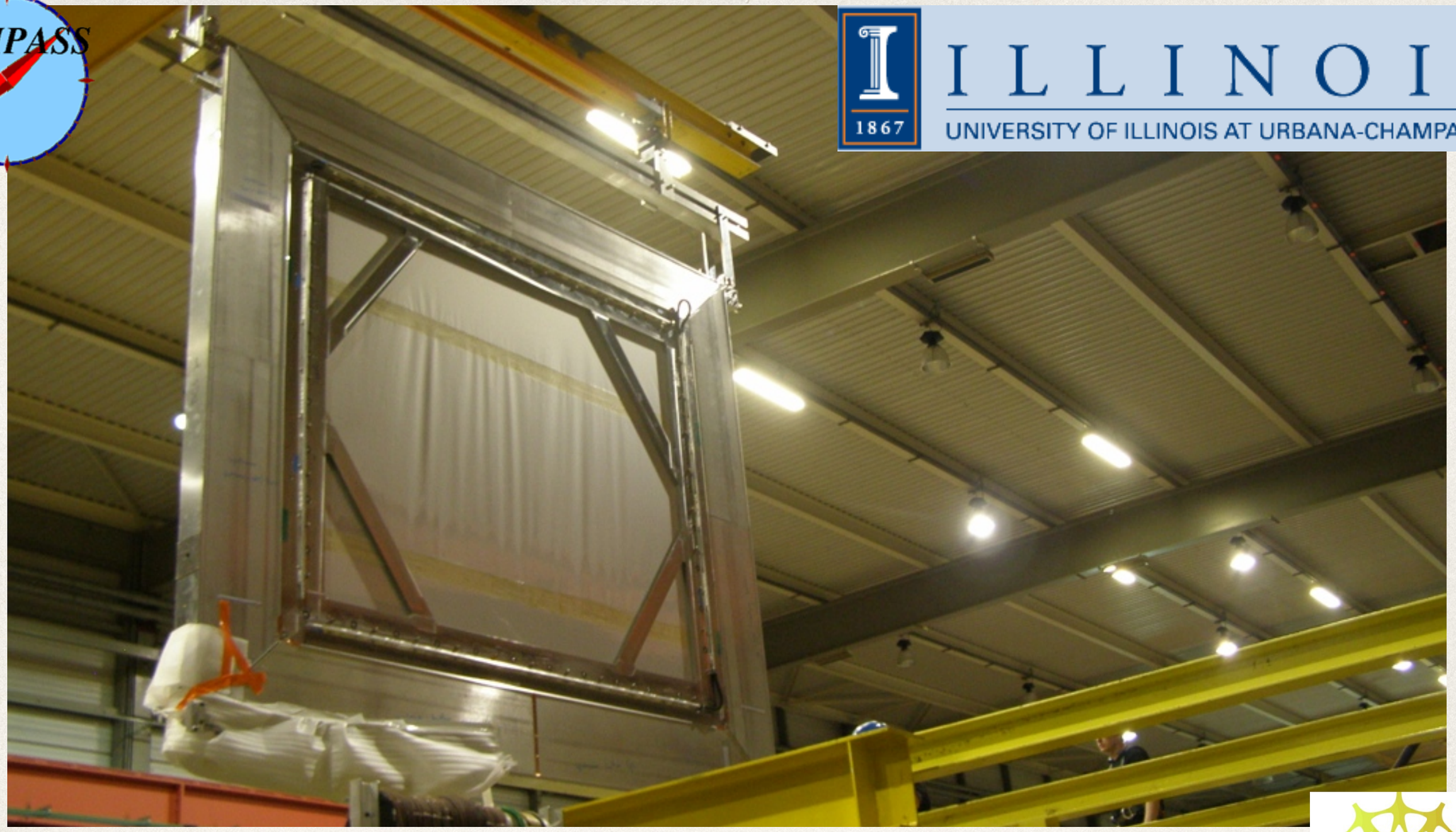


A Large-Area Planar Drift Chamber for the COMPASS Experiment at CERN

Robert Heitz

University of Illinois Urbana-Champaign

Spin 2016

September 27, 2016

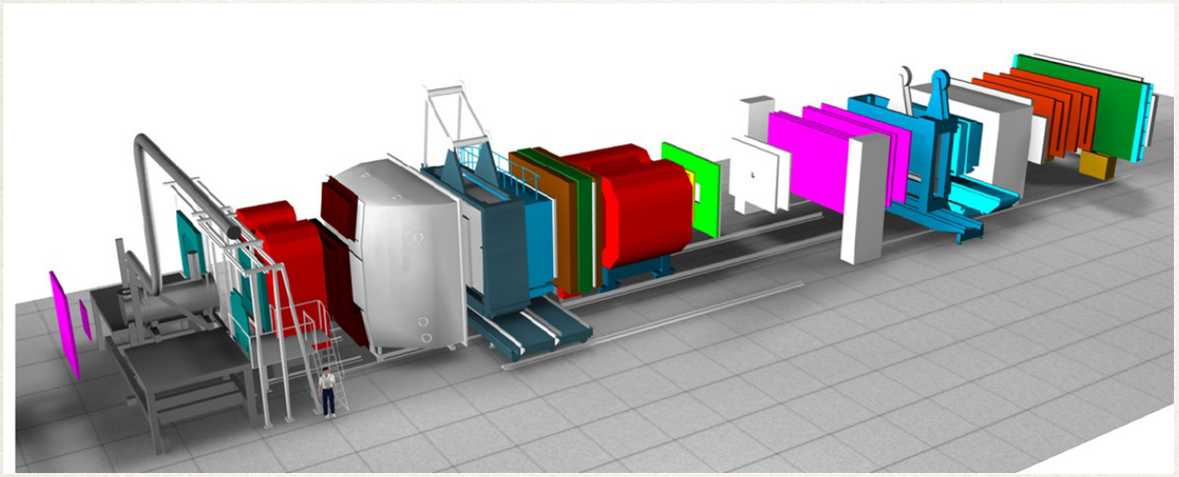
Outline

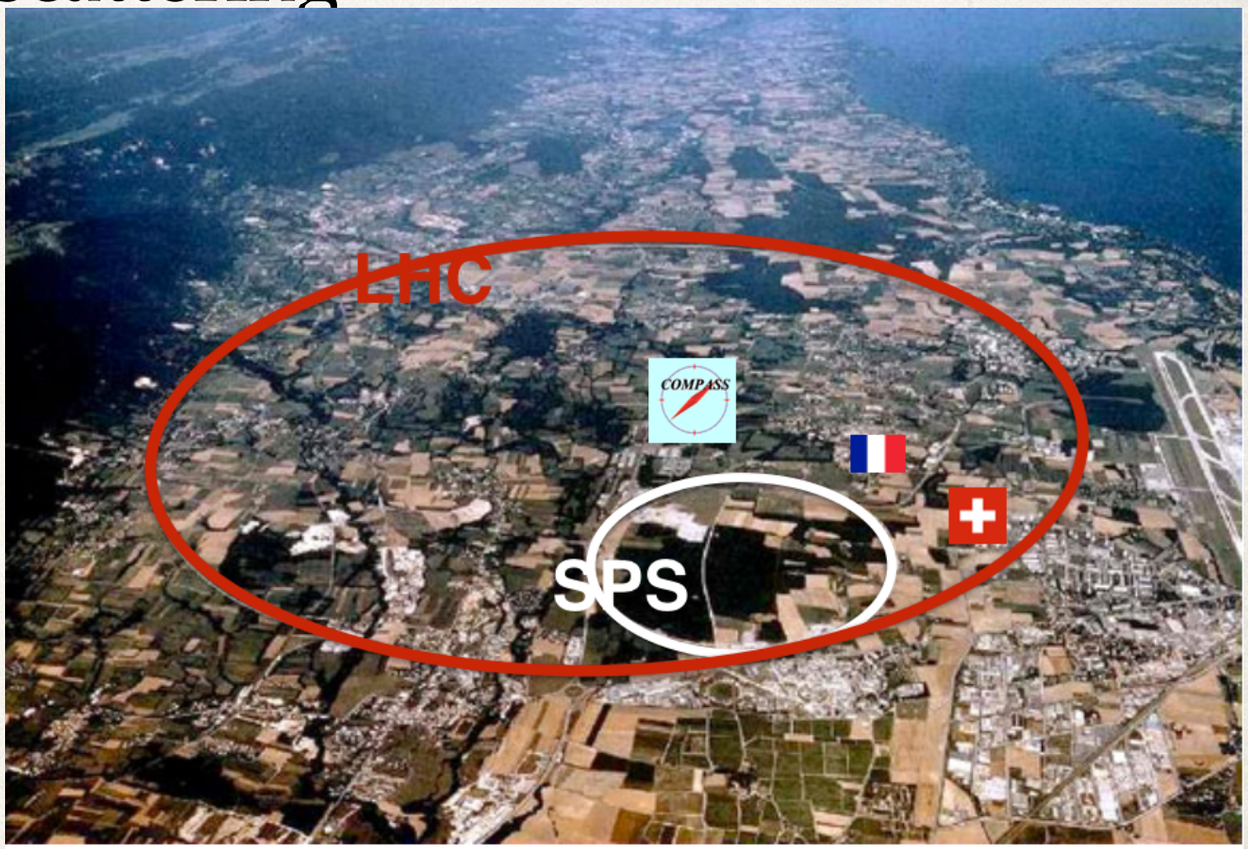
- Brief Physics Motivation
  - COMPASS spectrometer overview
- Need for Drift Chamber 05
- Preparation for the New Detector
  - Garfield Simulations
  - Prototype construction
- Design
  - Overview of working principles
  - Construction Material
- Building Techniques
- Detector Performance 2015
- Conclusion

