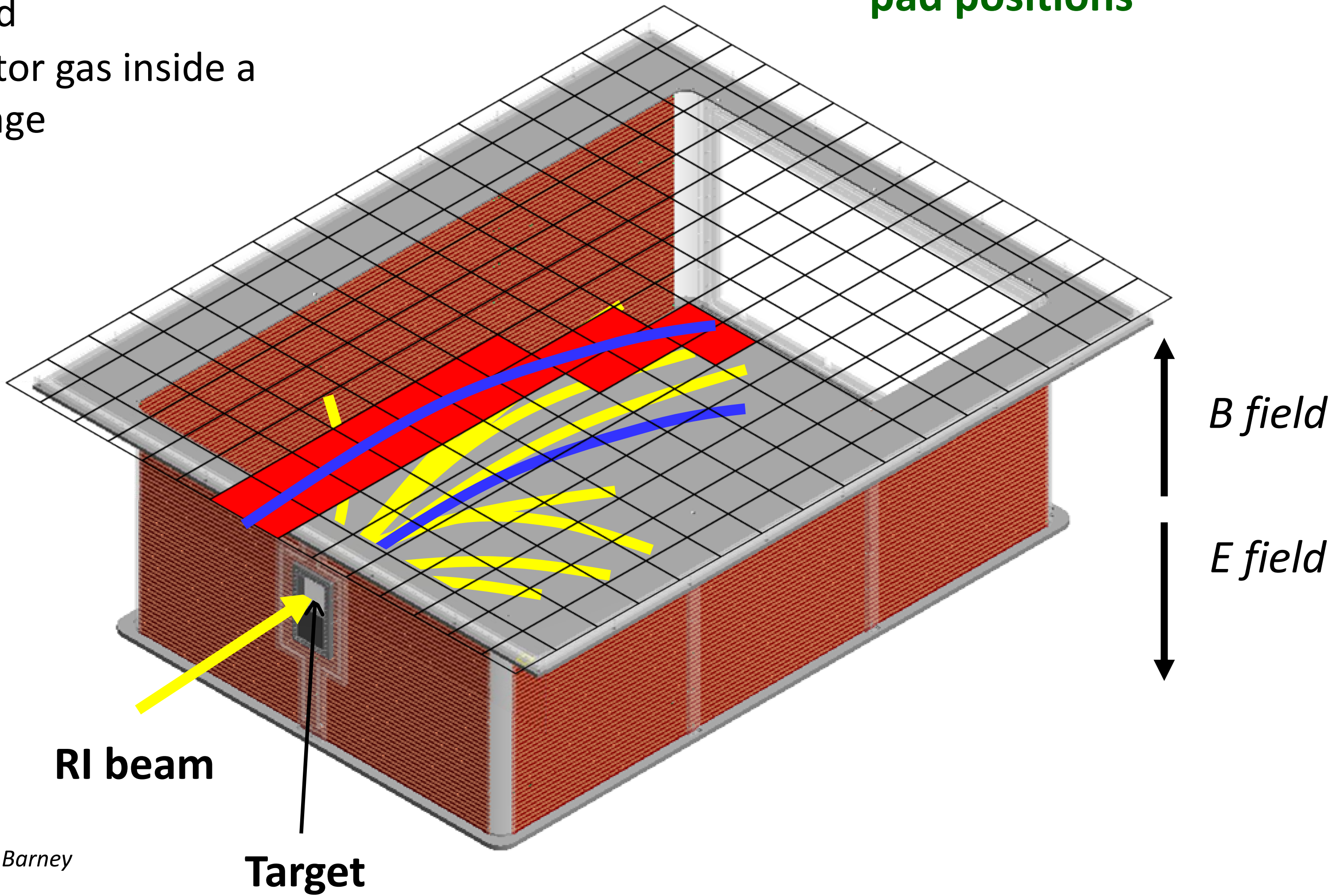


Figure by J. Estee and J. Barney

Time Projection Chamber – our camera for collisions

- Time projection chamber is ideally suited for identifying particles in magnetic field
- Products from reaction ionize detector gas inside a detection volume, called the field cage
- 2-D path traced out on pad plane
- The time at which the electrons hit the pads provides the third dimension

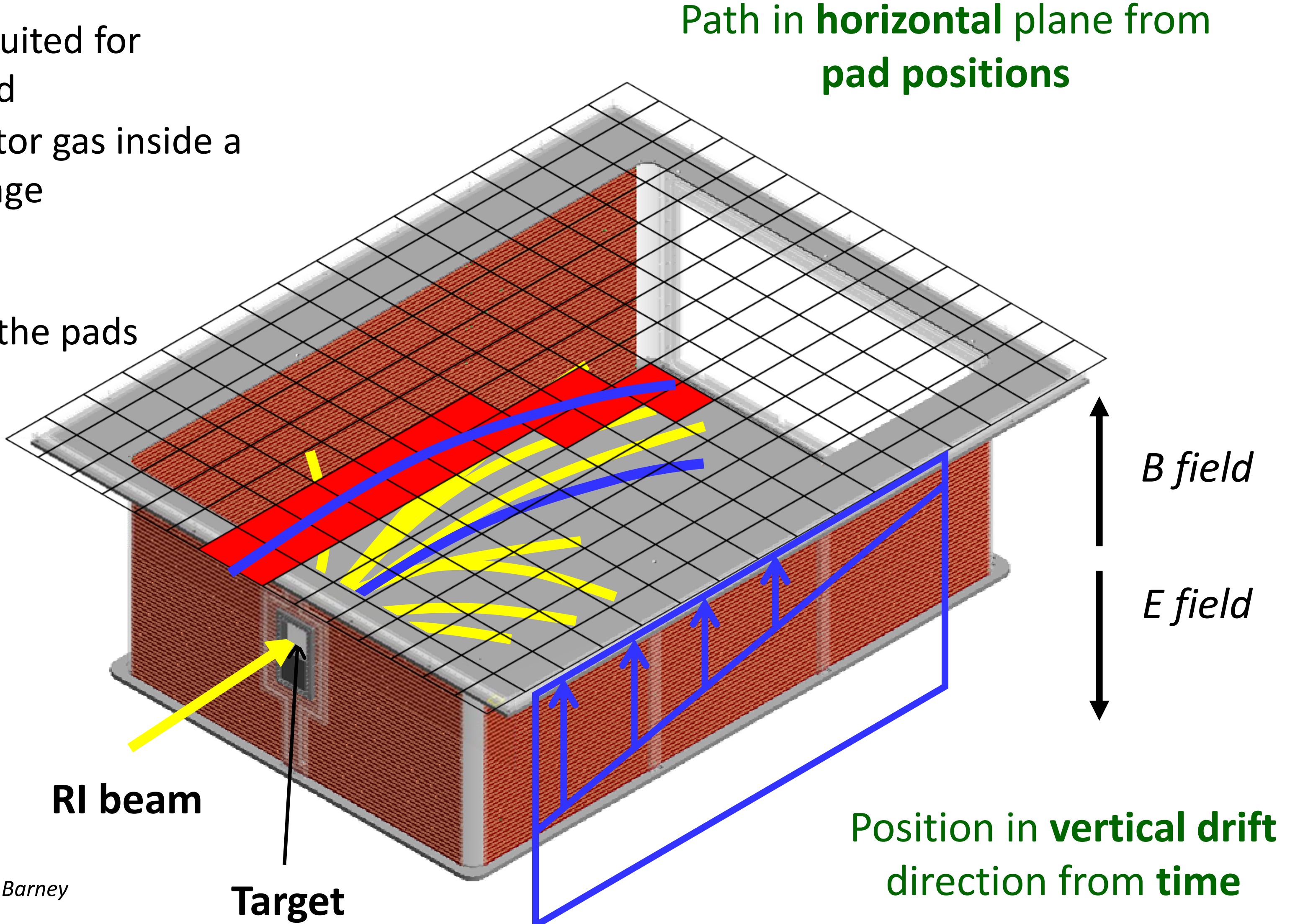


Figure by J. Estee and J. Barney

SpiRIT TPC- Design

- Design work split between NSCL and Texas A&M

Undergraduate involvement

- Design work split between NSCL and Texas A&M
- High level of undergraduate involvement in design and construction



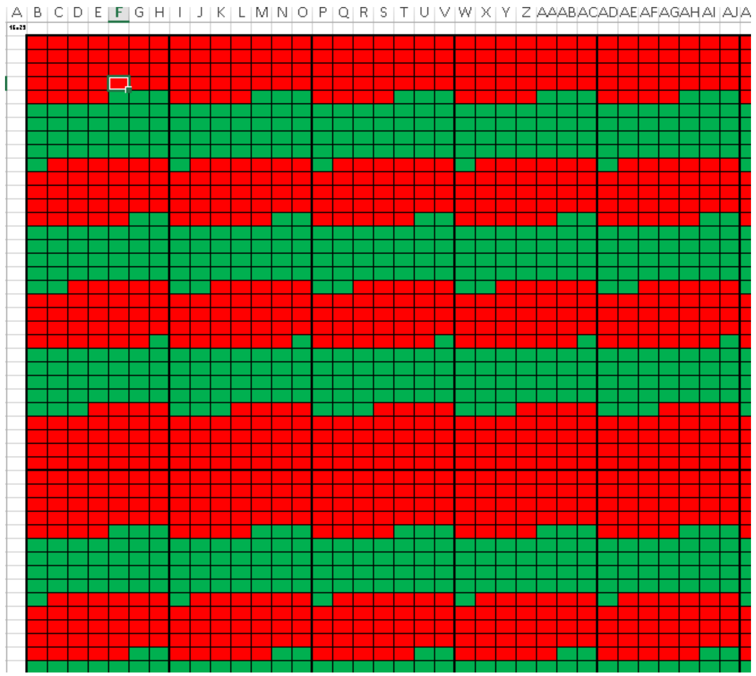


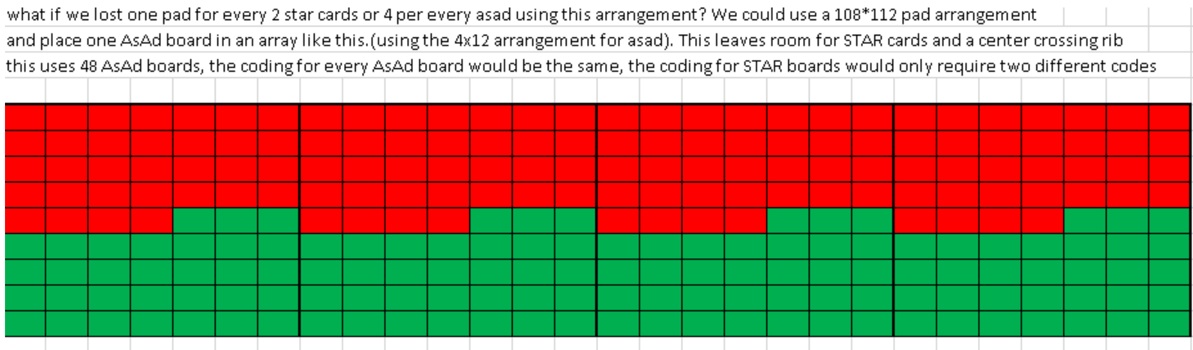




Pad plane layout

- Plan out pad plane (12,096 channels)
- How to arrange pad-to-electronics connections?
- Produce a pattern that can be used for two types of electronics:
  - STAR: 32 channel
  - GET: 256 channel
- Have to demonstrate ideas to collaborators

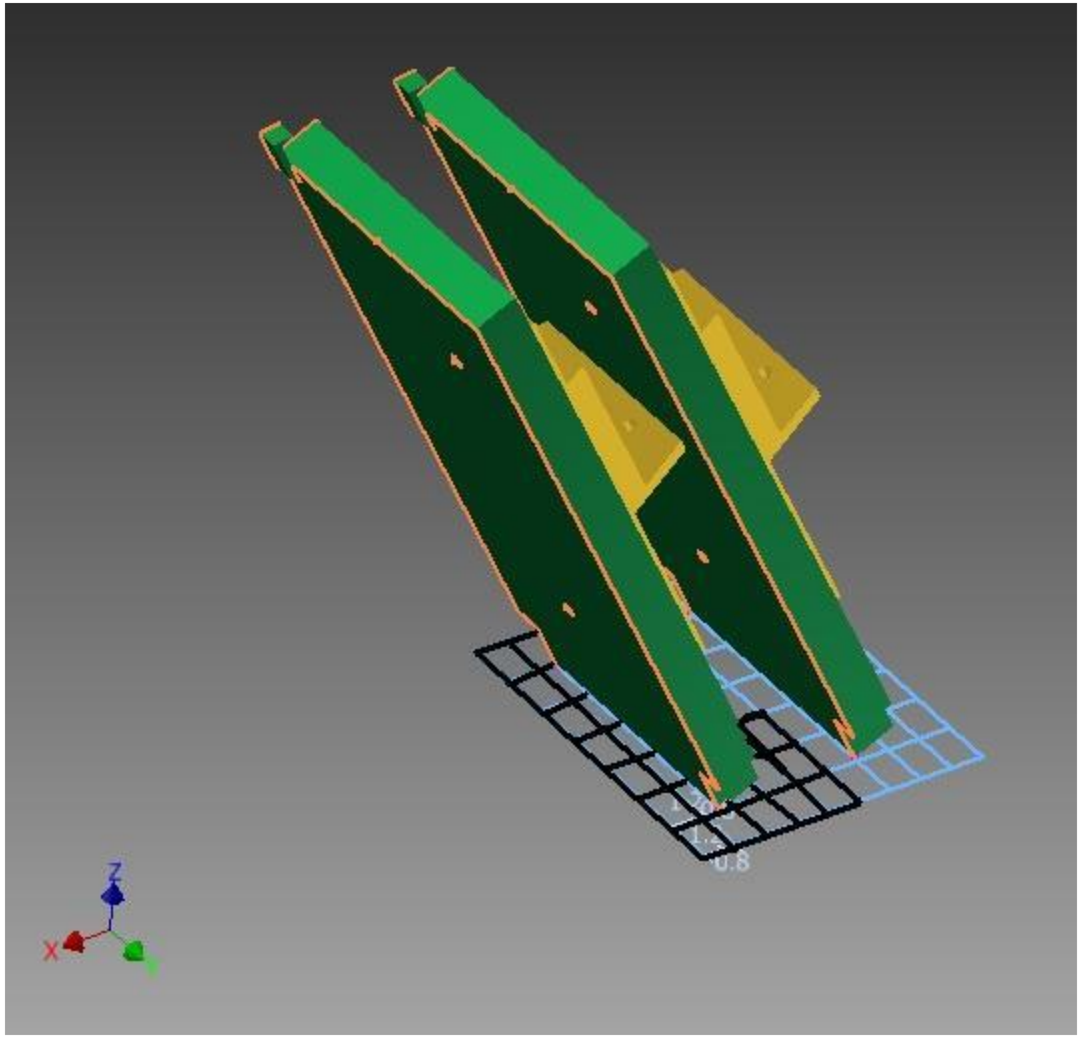




Initial ideas were done by making patterns in Excel.

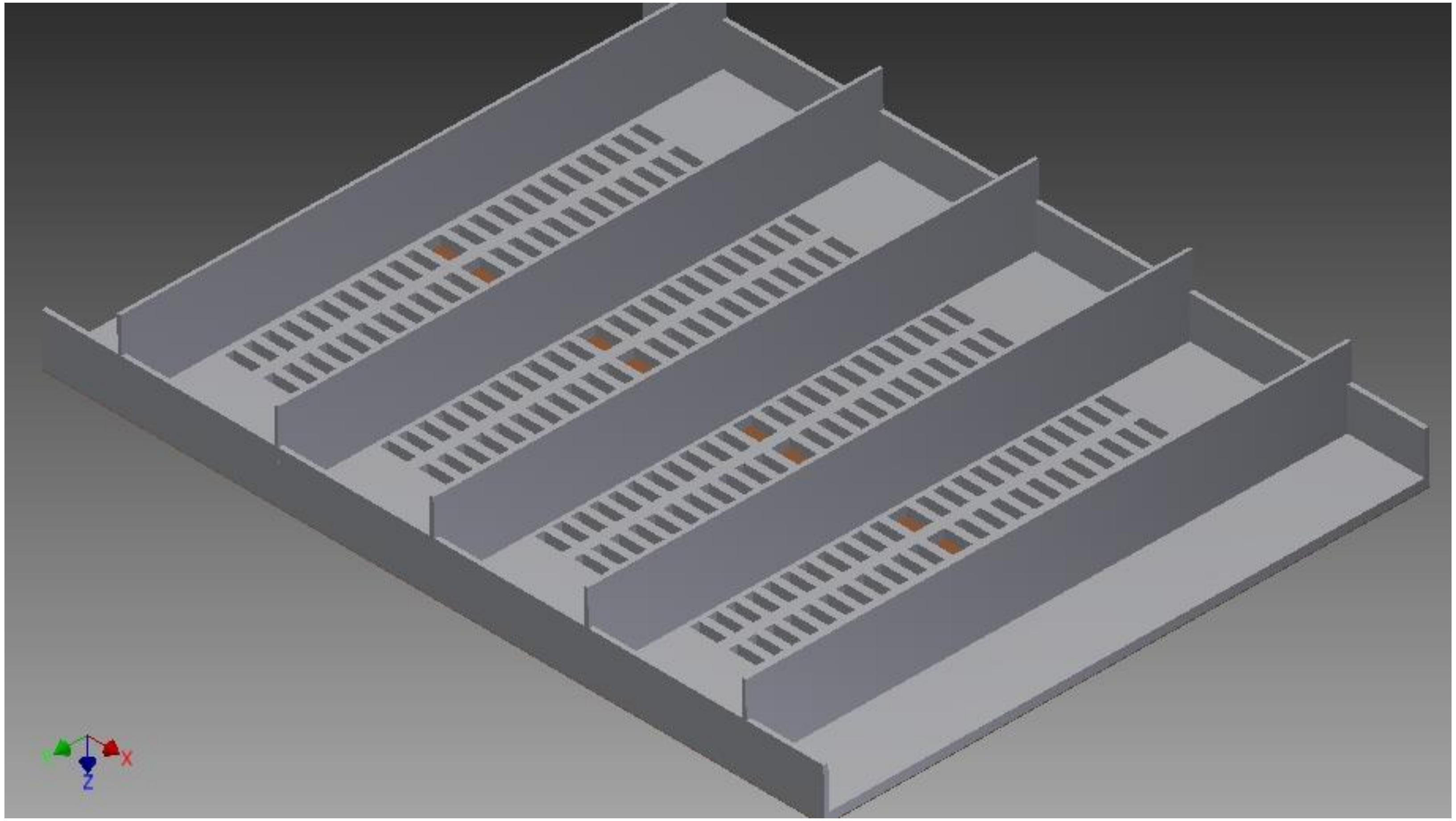
Pad plane layout

- 3D designs are necessary:
  - Demonstrate that electronics fit in allocated space
  - Much better presentation value
  - 3D files are very useful as we get more and more parts coming together

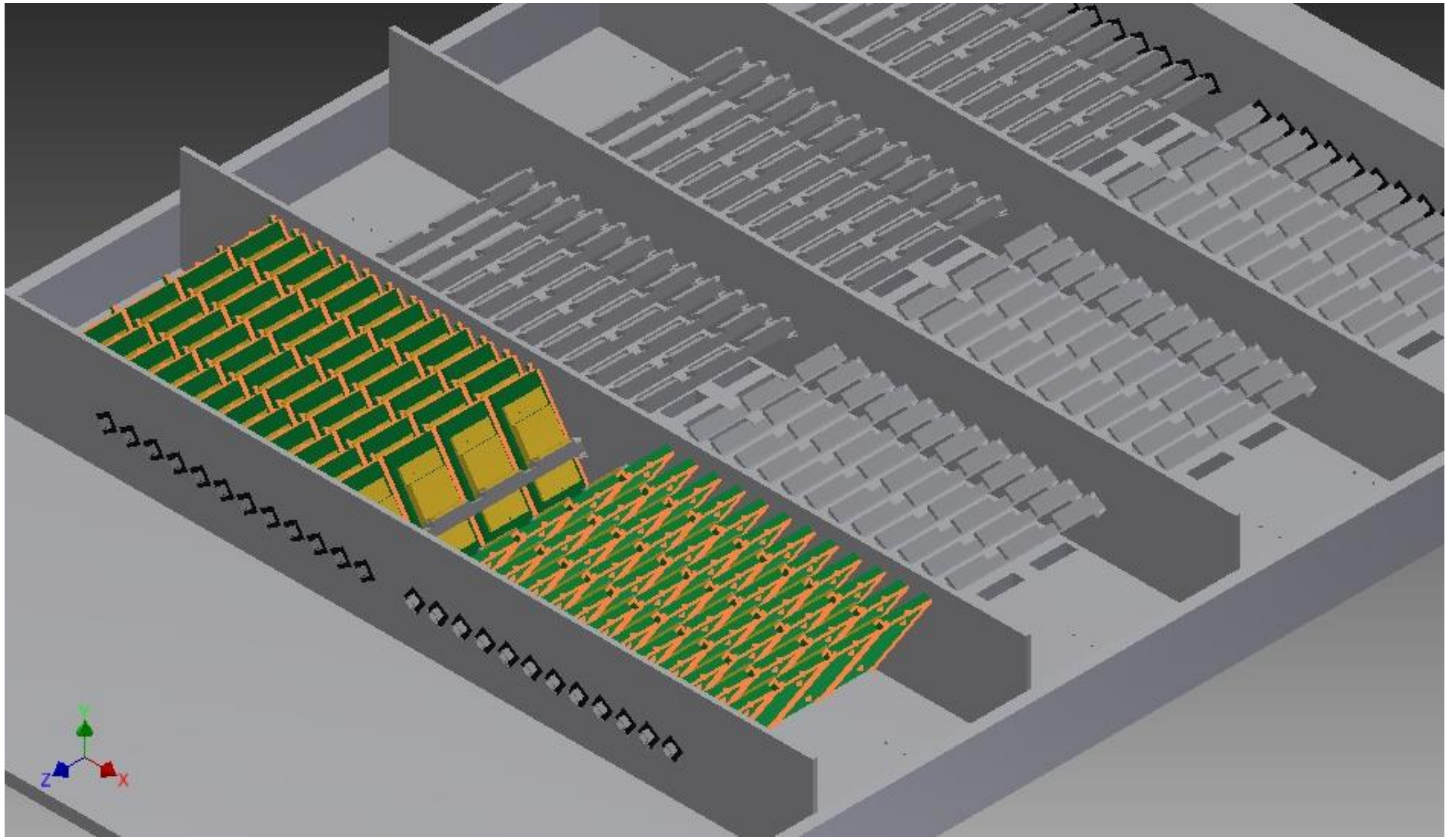


Later work was done with Autodesk Inventor Professional

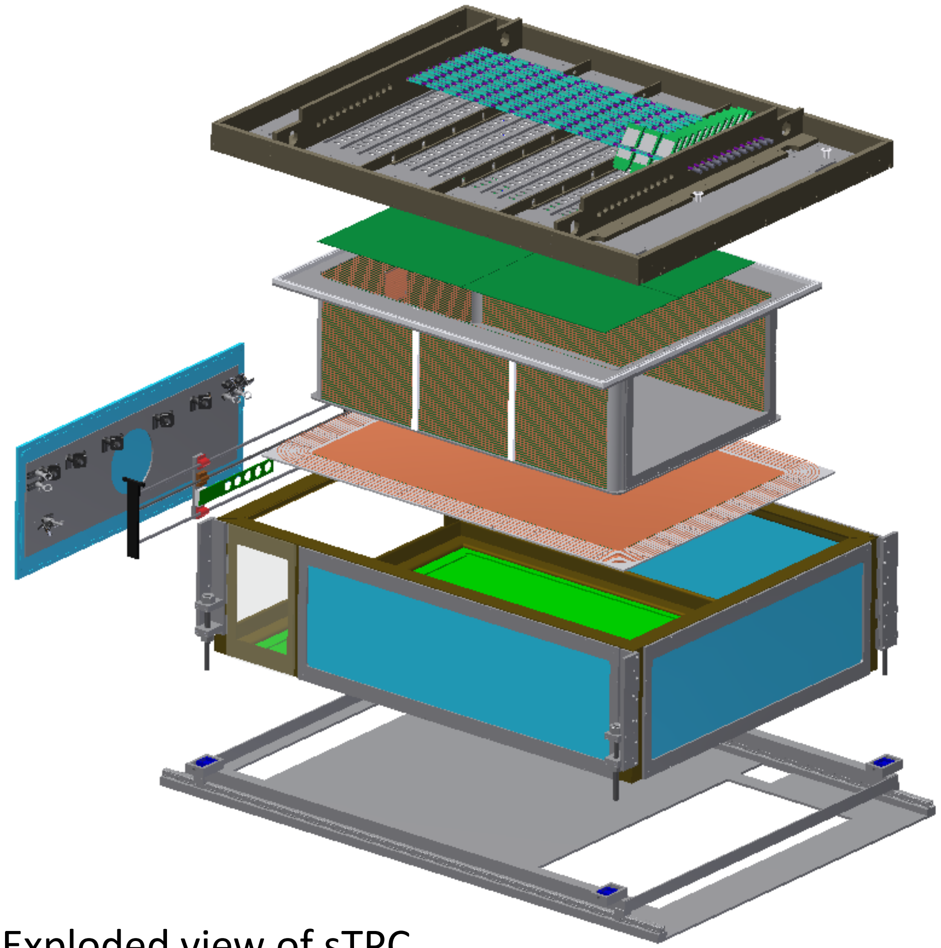
A frame to hold everything



And putting it together



SπRIT Time Projection Chamber



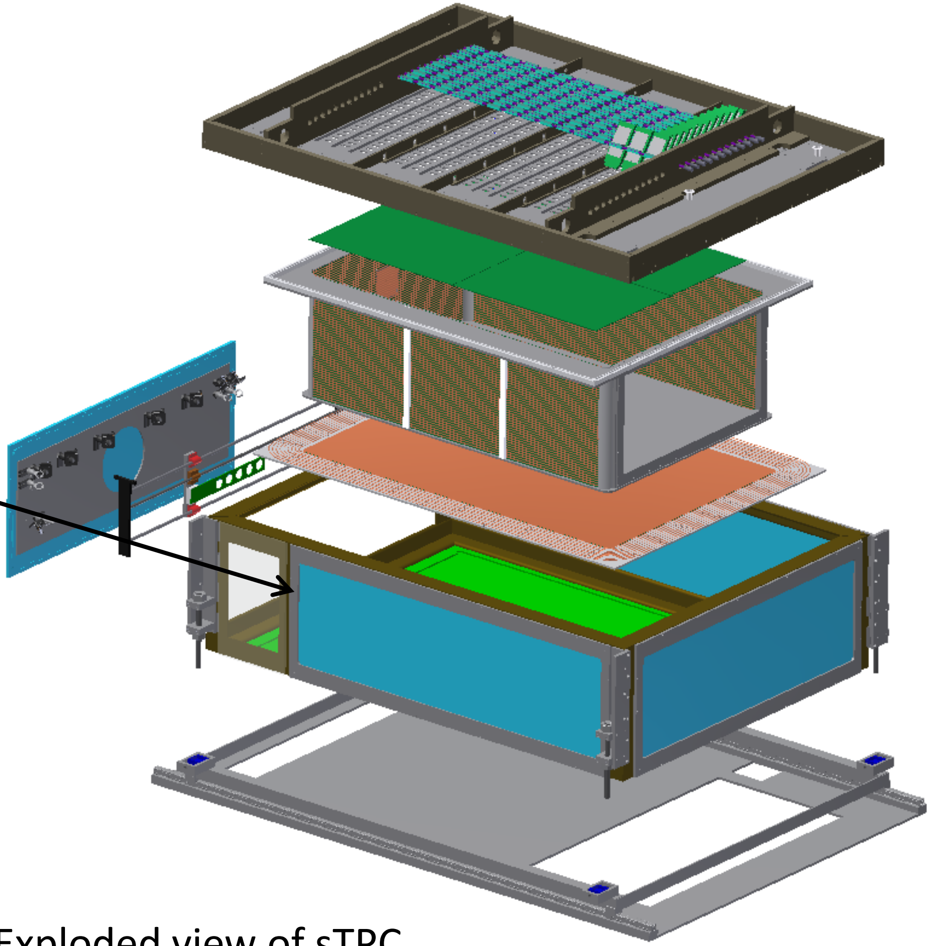
Exploded view of sTPC

Slide adapted from R. Shane

SπRIT Time Projection Chamber

Thin-Walled Enclosure

Thin-walled gas enclosure keeps gas in and lets particles out



Exploded view of sTPC

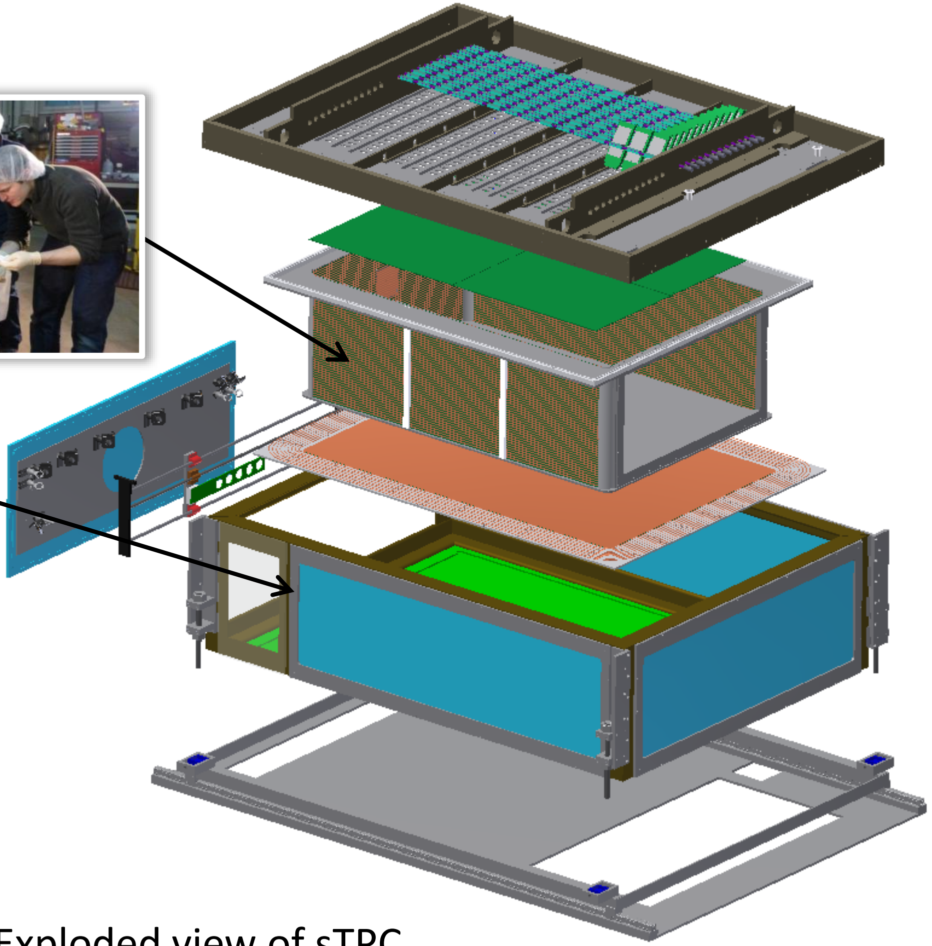
Slide adapted from R. Shane

SπRIT Time Projection Chamber

Field cage creates
electron drift region

Field Cage

Thin-Walled Enclosure



Exploded view of sTPC

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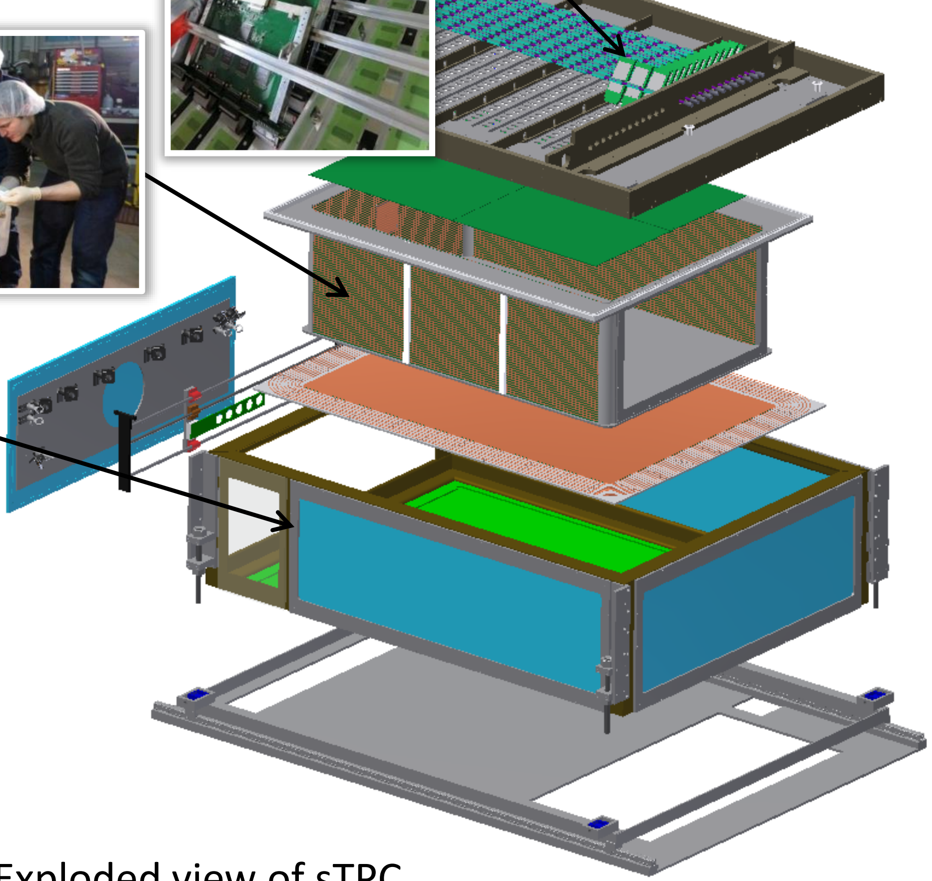
SπRIT Time Projection Chamber

Front End Electronics

Front End Electronics read out pad plane signal – Generic Electronics for TPC

Field Cage

Thin-Walled Enclosure



Exploded view of sTPC

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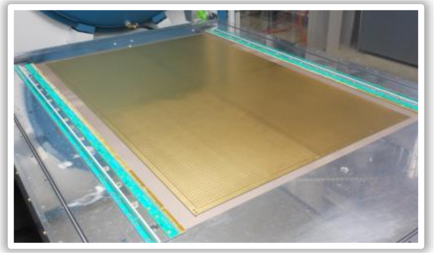
SπRIT Time Projection Chamber

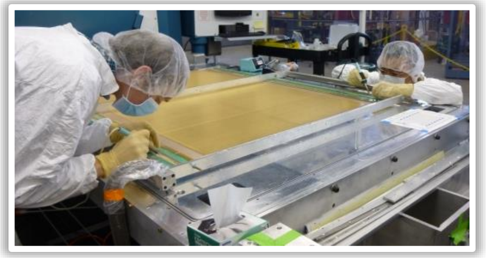
Front End Electronics

Pad Plane

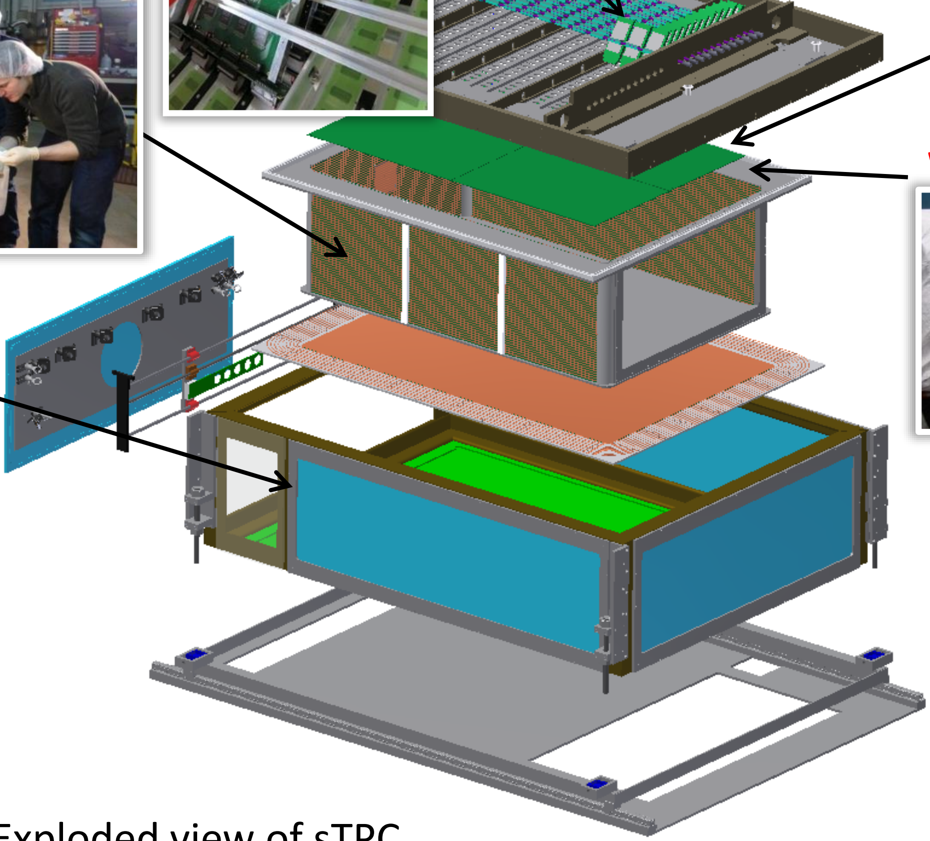


Field Cage

Wire Planes



Thin-Walled Enclosure



Exploded view of sTPC

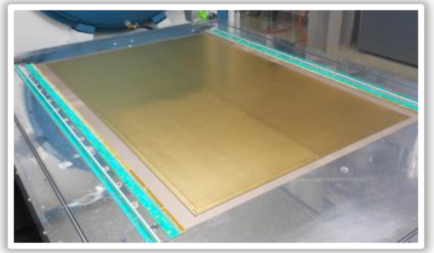
Wire planes amplify the electron signal, which is read out on the pad plane