COMPASS-II Physics Program

COmmon Muon Proton Apparatus for Structure and Spectroscopy

- COMPASS-II: Fixed target experiment which explores hadron structure and hadron spectroscopy through:
  - Drell-Yan π-p scattering
  - Semi-inclusive deep-inelastic scattering
  - Hard-exclusive processes





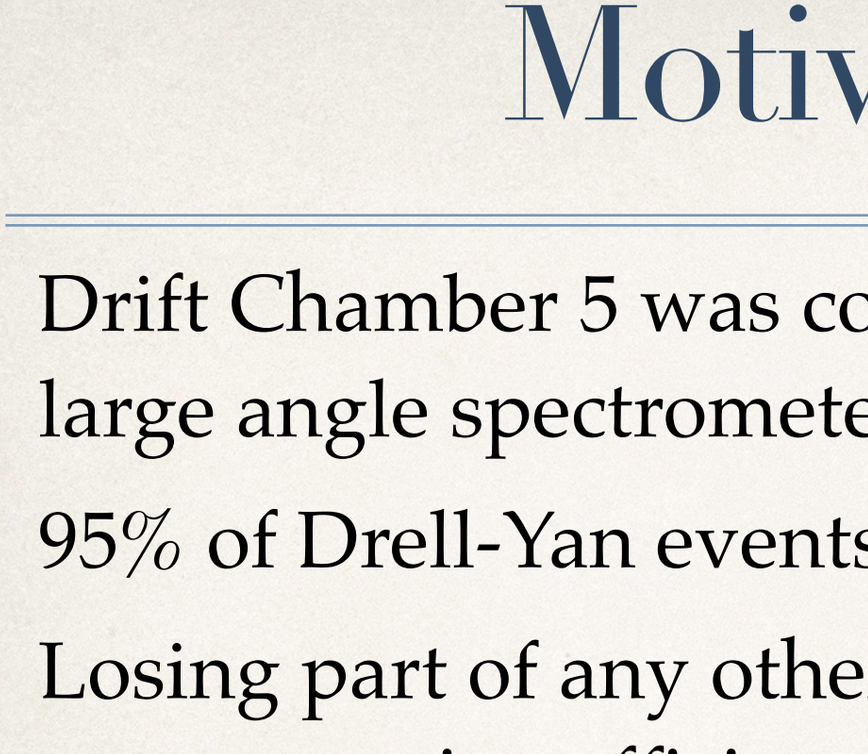
COMPASS-II Spectrometer

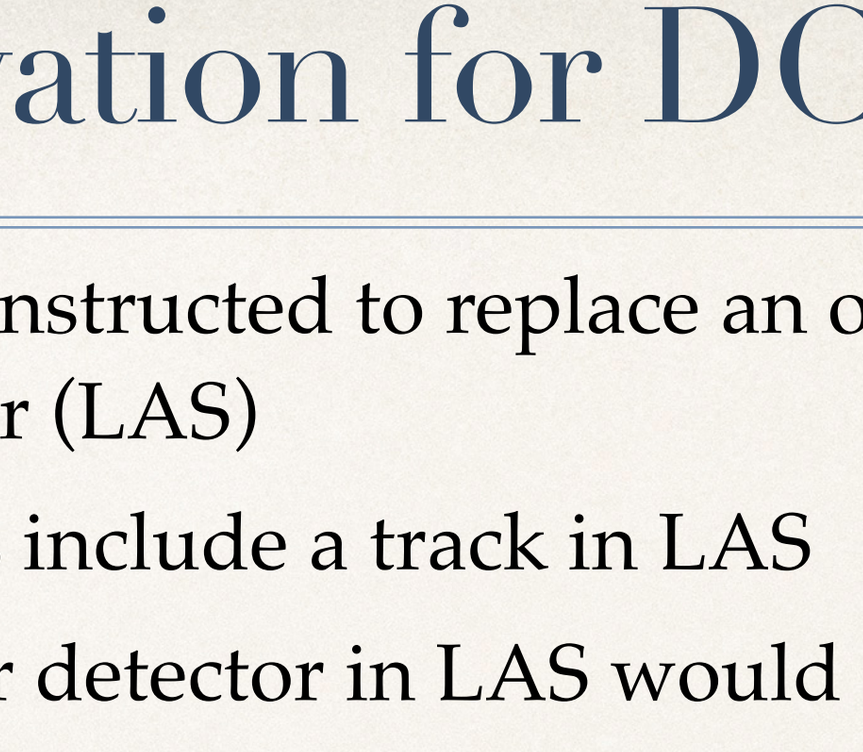
- Beam from SPS, M2 beam line - hadron beam (π/K/p 97/2/1%): 190 GeV
  - muon beam: 160 GeV
- Intensity: 10^8 π/sec (Drell-Yan physics 2015/2018)
  10^7 μ/sec (GPD physics 2016/2017)