Slide adapted from R. Shane

SπRIT Time Projection Chamber

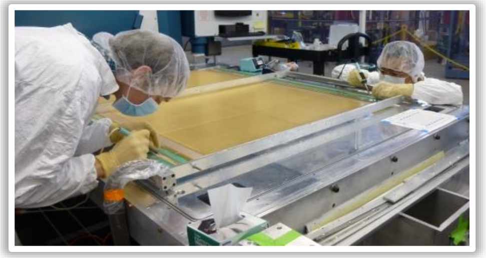
Front End Electronics

Pad Plane

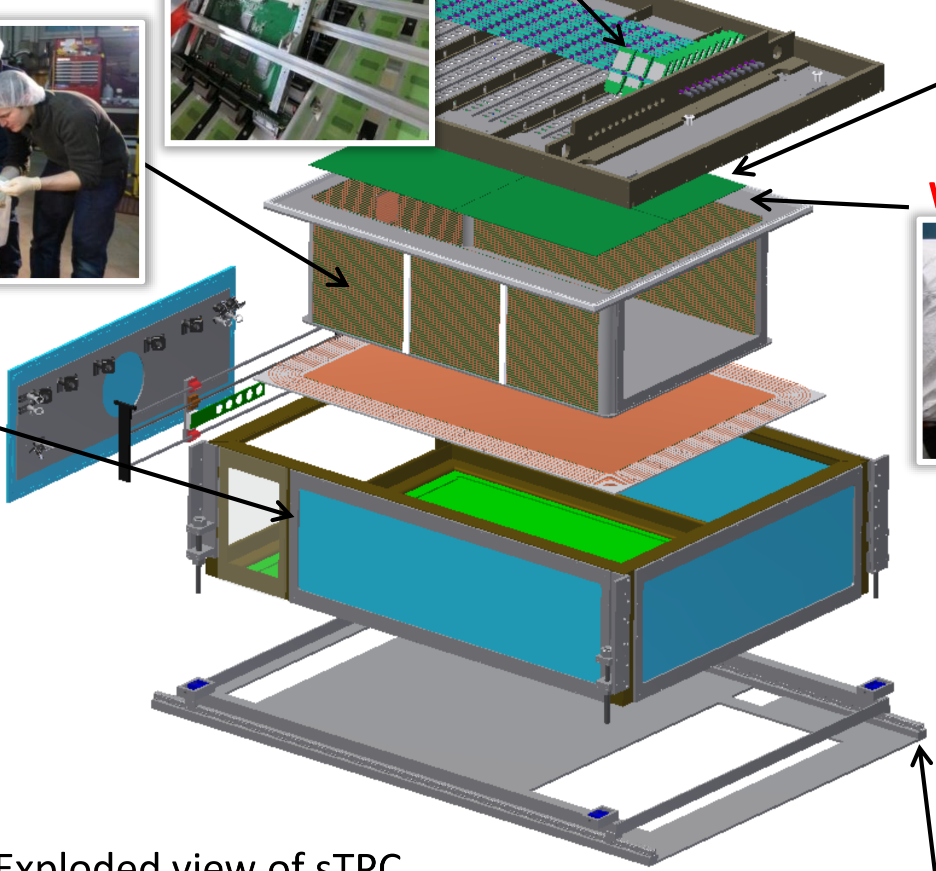


Field Cage

Wire Planes



Thin-Walled Enclosure



Rails for smooth, safe insertion of TPC into magnet

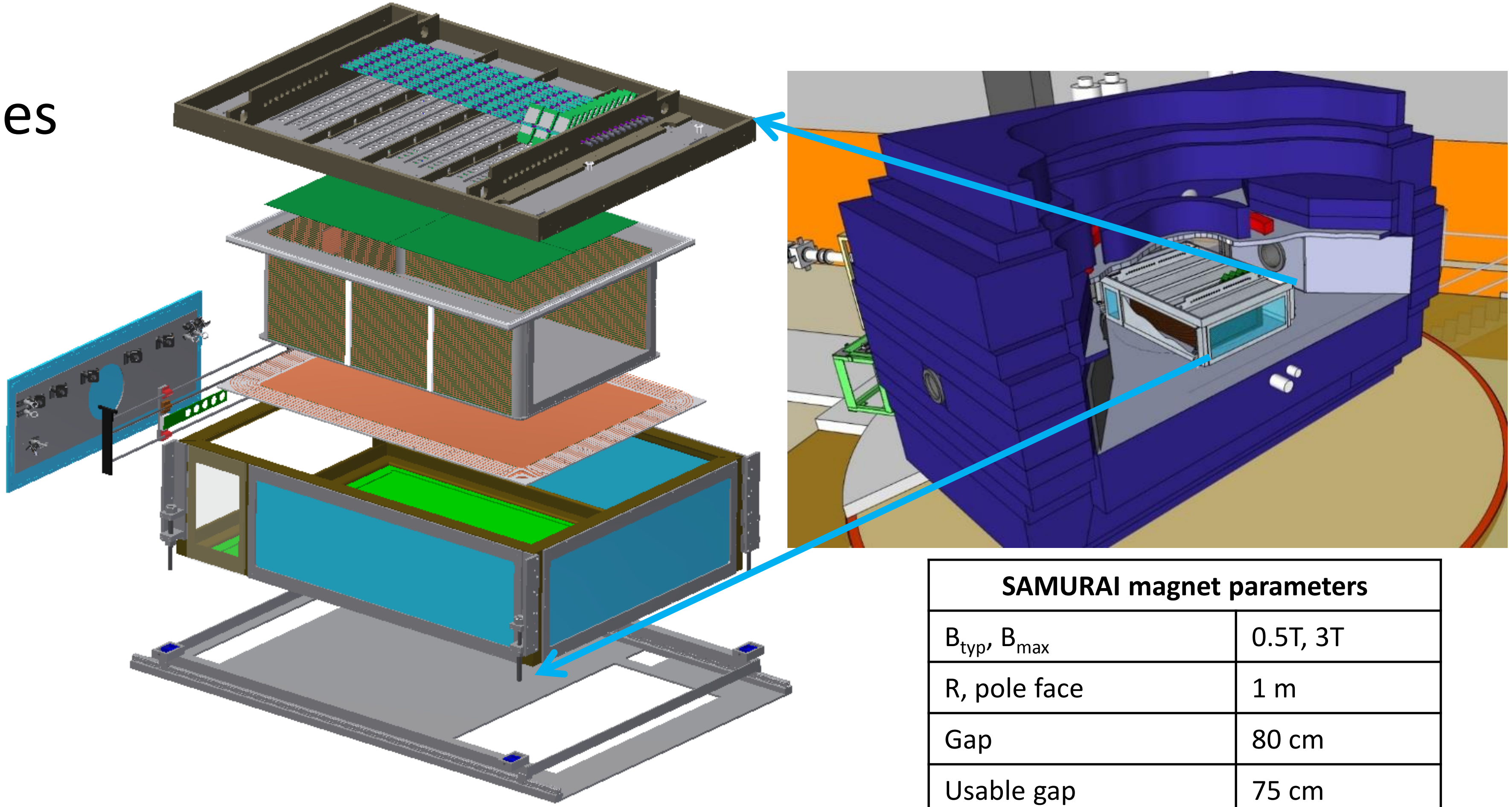
Exploded view of sTPC

Rails

Slide adapted from R. Shane

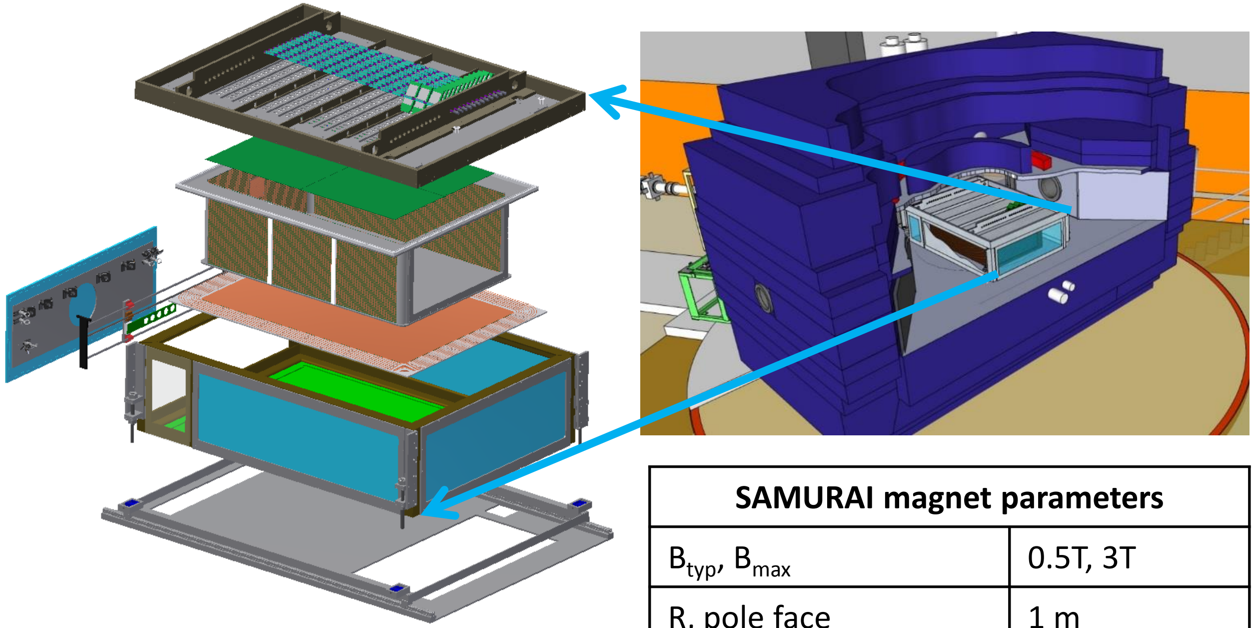
SAMURAI Spectrometer

- Magnetic field separates particles by m/q ratio



SAMURAI magnet parameters	
B_{typ}, B_{max}	0.5T, 3T
R, pole face	1 m
Gap	80 cm
Usable gap	75 cm

SAMURAI Spectrometer



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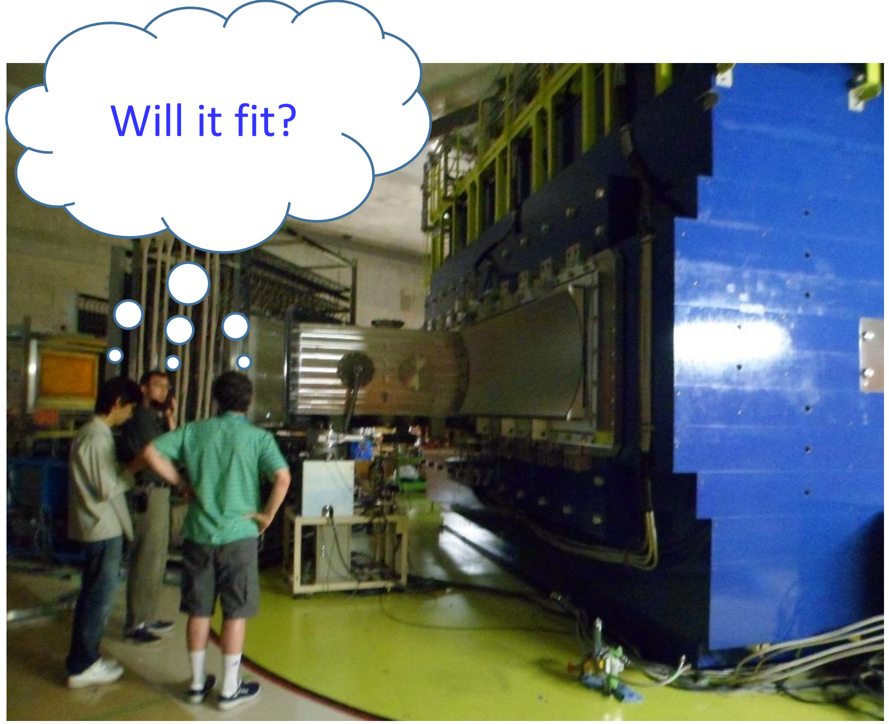
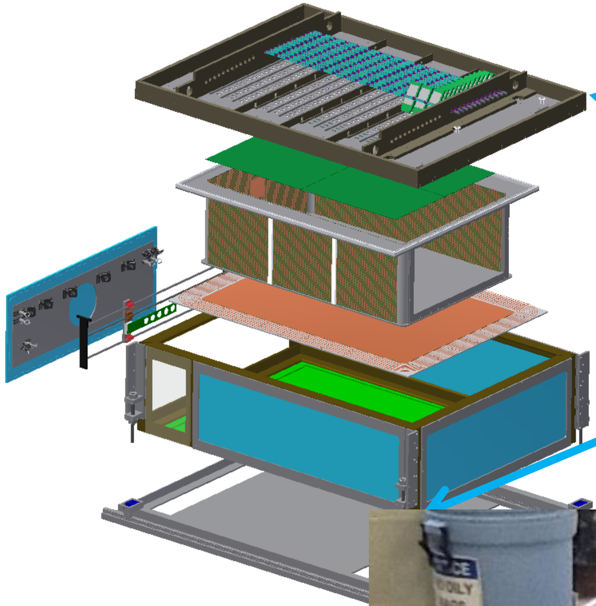
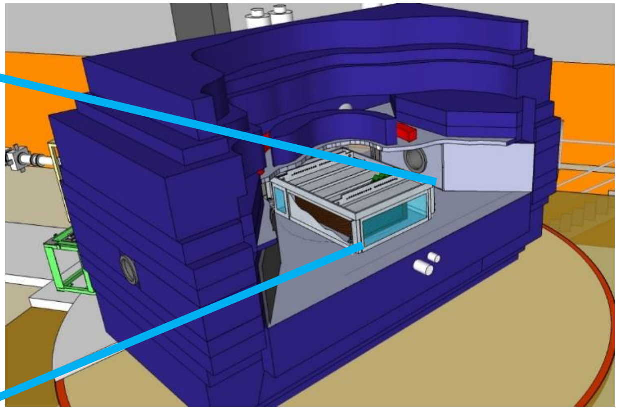
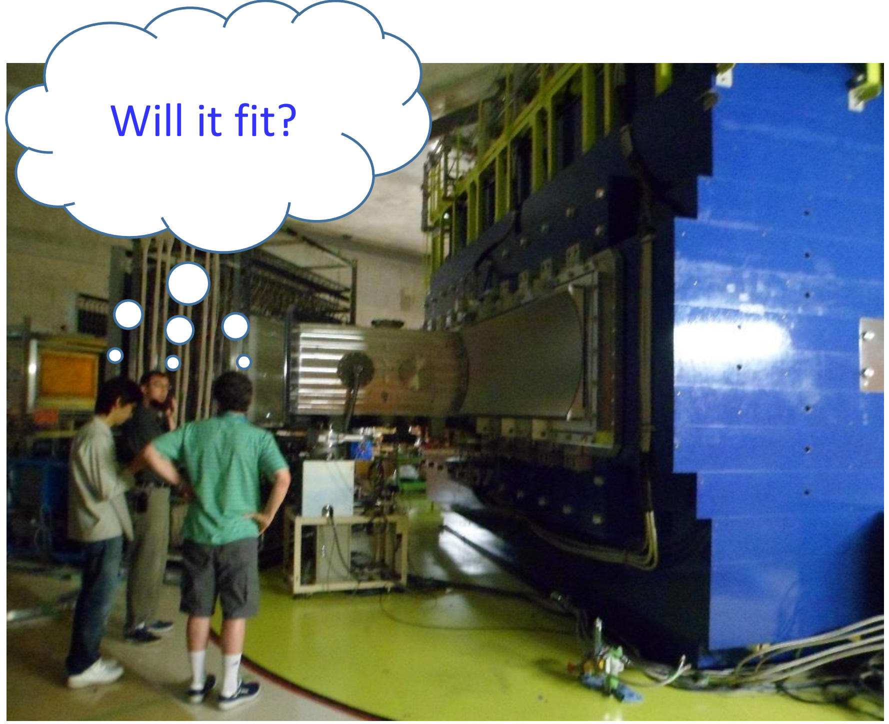


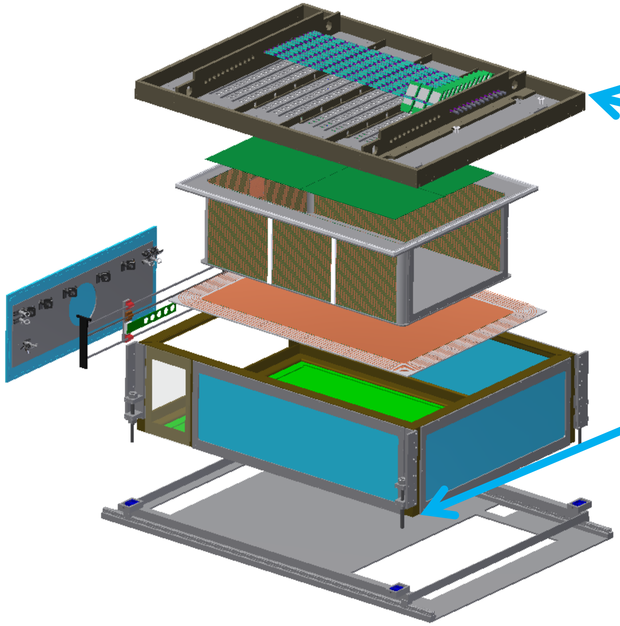
SAMURAI Spectrometer

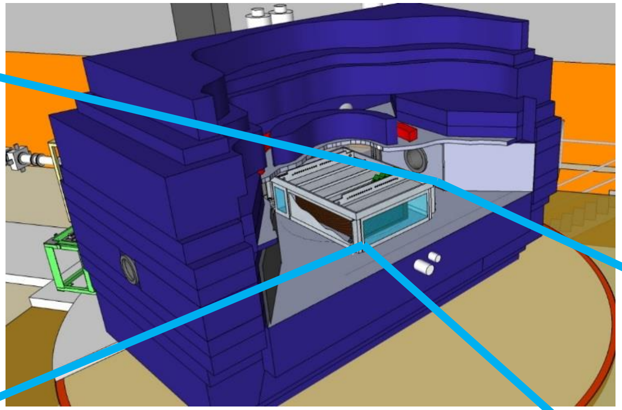


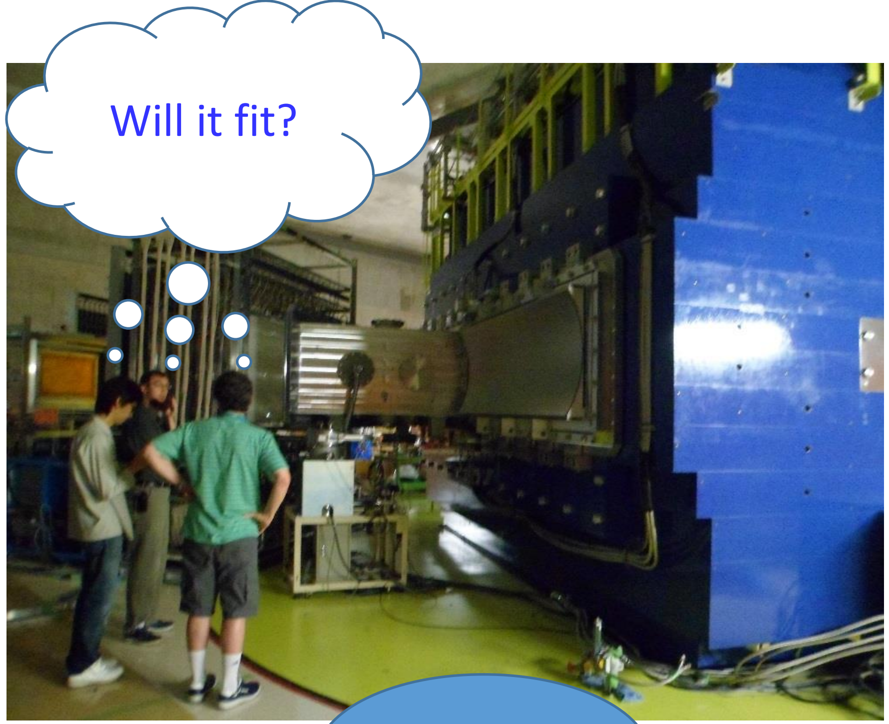




SAMURAI Spectrometer







We start to get parts…

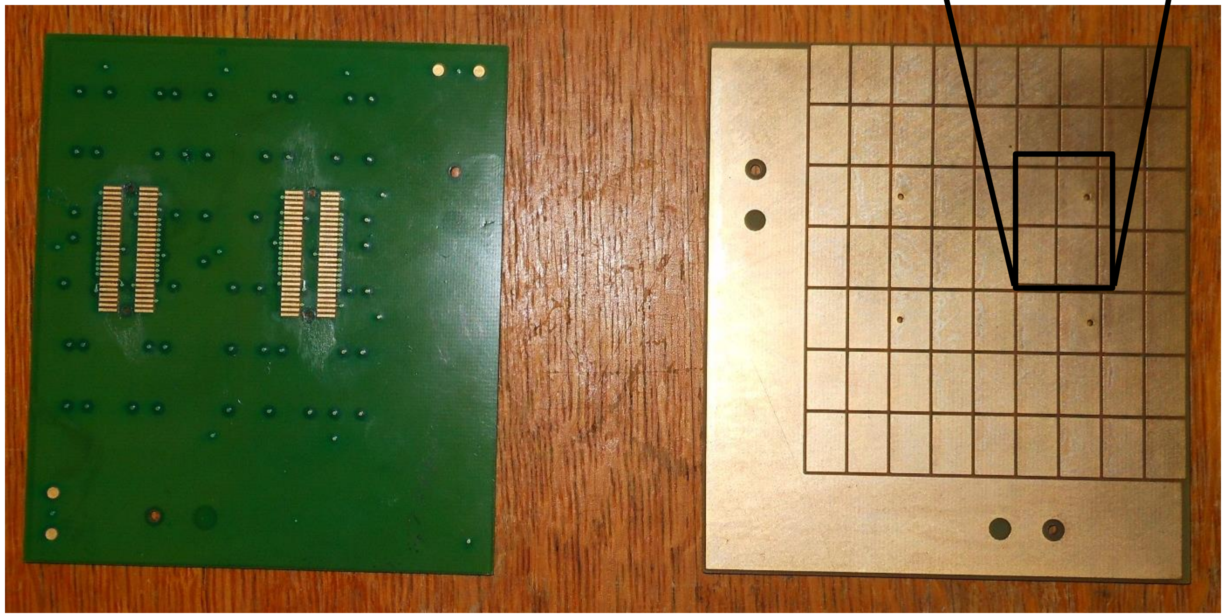
三思而后行
Measure thrice, cut once

Ready for the pad plane!

Prototype – a small sample

- Prove your design

Problems!

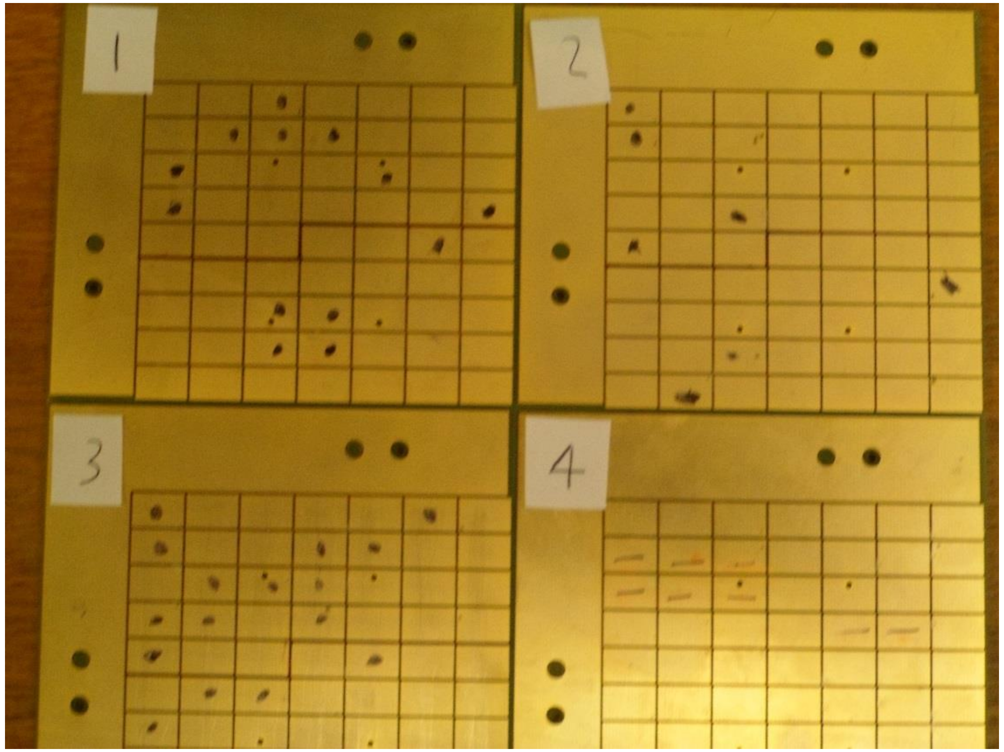


“Unit Cell” pad plane – 1/192 of actual pad plane

小钱仔细，大钱挥霍；省小钱花大钱
Don’t be penny wise, pound foolish!

Prototype – a small sample

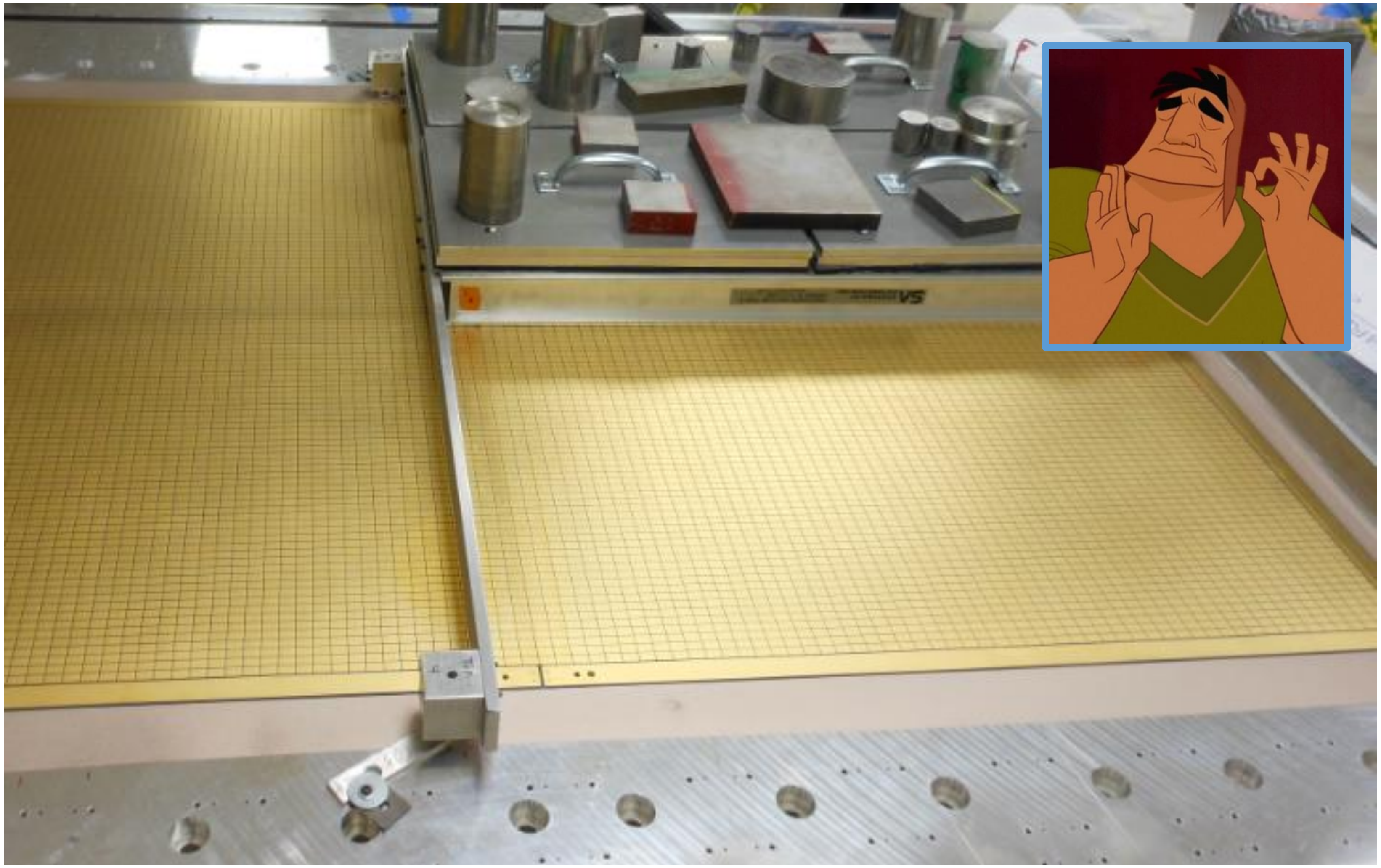
- Prove your design
- Prove the manufacturer



"Unit Cell" pad plane – Bad channels indicated with marker

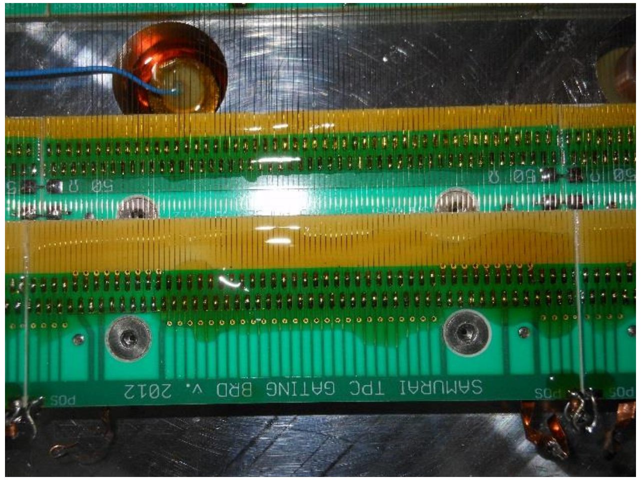
When the circuit boards fit just right

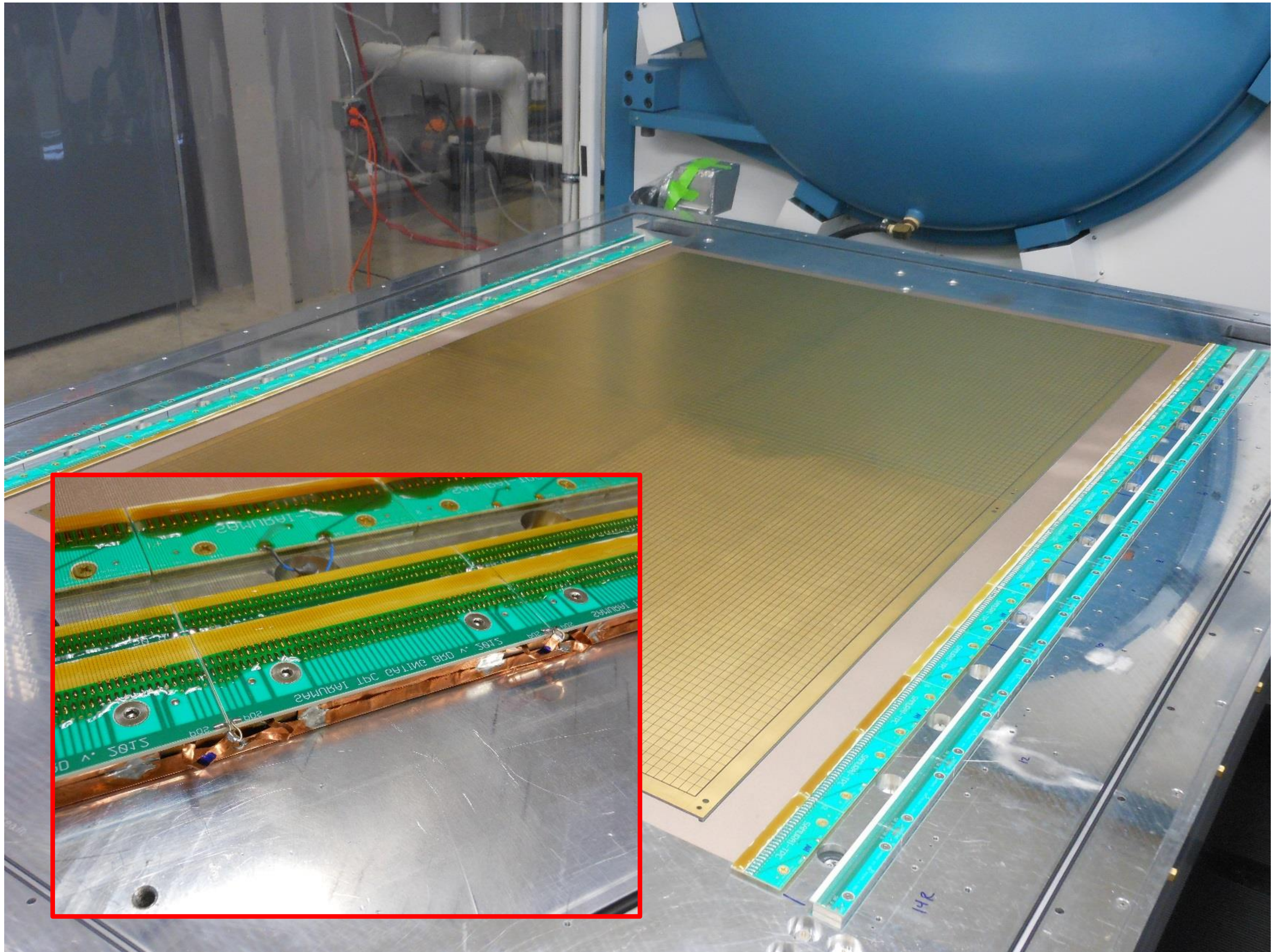
- Glued on in 4 sections
- Vacuum table to ensure flatness