- Two stage spectrometer:
  - Large Angle Spectrometer
    (LAS) ($35 < \theta < 180$ mrad)
  - Small Angle Spectrometer
    (SAS) ($18 < \theta < 35$ mrad)

Motivation for DC05

- Drift Chamber 5 was constructed to replace an old detector in the large angle spectrometer (LAS)
- 95% of Drell-Yan events include a track in LAS
- Losing part of any other detector in LAS would significantly reduce reconstruction efficiency





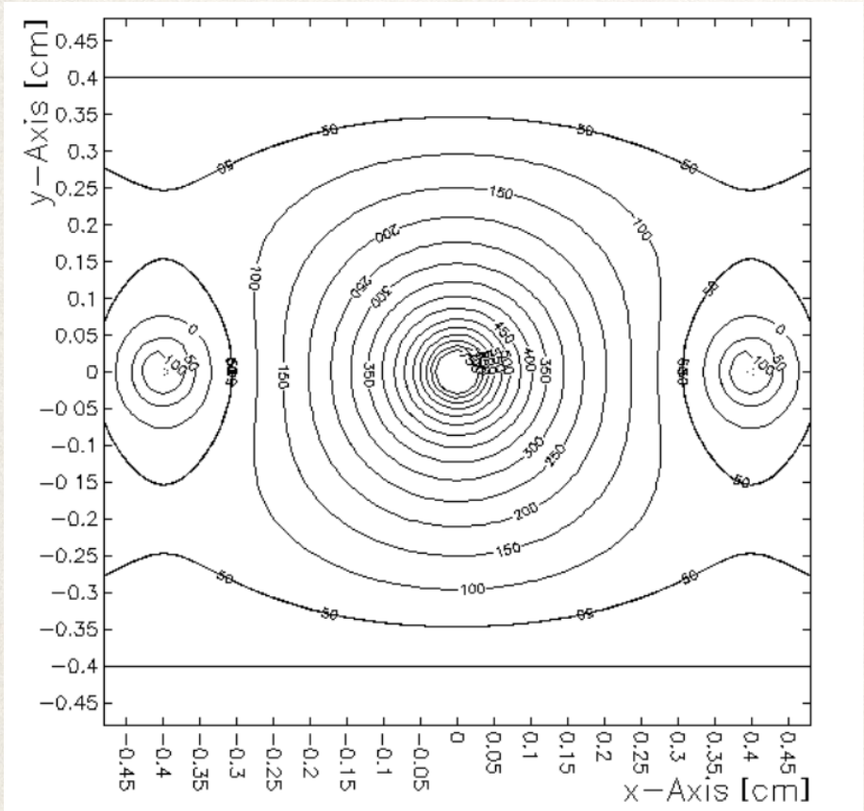
Plots courtesy of Catarina Quintans

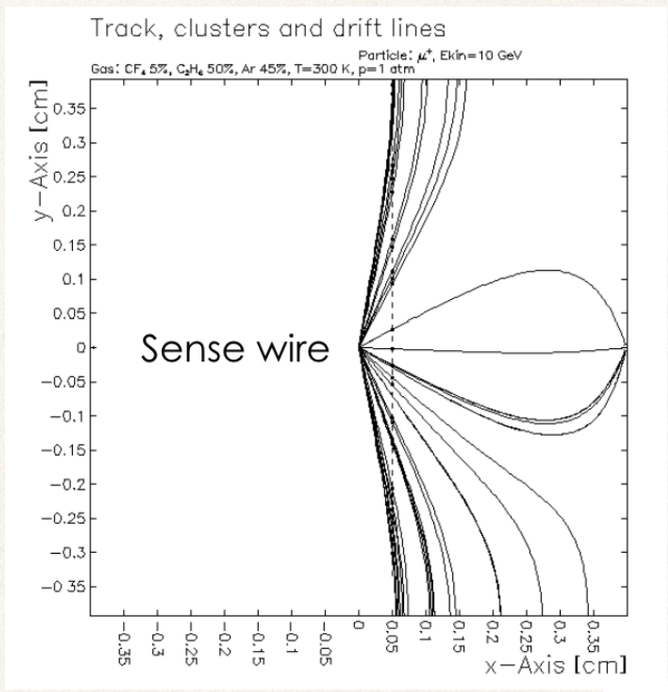
Drift Chamber 05

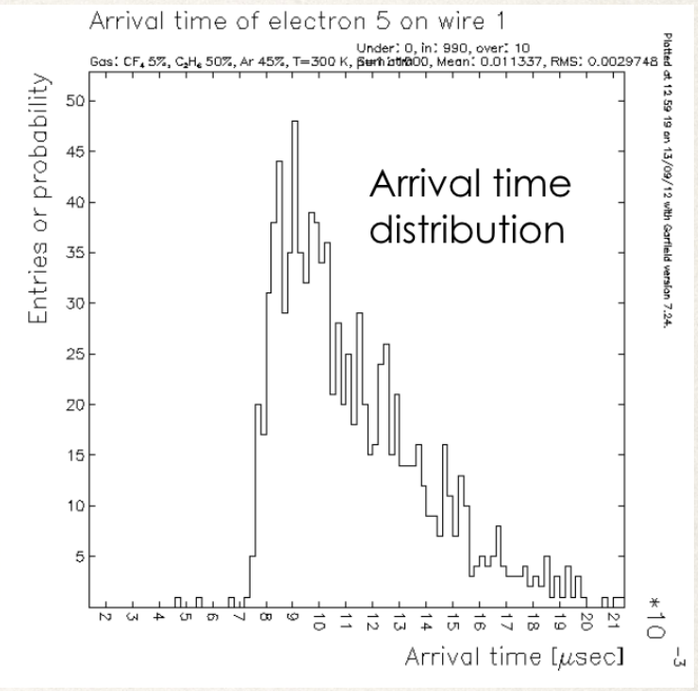
Straws (ST03) DC 04

Garfield Simulations

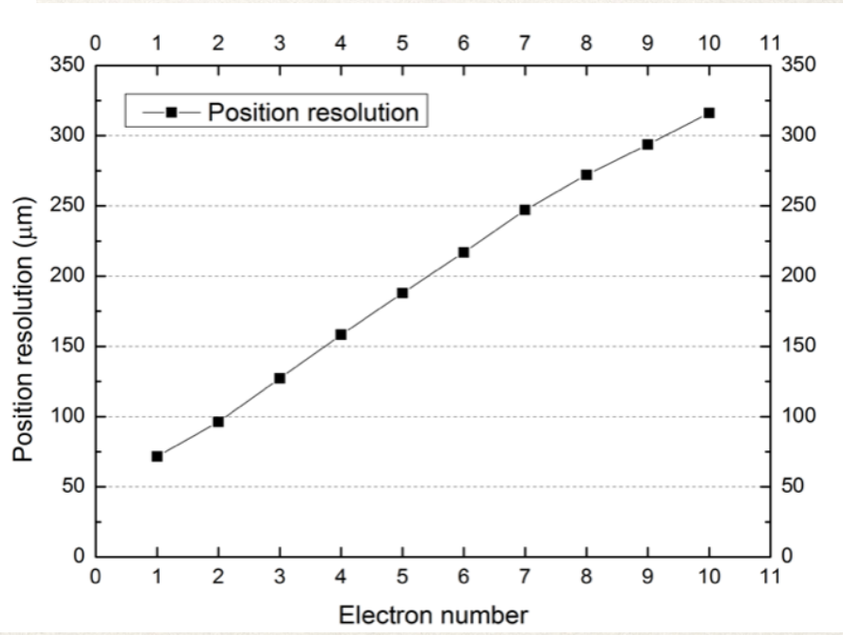