Add some wire planes…

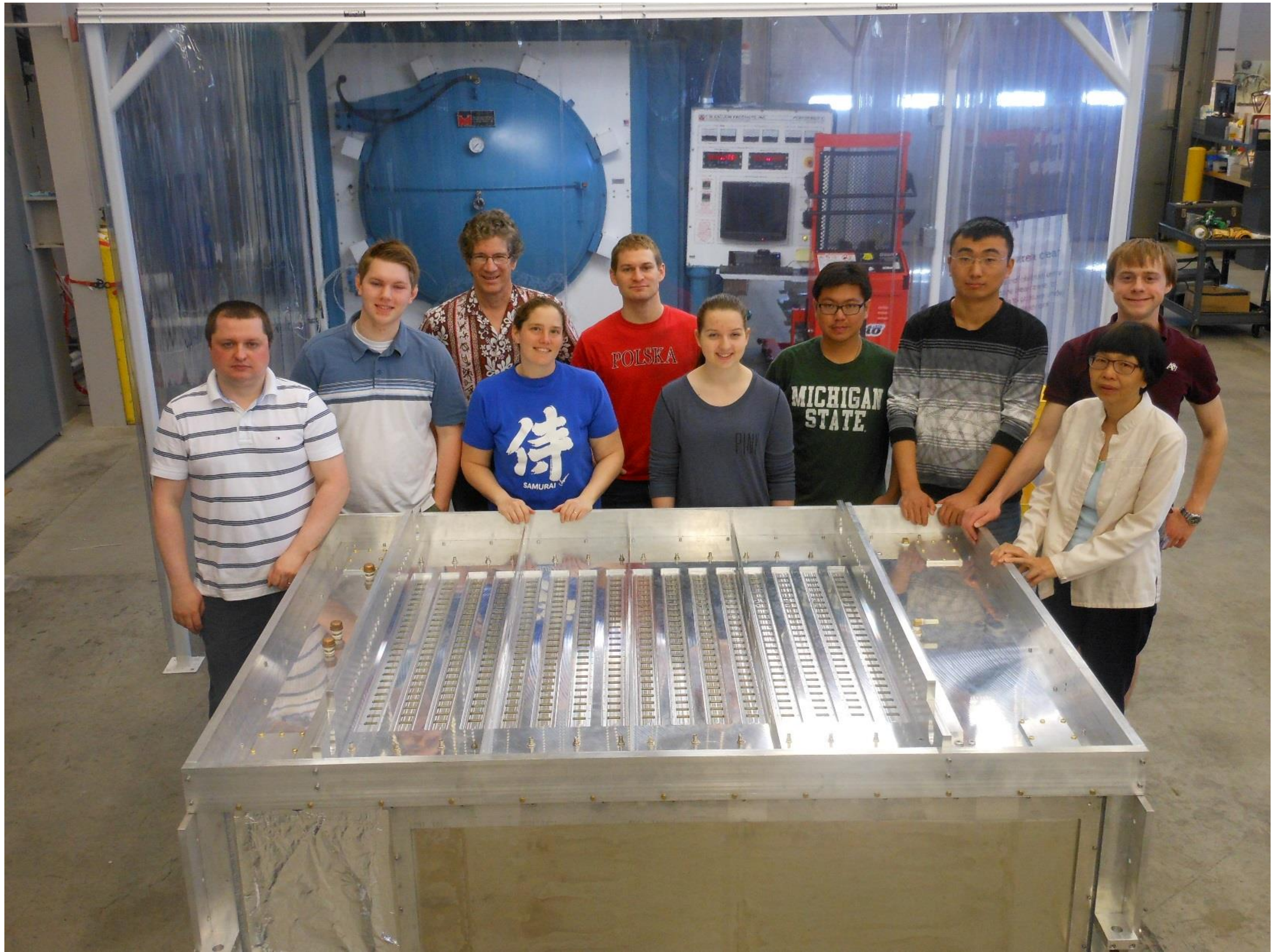
- Wire planes for amplification of charge
- Three separate wire planes
- Over 3000 tiny wires to solder





Some assembly required

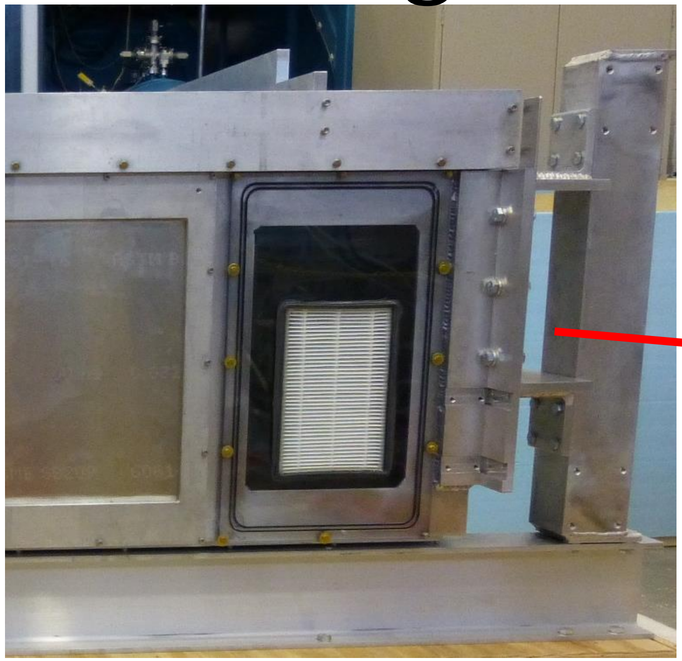
Let’s go!



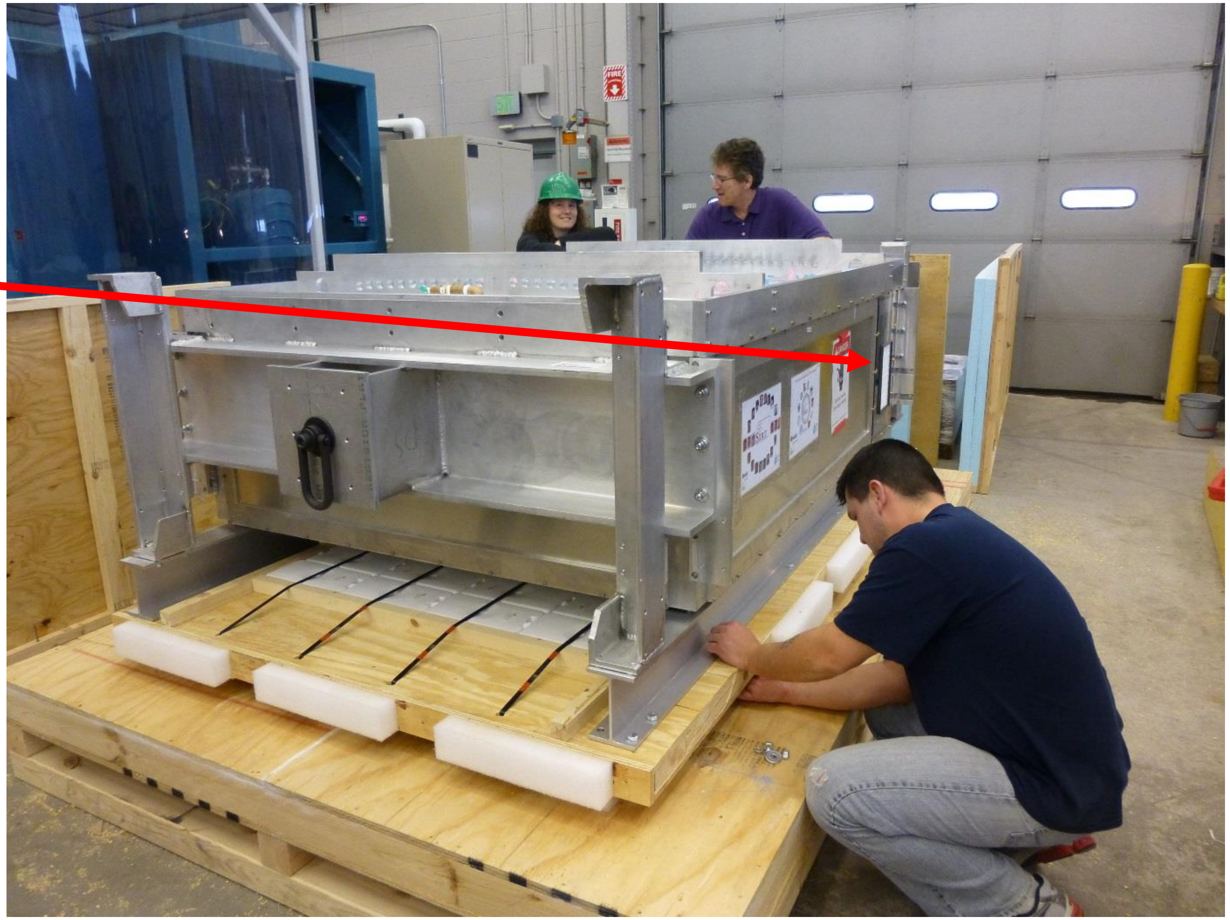
Getting ready to ship

Custom built shipping crate – designed by MSU packaging department

Getting ready to ship



Breathing allowed through filters (pressure equilibrium)



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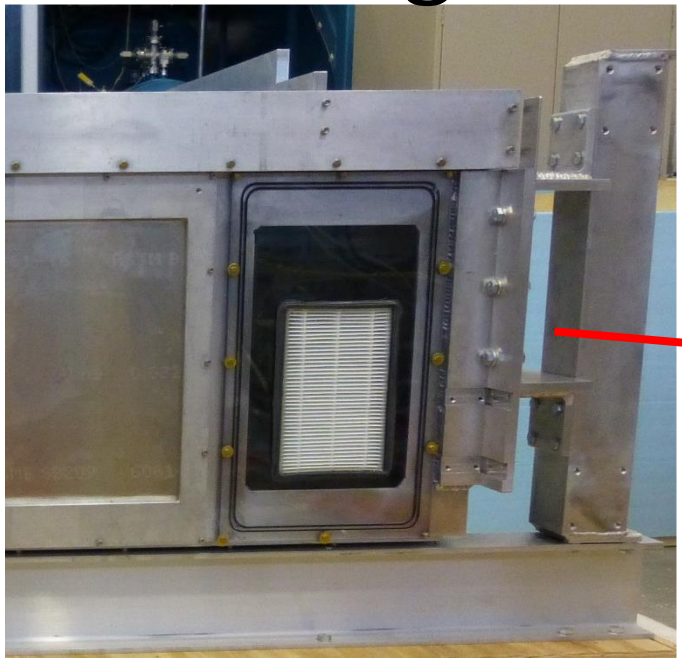

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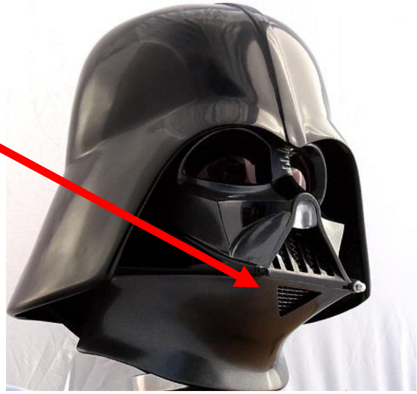
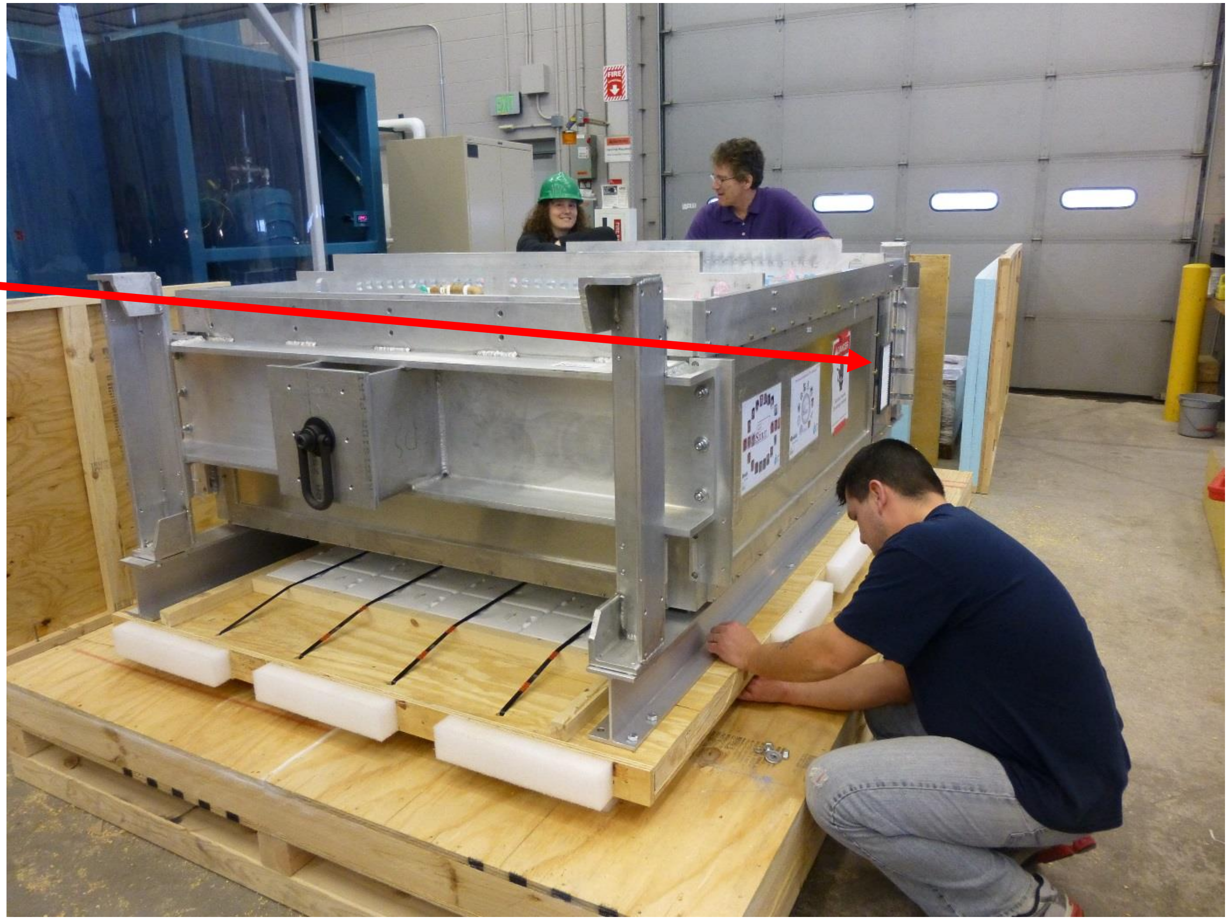
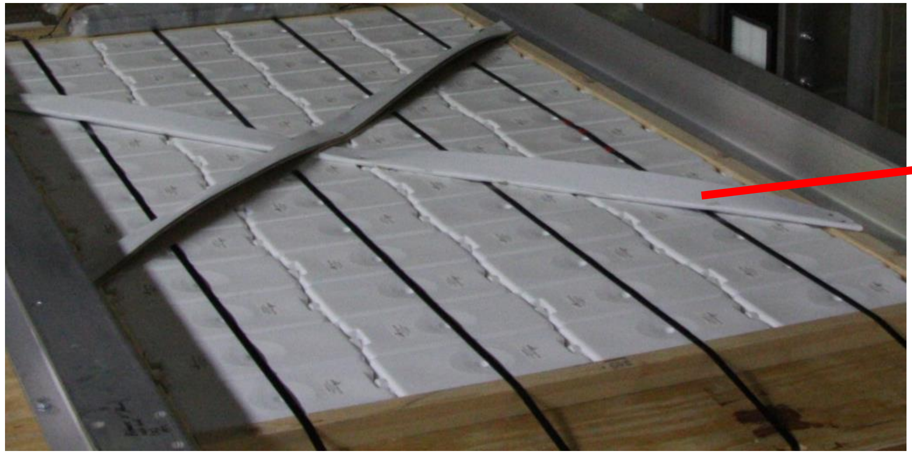
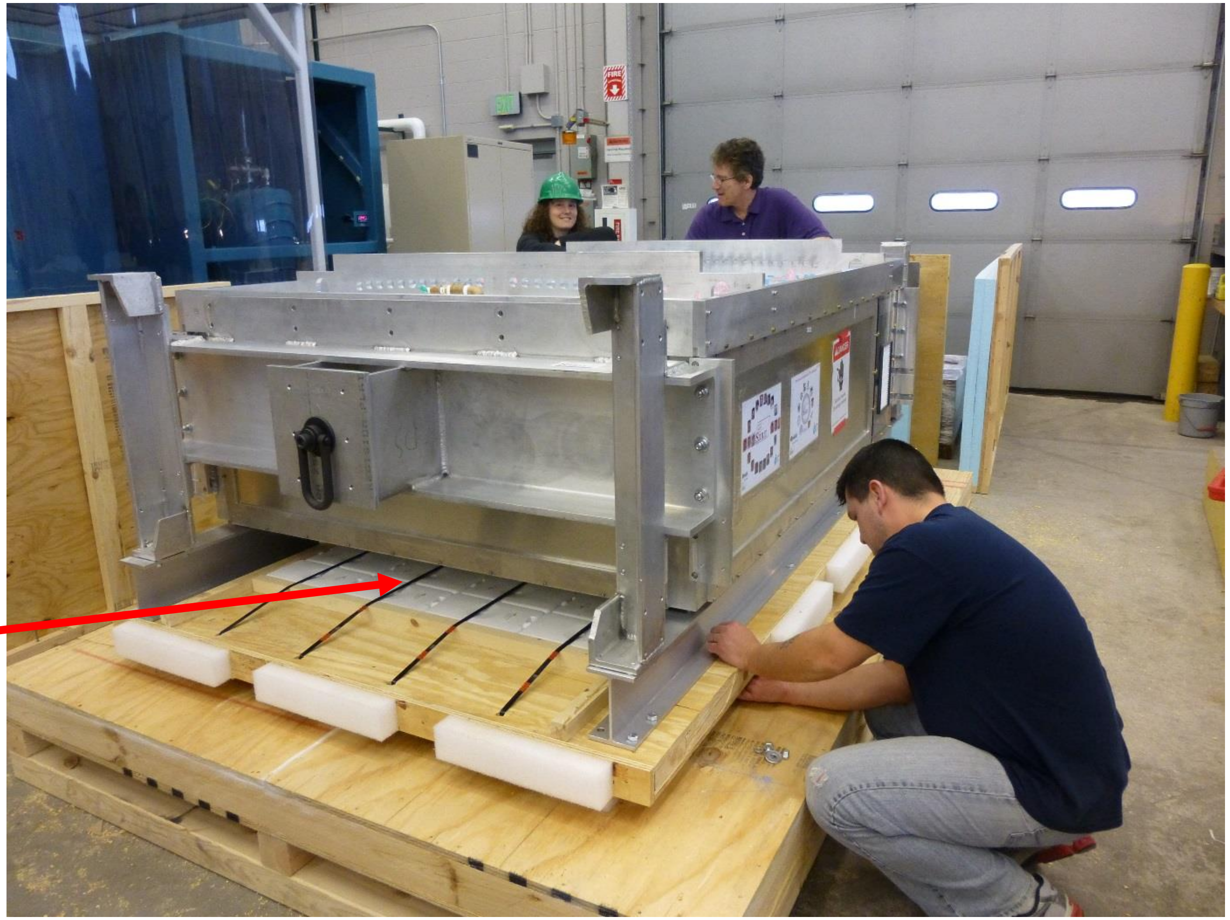