- Drift cell field lines were determined from Garfield simulations





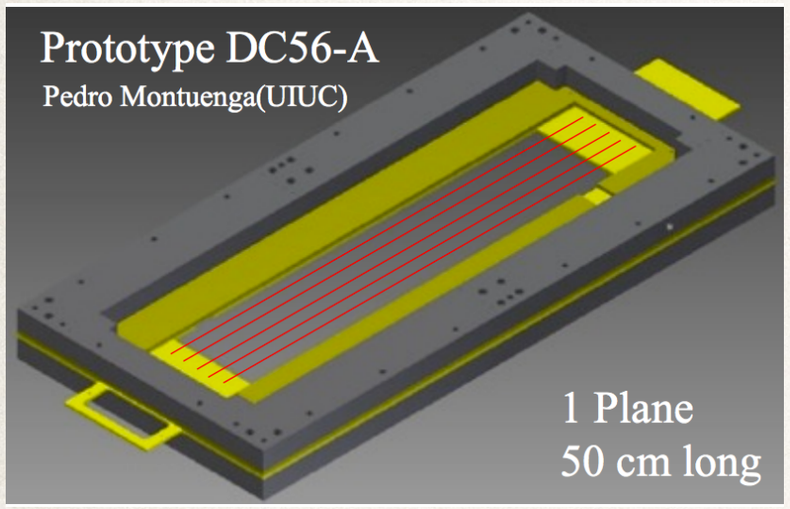


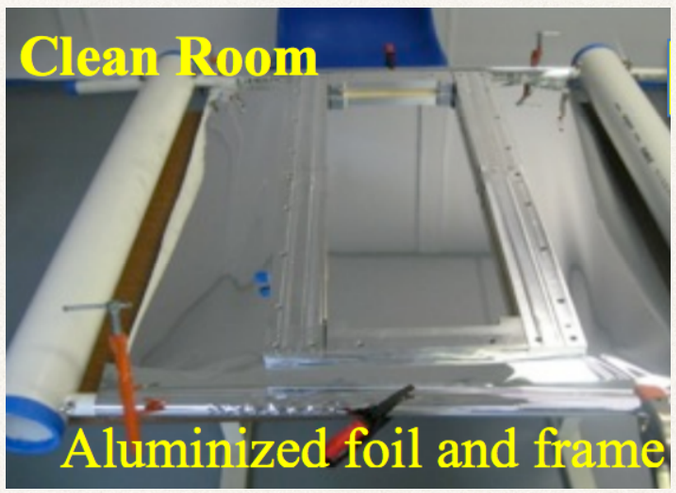
- Position resolution estimated from variations in ionized electron arrival times
- High resolution (~200 microns) can be achieved with a threshold detecting the 5th electron

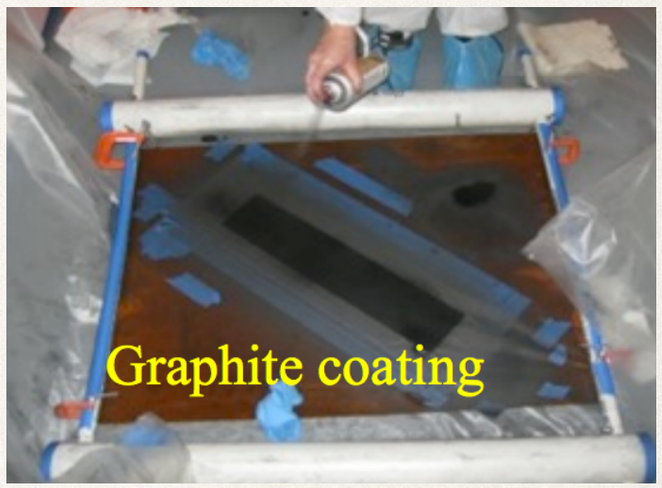


Construction of Prototypes

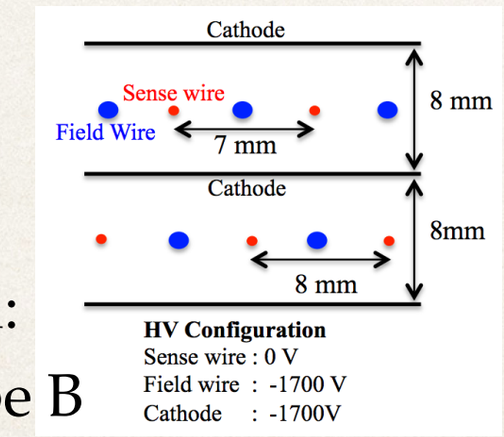
- Two prototypes were built to gain experience before construction
  - Prototype A: 1 plane, 8 wires and 50 cm length
  - Prototype B: 2 planes, 16 wires/plane, 163 cm length
- Hand construction in UIUC clean room

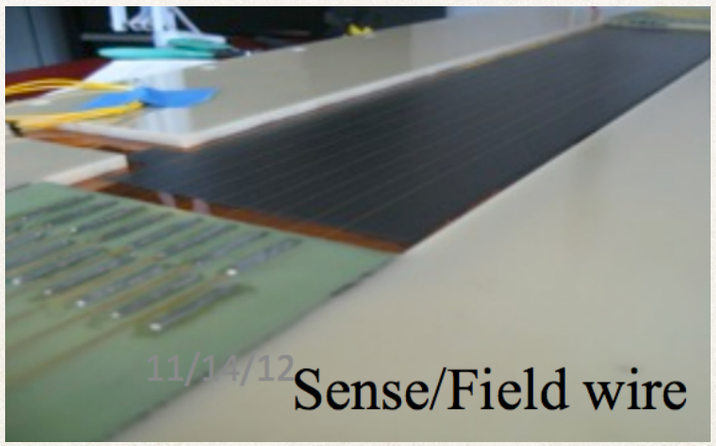






Drift Cell: prototype B





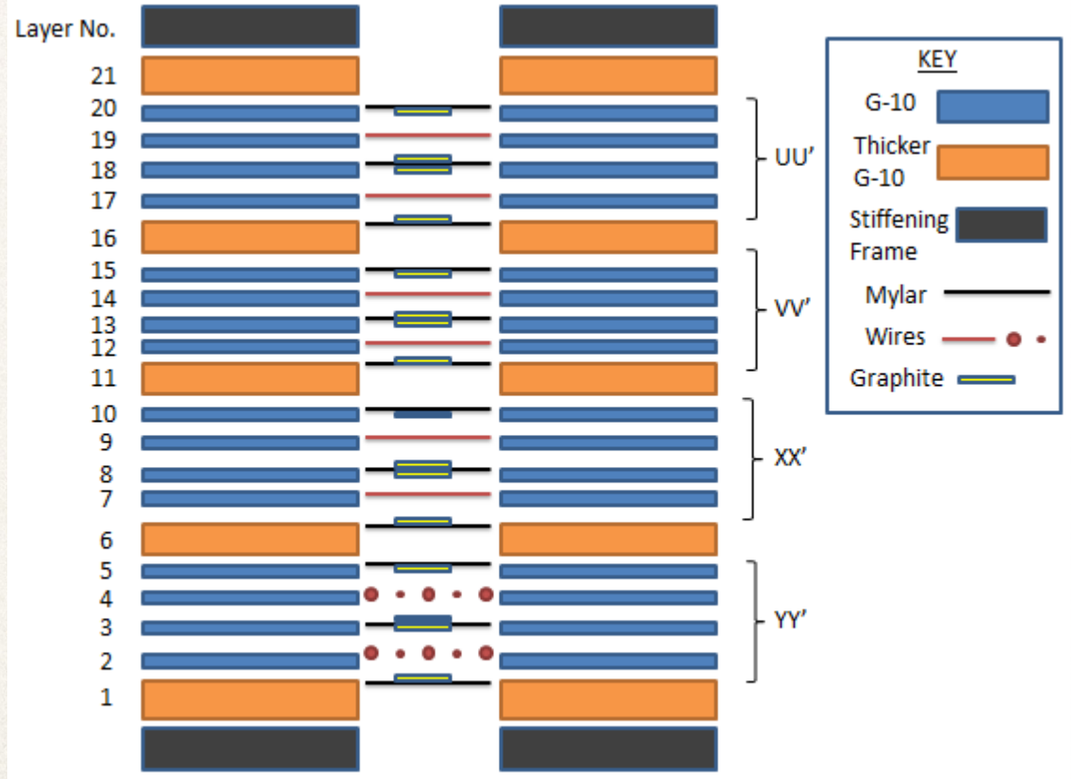
Drift Chamber 05 Design

- Large-area planar drift chamber: active area 249x209 cm^2
- Designed based off previous COMPASS drift chamber.
- Consist of eight planes for tracking redundancy:

  2 planes for each horizontal (X, X'), vertical (Y, Y') and

  $\pm 10^o$ to horizontal (U, U', V, V').

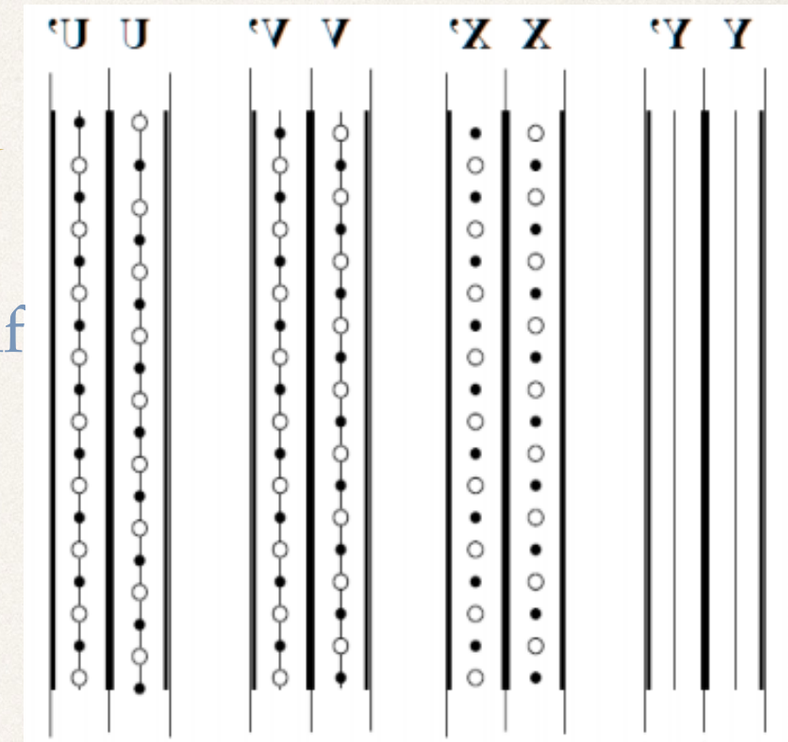
- 2 precision stainless steel stiffening frames support 21 G-10 frames



Drift Chamber Views

- The central beam killers (BK) are on a separate high voltage input.
- Possibility to turning on or off central dead zones depending on if the beam flux is too high or not.

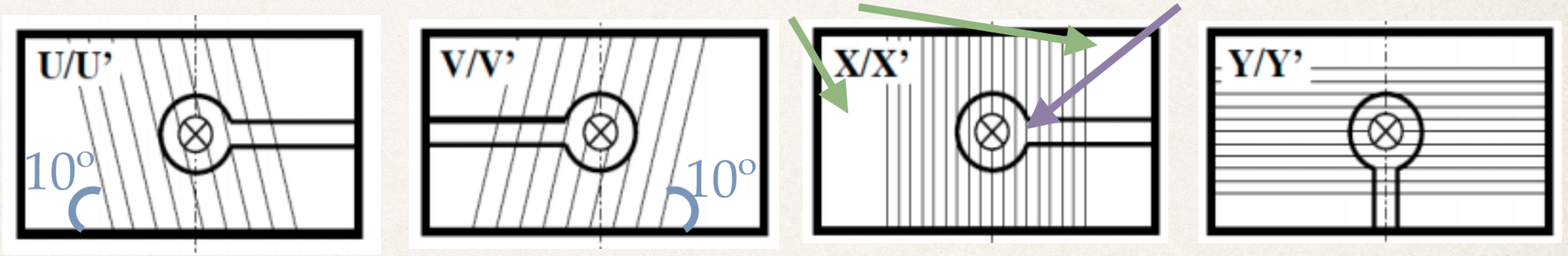
Beam



Sense wires shifted half a drift cell between common projection planes to distinguish left/right ambiguity