Getting ready to ship

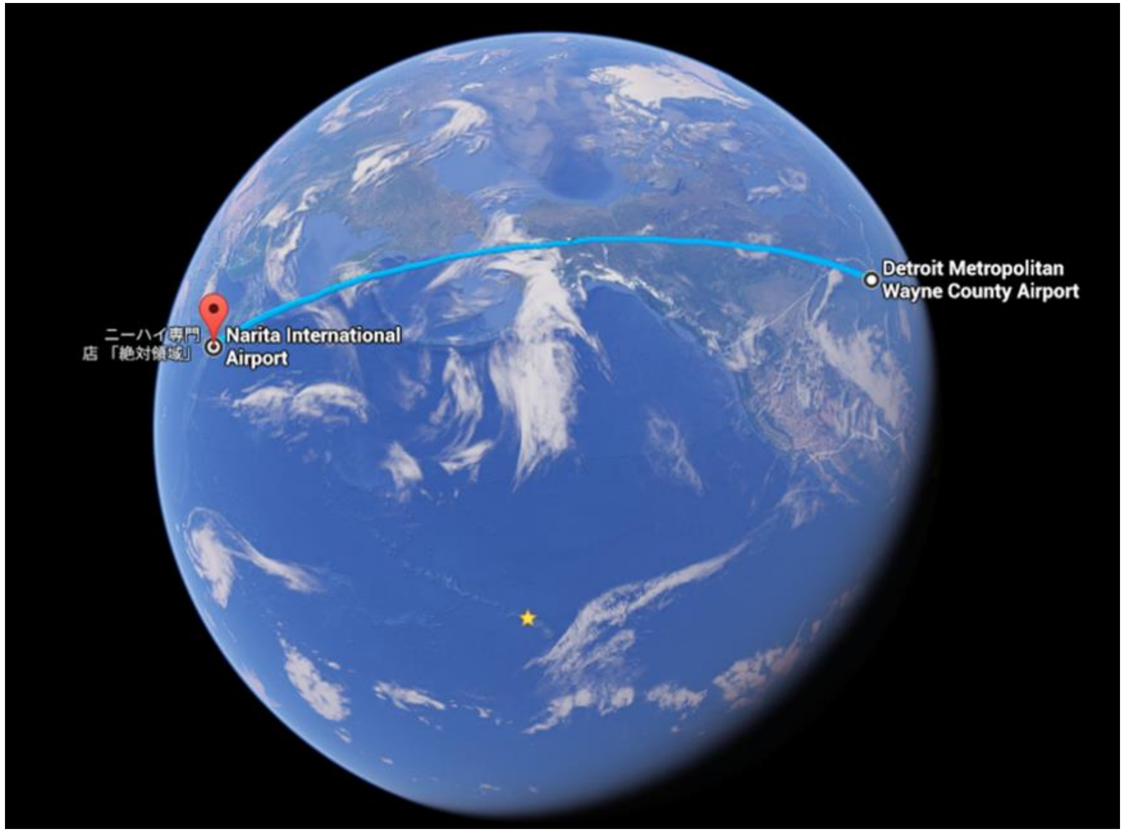
“Phase-change” material – transition between solid and liquid requires massive energy





Travel

- Travel by plane 10,000 km



Travel

- Travel by plane 10,000 km
- Arrives at RIKEN by truck

Travel

- Travel by plane 10,000 km
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Travel

- Travel by plane 10,000 km
- Arrives at RIKEN by truck
- Lowered into experimental area by crane

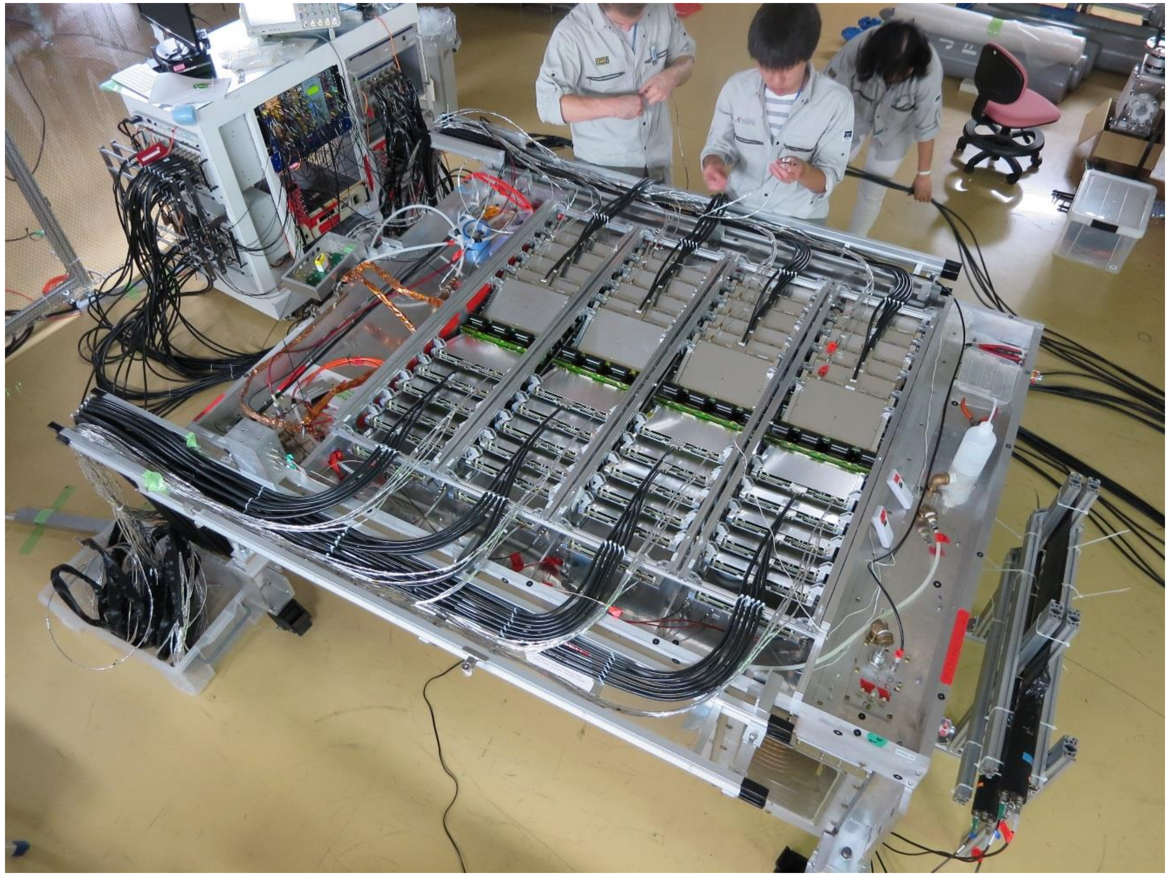
Travel

- Travel by plane 10,000 km
- Arrives at RIKEN by truck
- Lowered into experimental area by crane

Upgrades

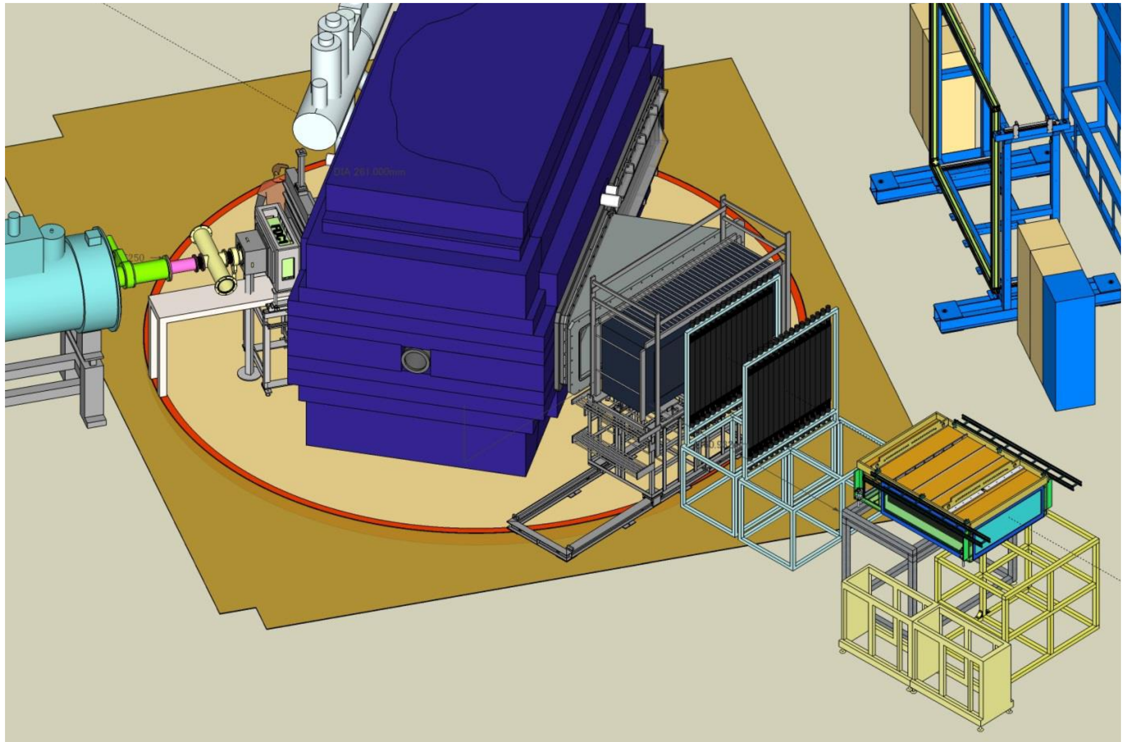
- Generic Electronics for TPC (GET)

- New electronics =
  - New capabilities
  - New challenges



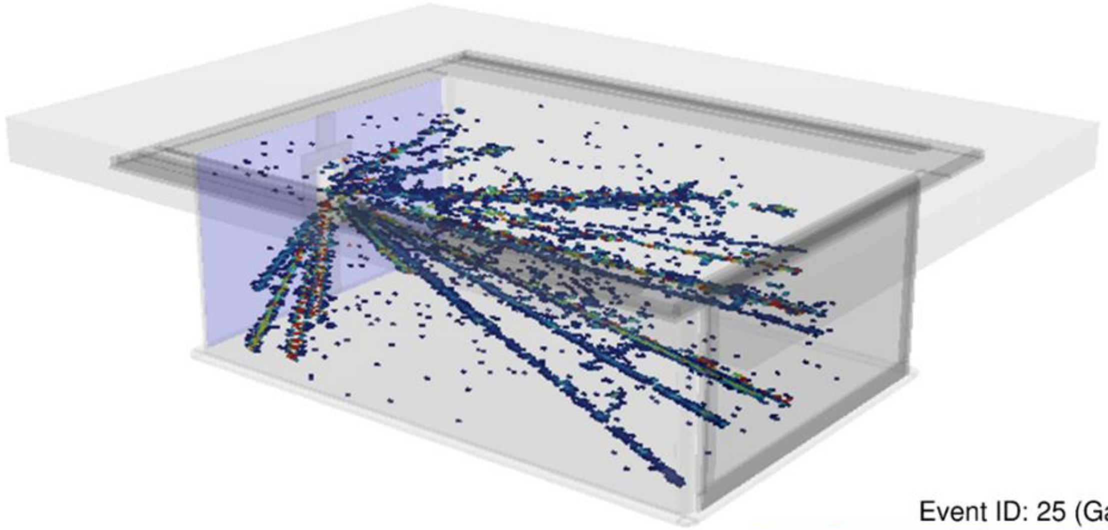
Parasitic beam run

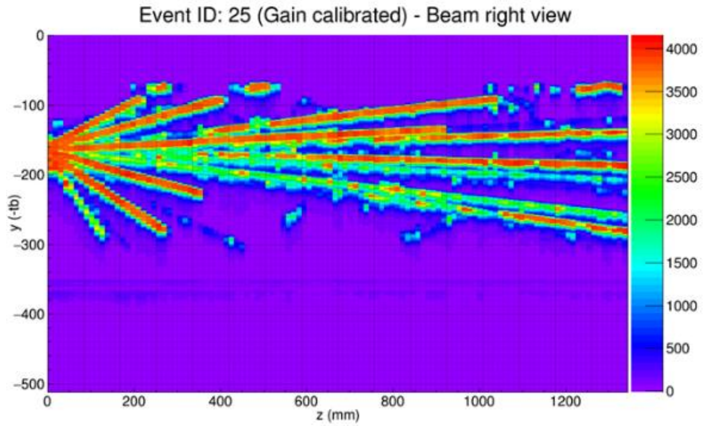
- Proving functionality

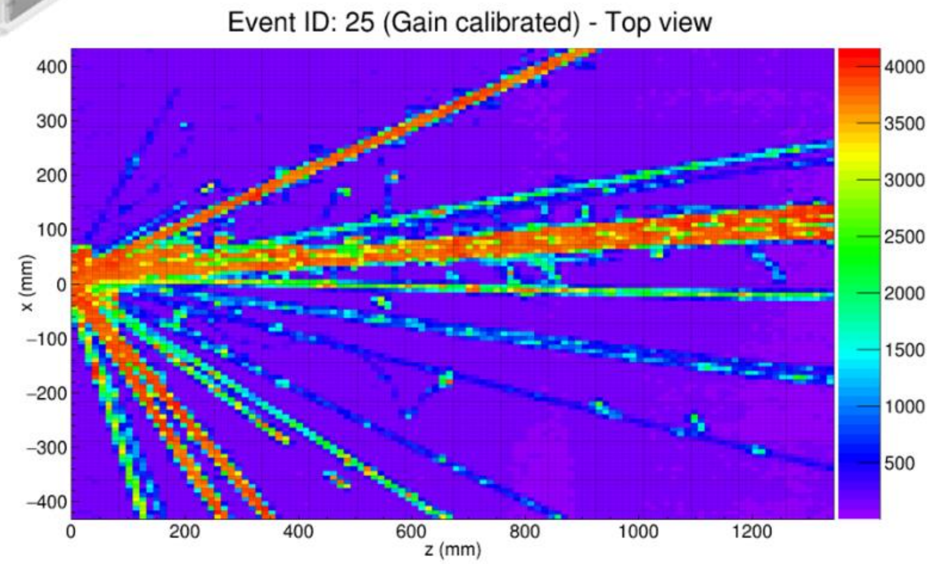


SπRIT Commissioning run
October 2015

- Functionality proven
- Useful data for calibrating TPC
- Useful for development of tracking software