Cathode: - 1675V BK: Nominally - 900V

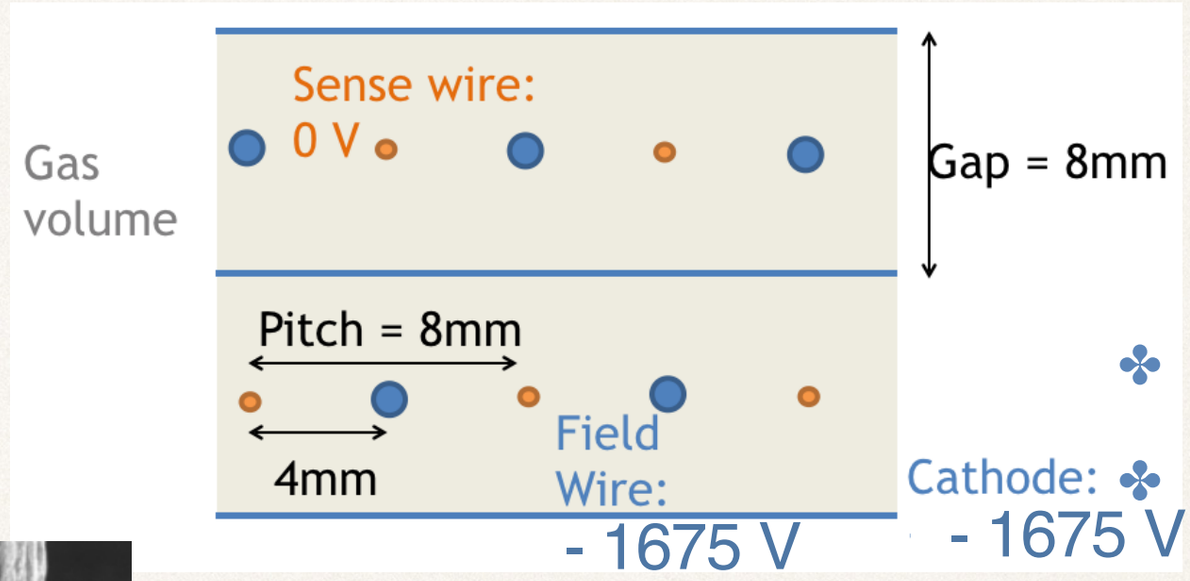
Beam



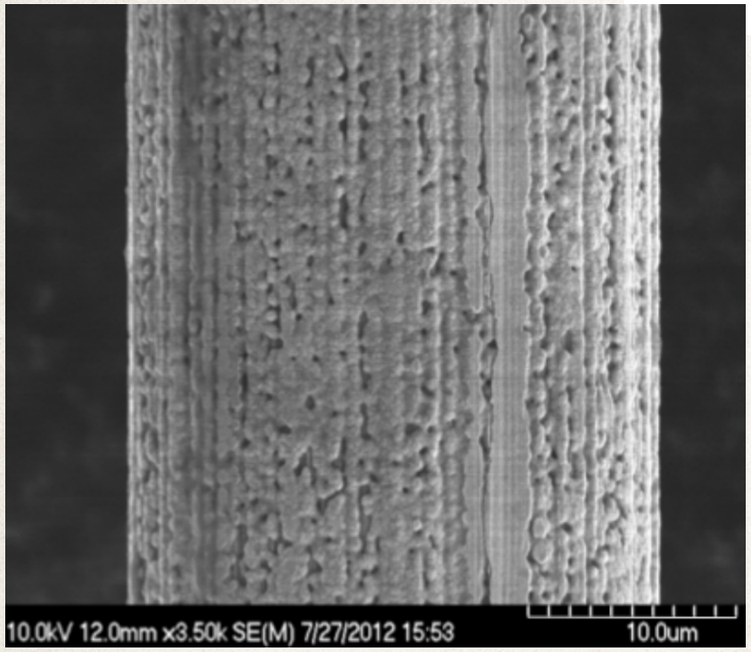
The four different projection views and corresponding wire orientations for each view. The circular beam killer and direction of the beam killer high voltage feed is also shown.

Drift Cells

- Common gas volume consisting of:
  - Ethane 45%
  - Argon 45%
  - CF_4 10%



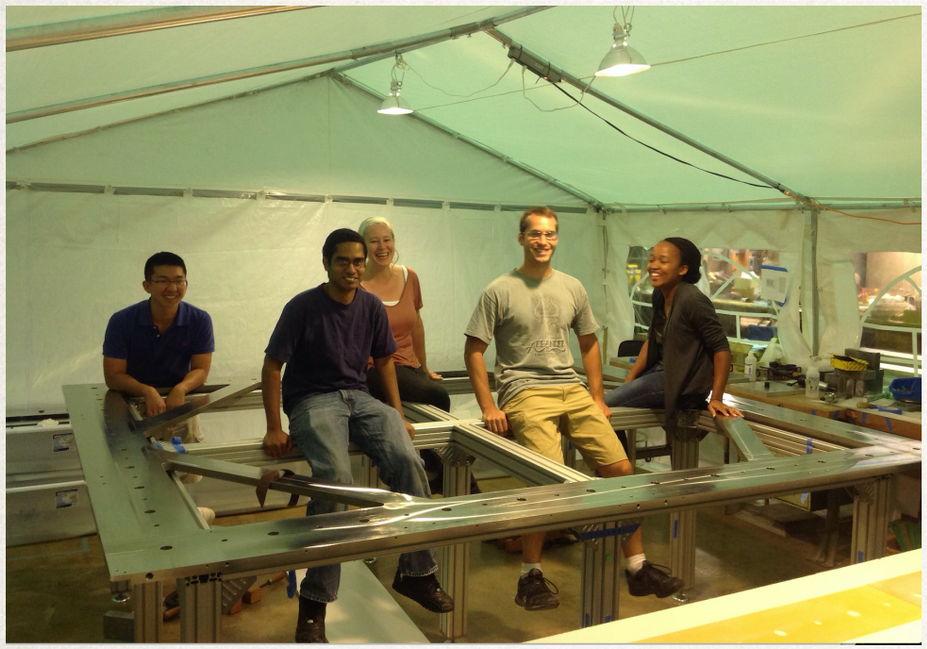
- Nominal high voltage of -1675 V on cathode planes and wires
- 0 V on sense wires
- Gain ~ 10^4



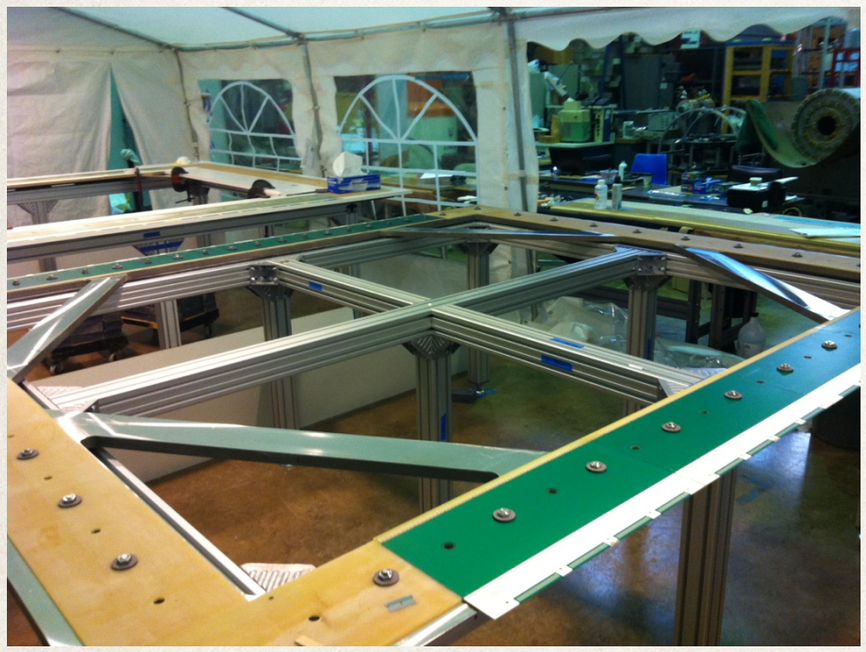
Sense wires from a scanning electron microscope

- Sense wires: 20 micron gold-plated tungsten
  - X/Y views have 256 sense wires each
  - U/V views have 320 sense wires each
- Field wires: 100 micron gold-plated copper beryllium

Construction



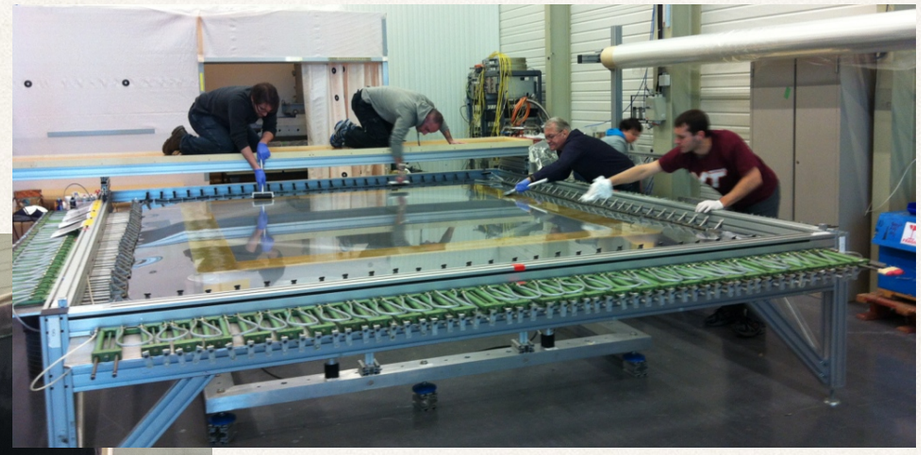
- Two stainless steel stiffening frames were water jet cut on top of each other for better precision
- Frames were custom milled from G-10 strips at UIUC
- A Haas VF-10 milling machine was purchase for precise milling



- Four strips were epoxied together on the stiffening frame to form part of a view
- PCB boards were positioned and epoxied on the frames the following day

Producing Cathodes and Anodes

- Mylar was stretched and epoxied on frames to make cathode planes at CERN
- Custom stretching machine was used for COMPASS drift chambers

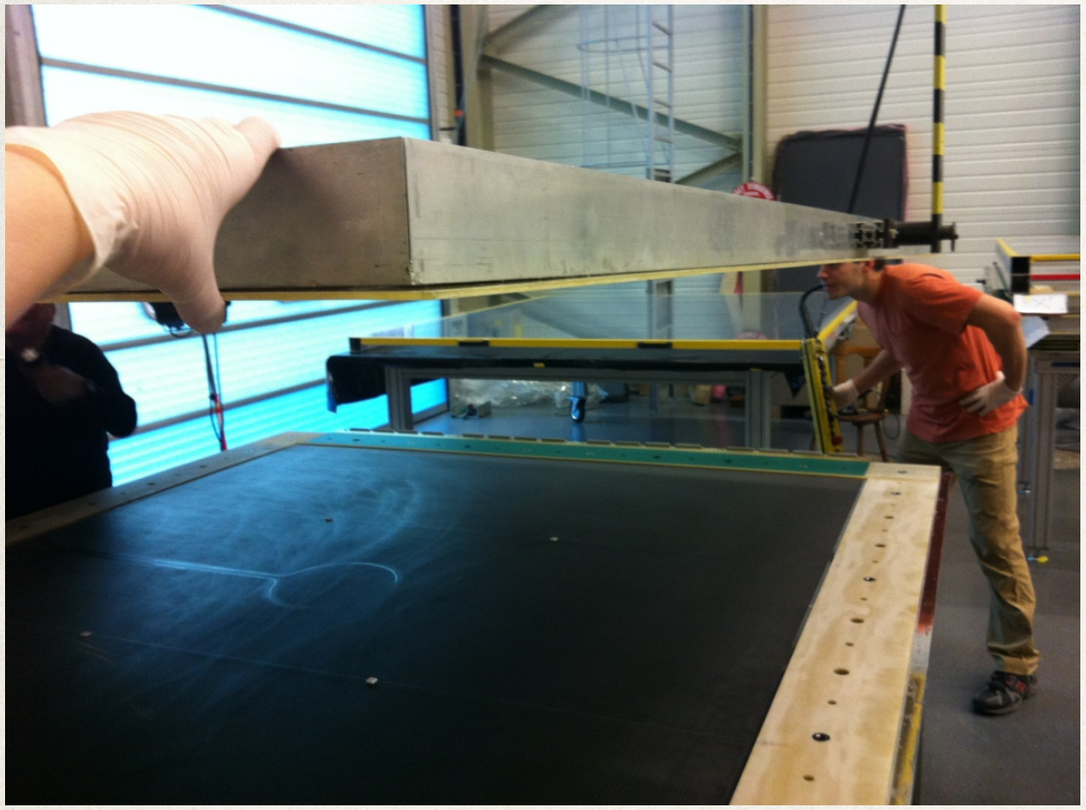


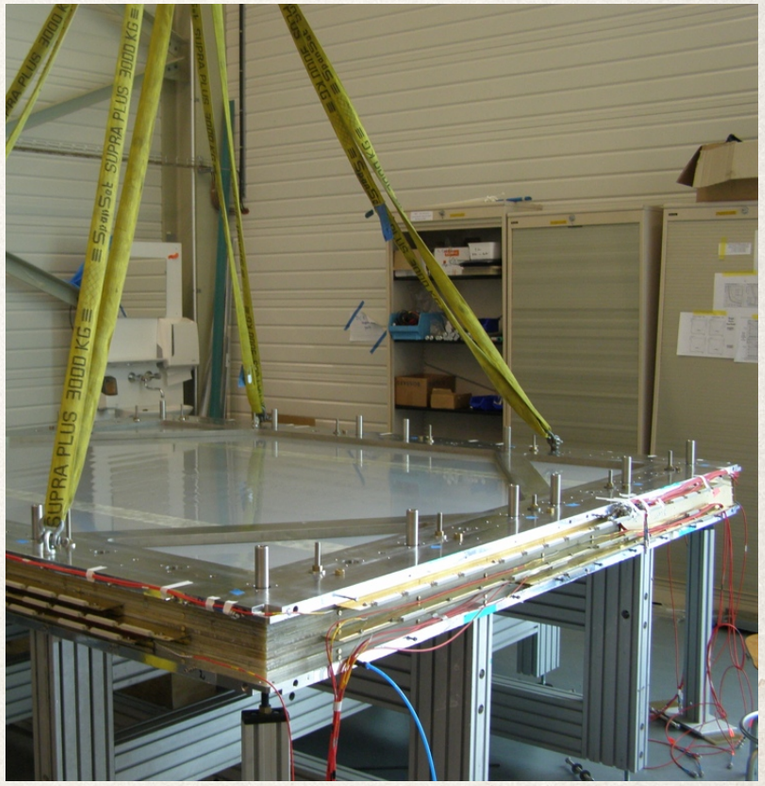
- Cathodes were hand sprayed to form a thin layer of carbon
- Resistance of cathode planes ~30 kΩ/m