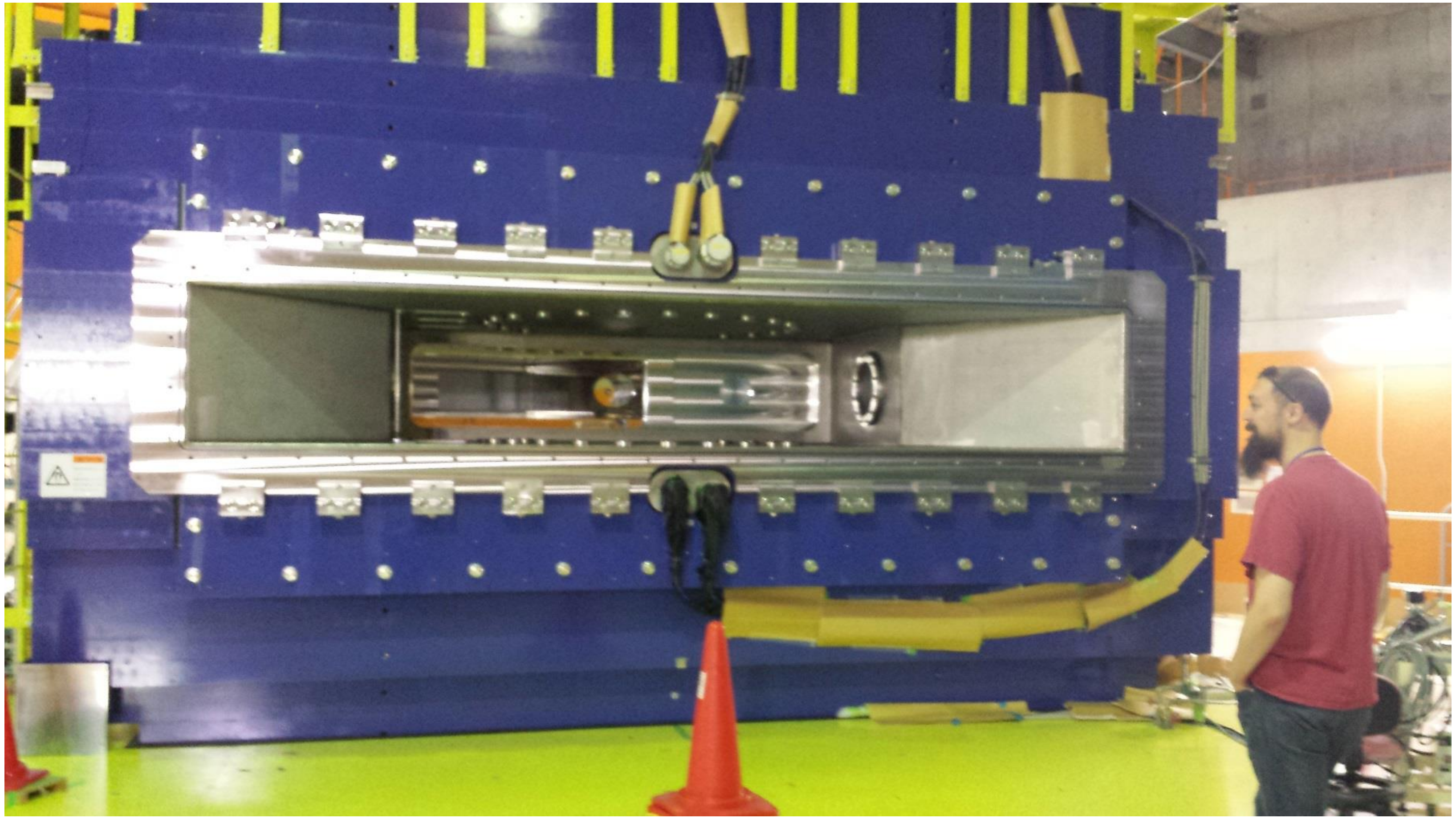
Installation

Running experiment

- Experimenters at work

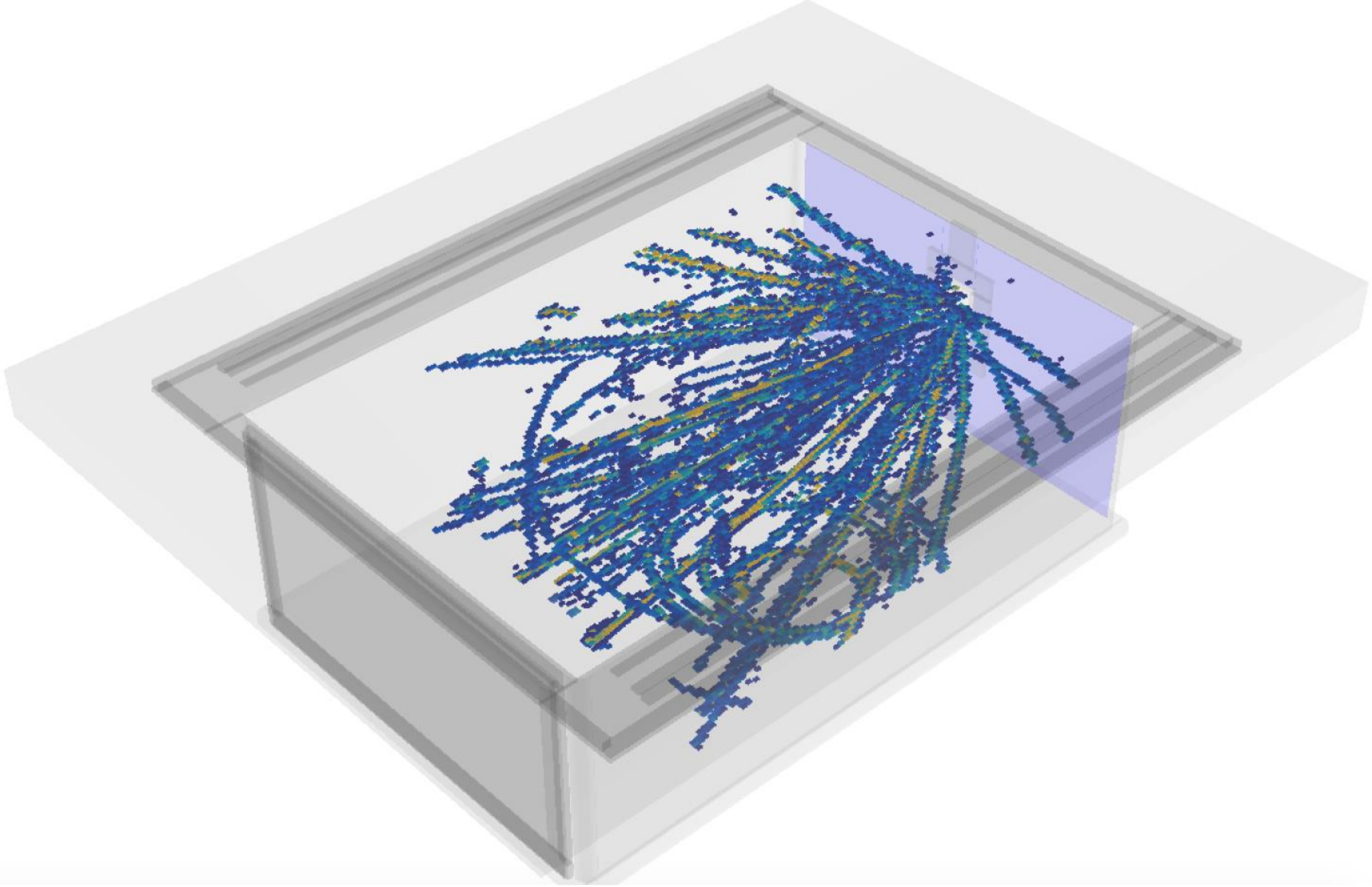
Experiment over

Cleanup completed



Pions detected

- Analysis has just begun!



Thank you!

Acknowledgements

SPiRIT TPC Collaboration:

United States: C. Anderson, J. Barney, Z. Chajecki, G. Cerizza, P. Danielewicz, J. Estee, M. Famiano, U. Garg, W. Lynch, A. McIntosh, P. Morfouace, C. Santamaria, H. Setiawan, R. Shane, M. B. Tsang, T. Tsang, S. Tangwancharoen, G. Westfall, S. Yennello, M. Youngs

Japan: H. Baba, K. Ieki, T. Isobe, M. Kaneko, T. Murakami, J. Murata, Y. Nakai, N. Nakatsuka, M. Nishimura, S. Nishimura, A. Ono, H. Otsu, H. Sakurai, A. Taketani

China: F. Lu, R. Wang, Z. Xiao, Y. Zhang

United Kingdom: M. Chartier, R. Lemmon, W. Powell

France: E. Pollacco

Italy: G. Verde

Korea: B. Hong, G. Jhang, Y. J. Kim, H. S. Lee, J. W. Lee

Poland: P. Lasko, J. Lukasik, P. Pawlowski, K. Pelczar

For Nick.

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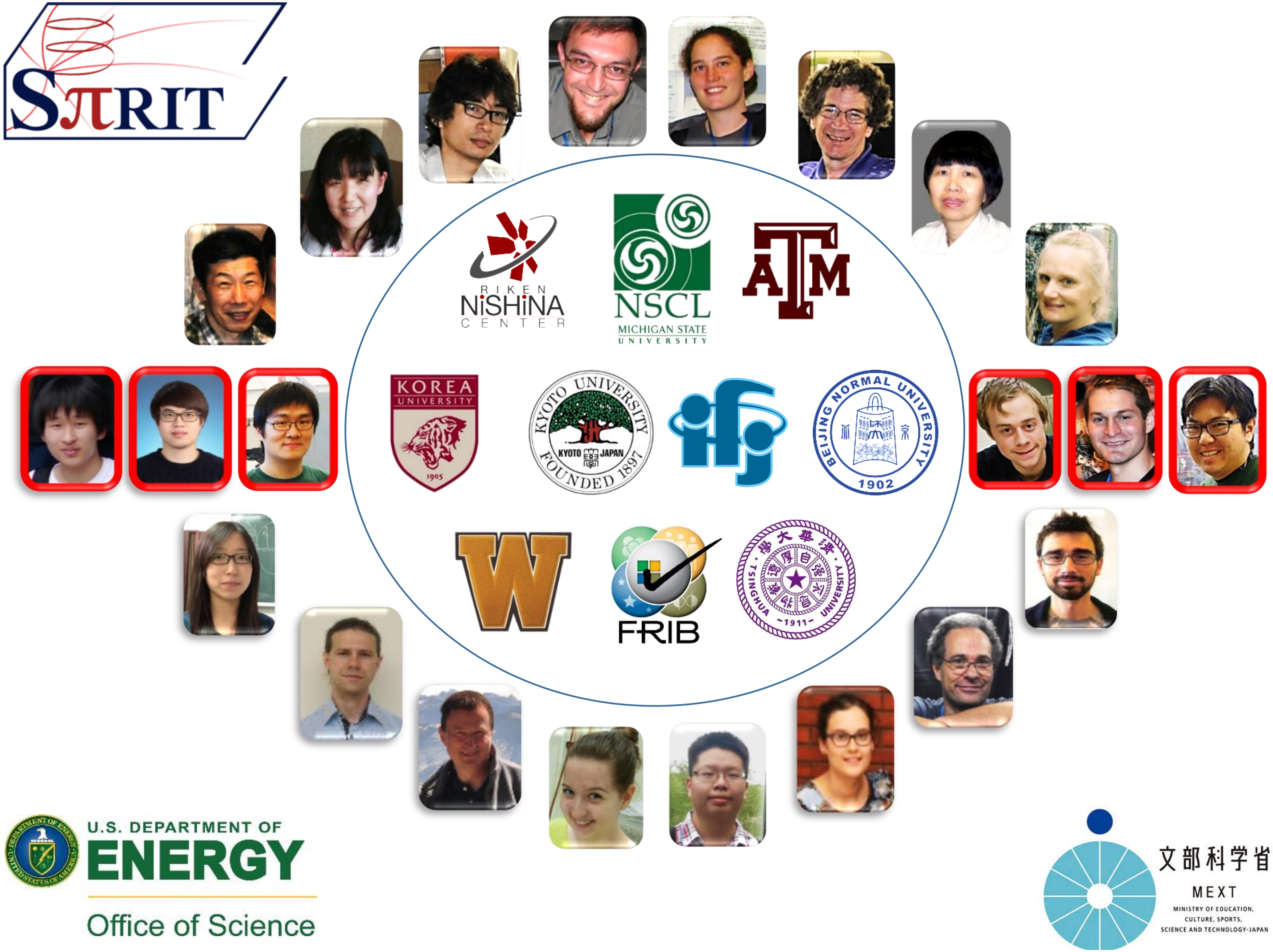
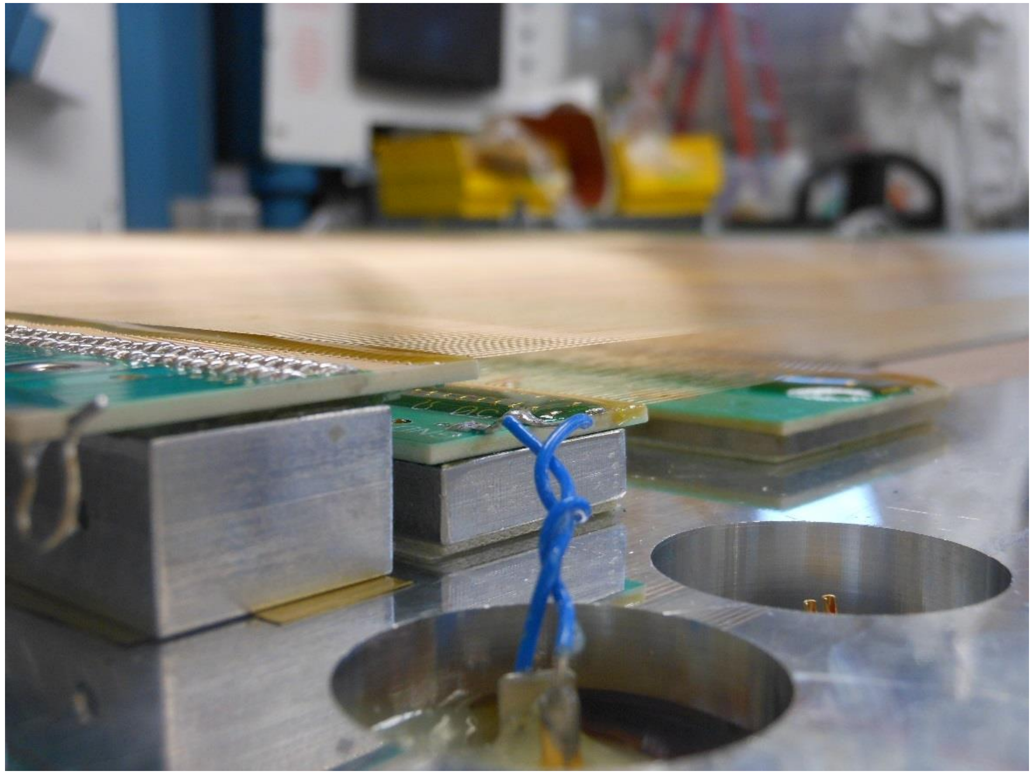
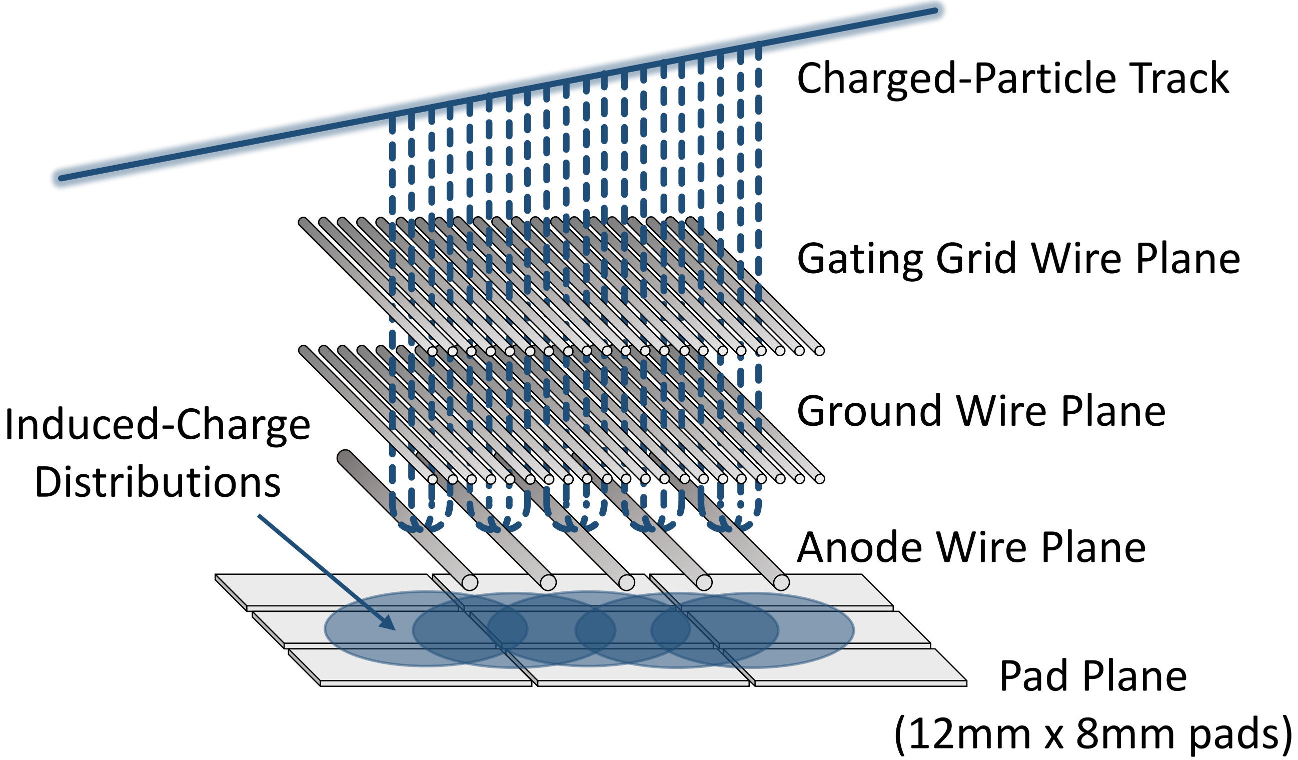


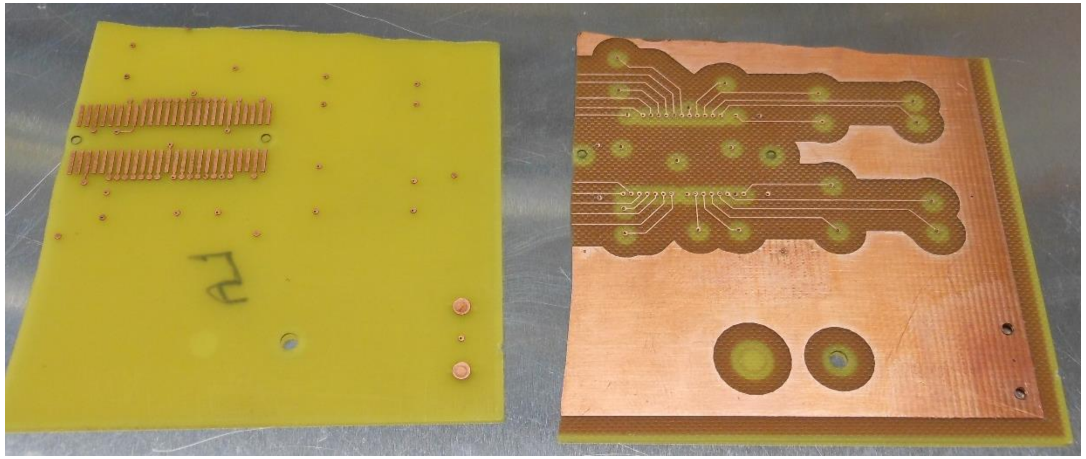
SπRIT
RIKEN NiSHiNA CENTER
NSCL
MICHIGAN STATE UNIVERSITY
ATM
KOREA UNIVERSITY
1905
KYOTO UNIVERSITY
KYOTO JAPAN
FOUNDED 1897
ifj
BEIJING NORMAL UNIVERSITY
1902
W
FRIB
TSINGHUA UNIVERSITY
1911
U.S. DEPARTMENT OF
ENERGY
Office of Science
文部科学省
MEXT
MINISTRY OF EDUCATION,
CULTURE, SPORTS,
SCIENCE AND TECHNOLOGY-JAPAN

Wire planes

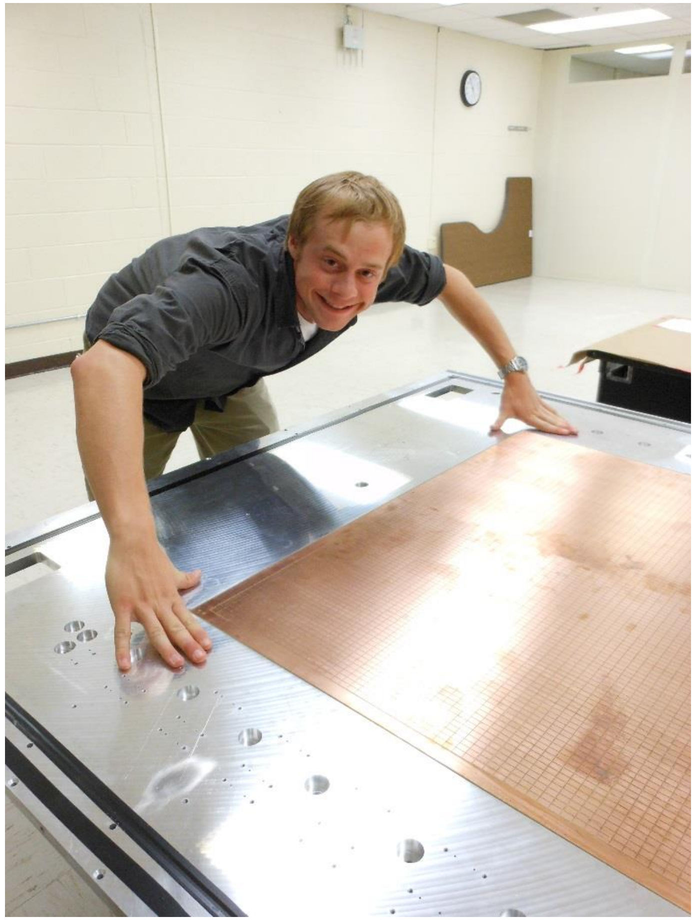



Charged-Particle Track
Gating Grid Wire Plane
Ground Wire Plane
Induced-Charge Distributions
Anode Wire Plane
Pad Plane (12mm x 8mm pads)

Even mistakes provide new opportunities



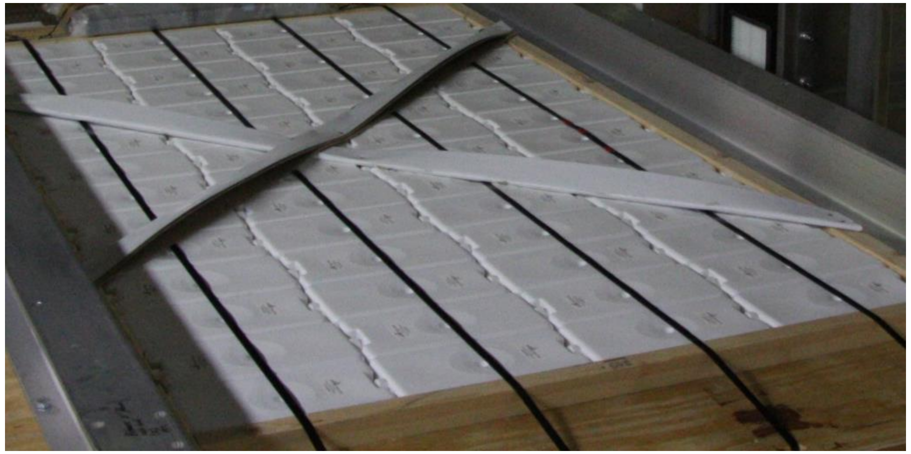
Dissection of pad plane

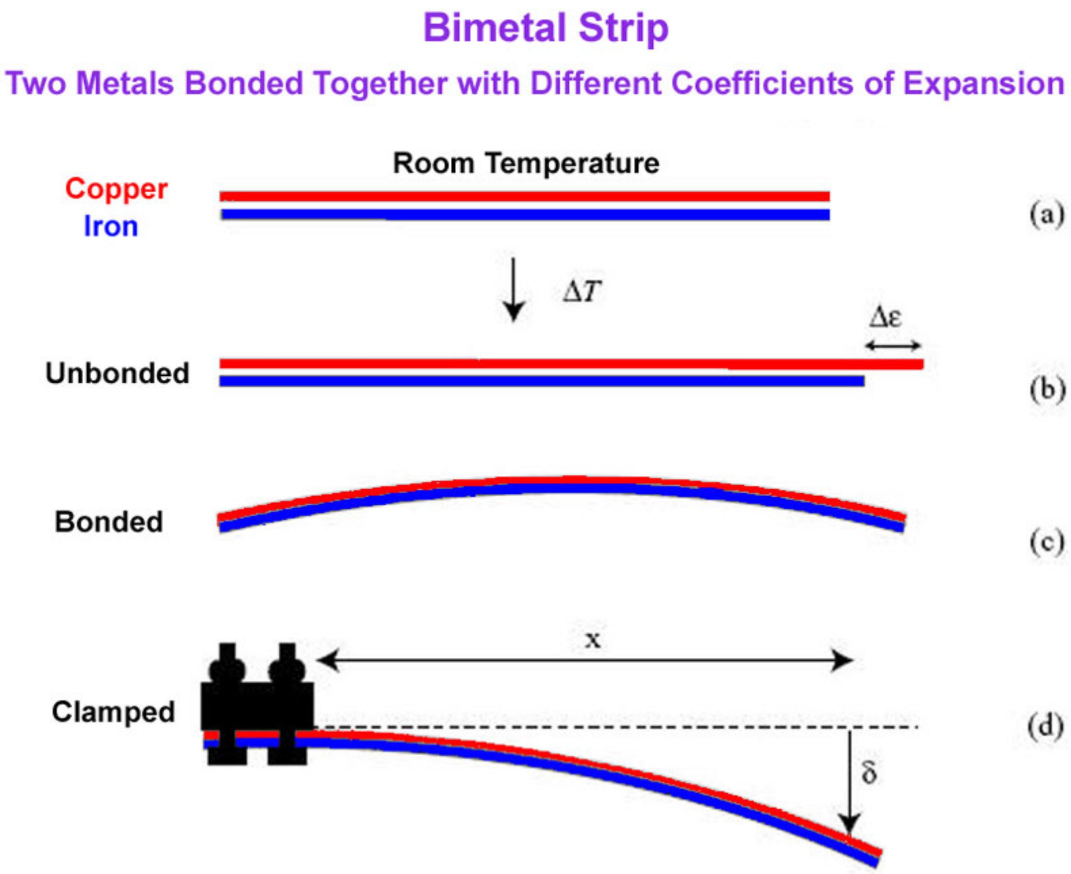


Testing the fit using an
improperly manufactured board

Constant temperature when shipping

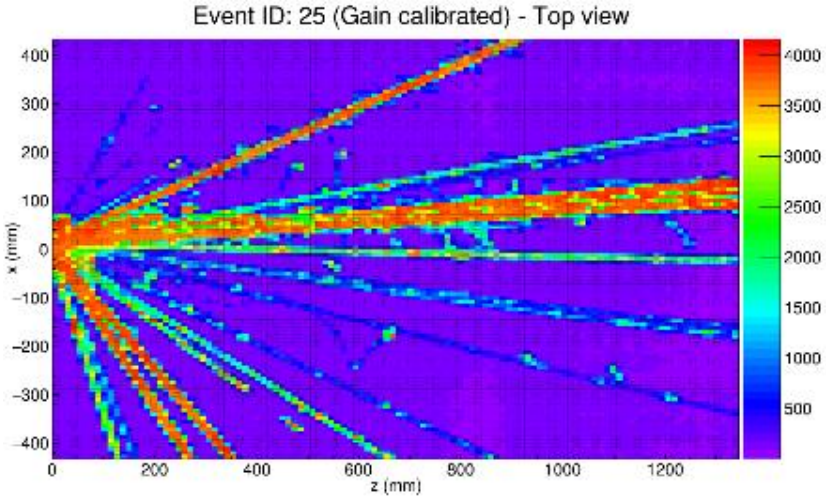
- Phase change material requires a large amount of energy to change temperature

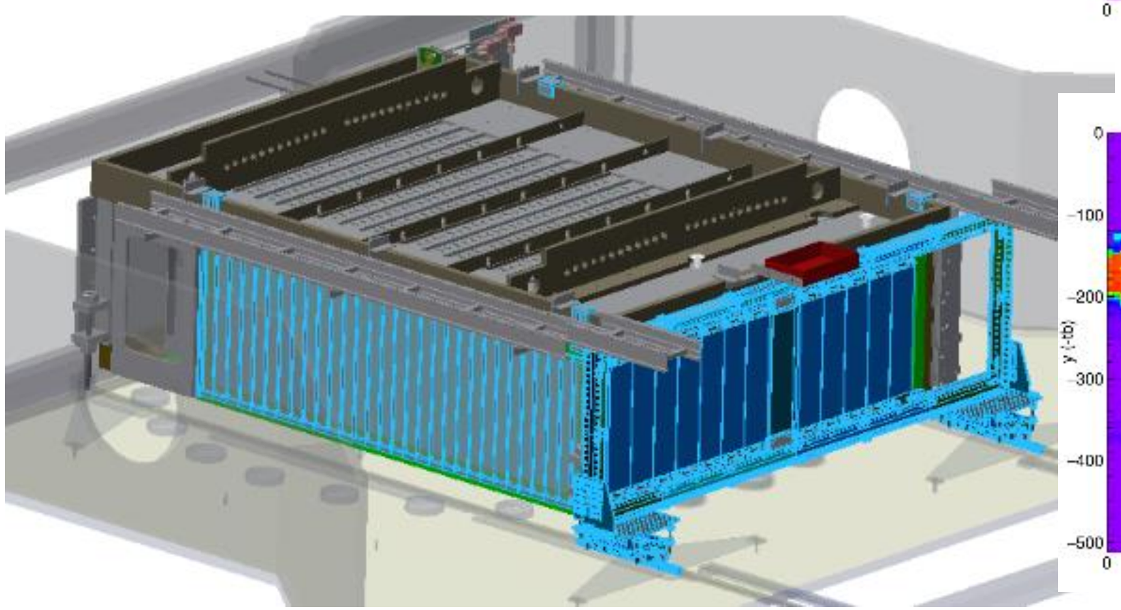


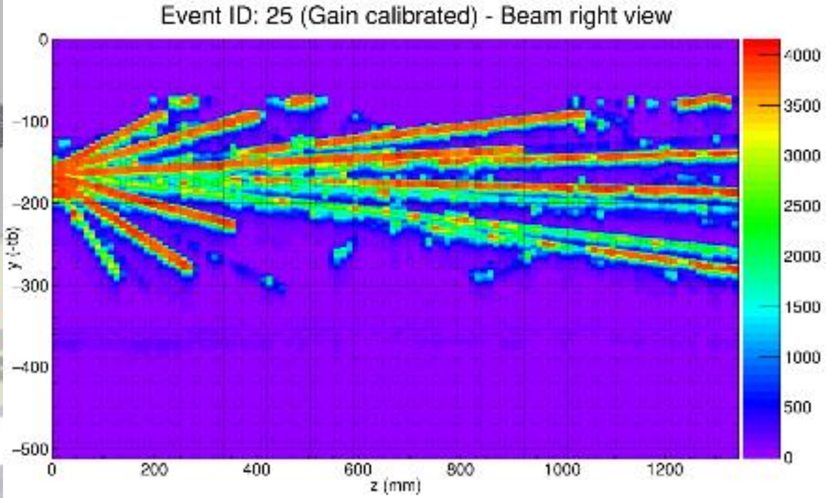


Triggering

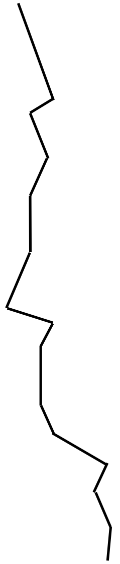
- Want to maximize central events



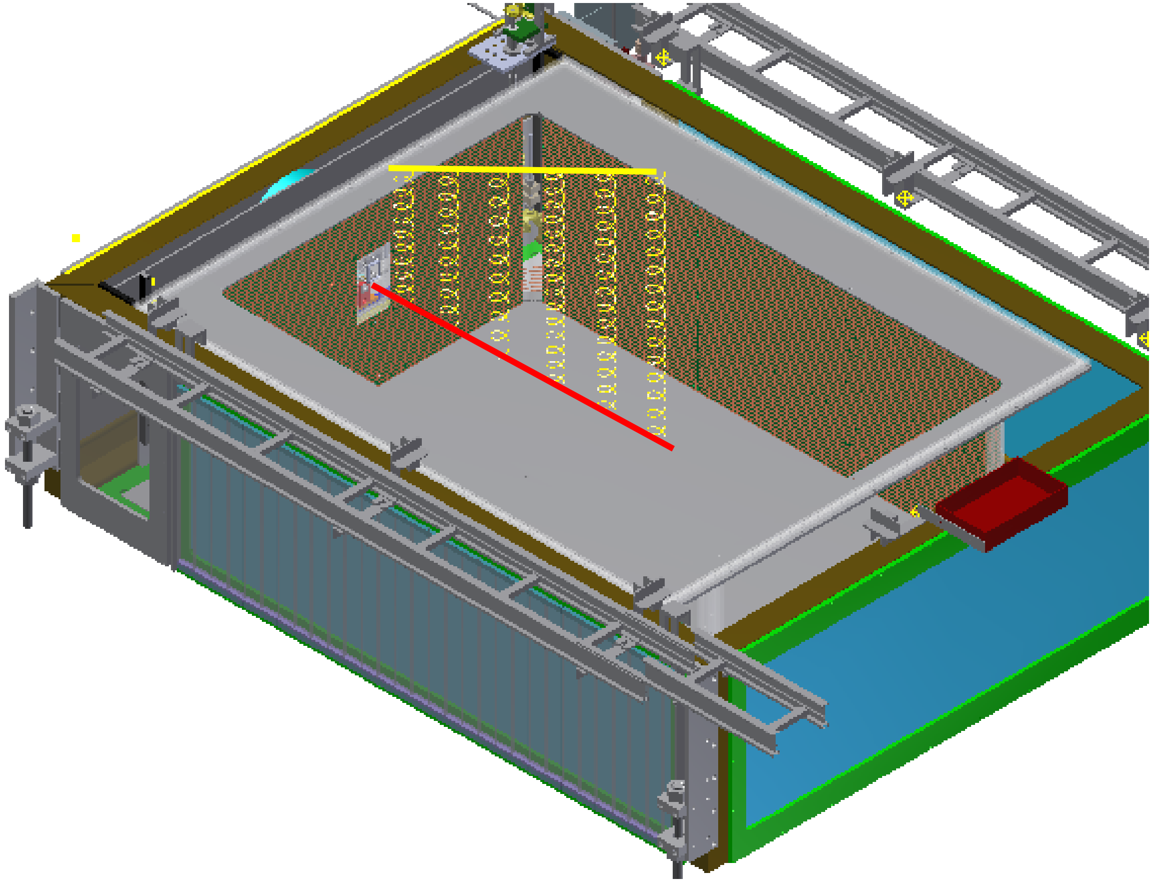




Magnetic field:
Electrons spiral
around the electric,
magnetic field lines



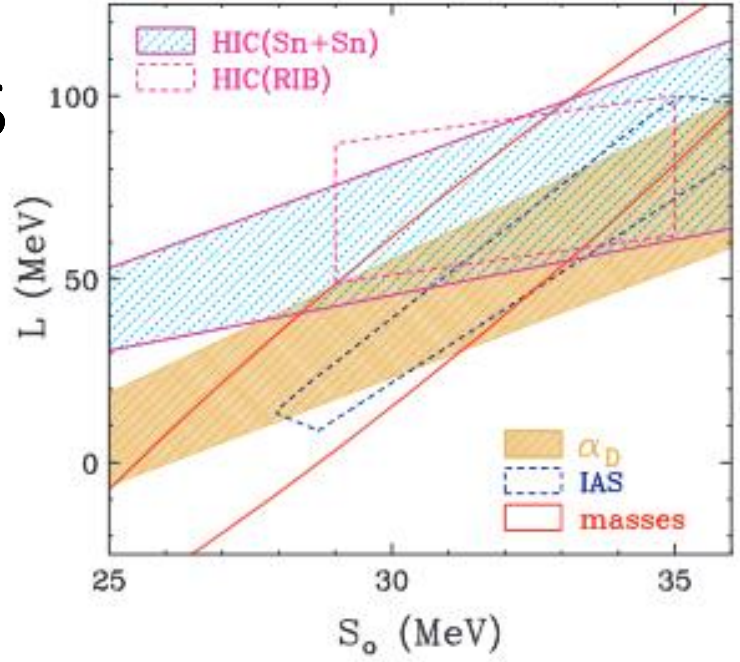
No magnetic field:
Electrons drift in
unpredictable way
due to collisions

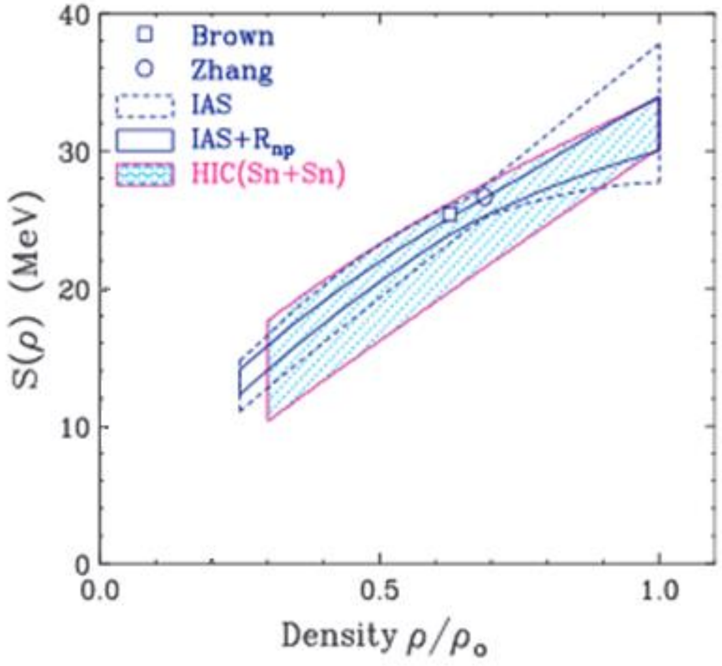


Lab Observables

Laboratory observables for symmetry energy:

- Masses
- Isobaric Analog States (IAS) (Brown, Zhang)
- Electric dipole polarizability (a_D)
- Diffusion of neutrons and protons between nuclei of differing N/Z ratios in peripheral collisions HIC (Sn+Sn)
- Transverse flow HIC (RIB)





Horowitz et al. J. Phys. G: Nucl. Part. Phys. 41 (2014) 093

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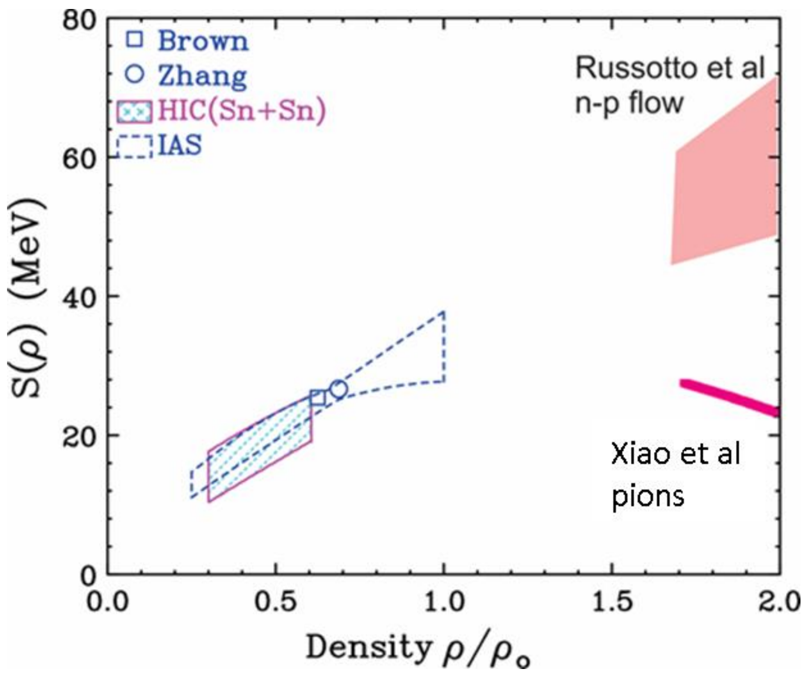
We need to constrain higher density behavior of the symmetry energy!



Adapted from ICNT 2013 Summary report Horowitz, et al.

First Tasks - Design

- Based on the EOS TPC