- Each of the 2304 sense wires and 2312 field wires were hand soldered at Old Dominion University, UIUC and CERN
- High precision (~10 micron) wire placement was achieved by eye and verified by microscope

Final Assembly

- Anodes and cathodes were stacked alternatively in a clean room at CERN
- Copper shielding was added on extruding PCBs and around the exterior of the chamber
- 40 positioning pins were inserted to ensure the precision of the stiffening frames is transferred to the G-10 frames

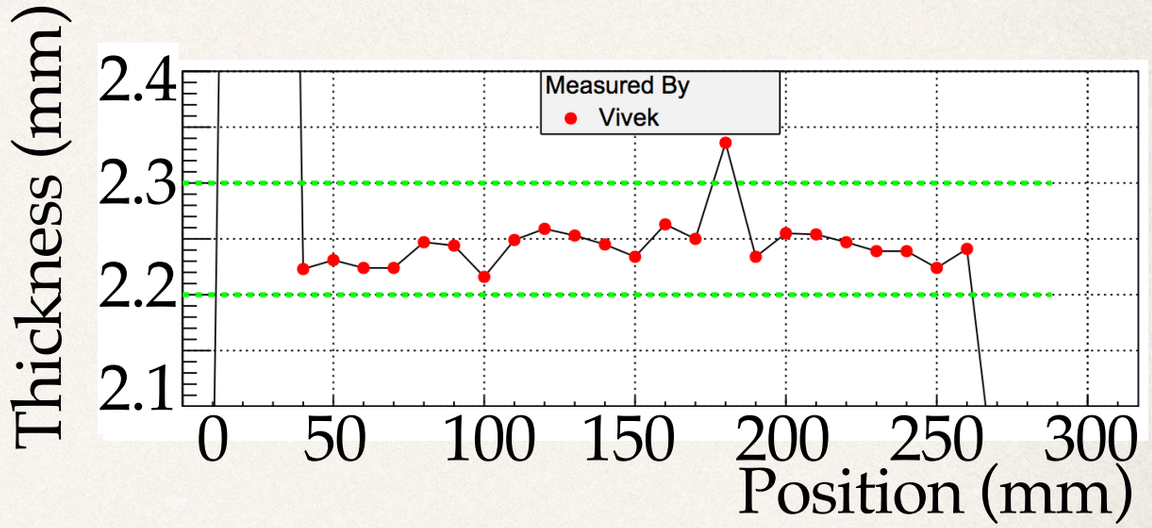




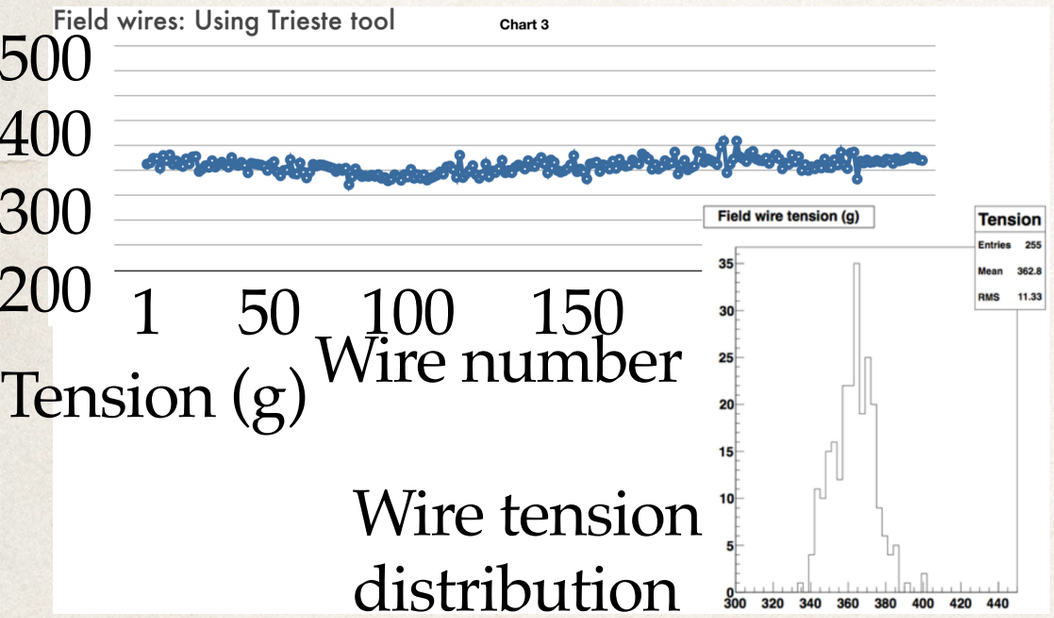
Quality Assurance

Various test preformed after each step of construction

- Thickness of every G-10 strip measured to within 50 microns
- Wire tension measurements
- Measured leakage current of sense wires
- Amplification tests using source

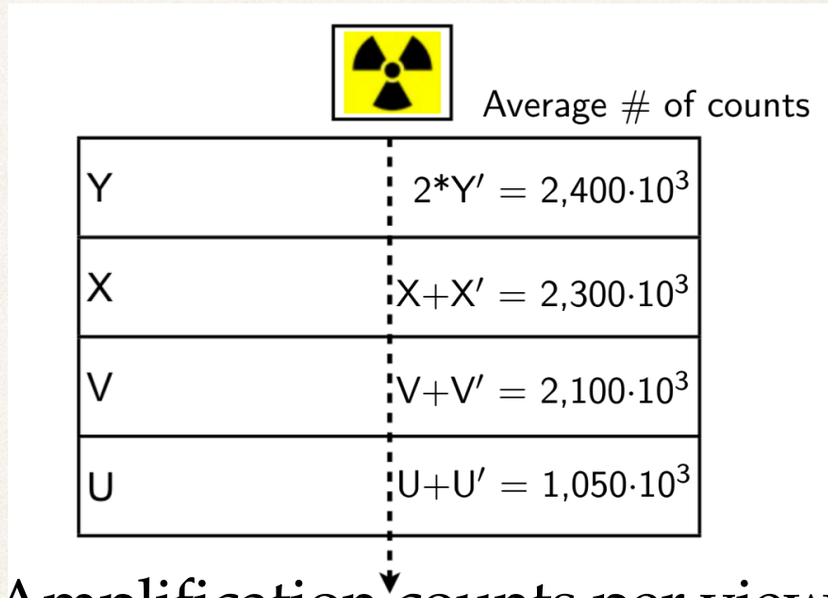


Example thickness measurements for a G-10 strip



Wire tension distribution

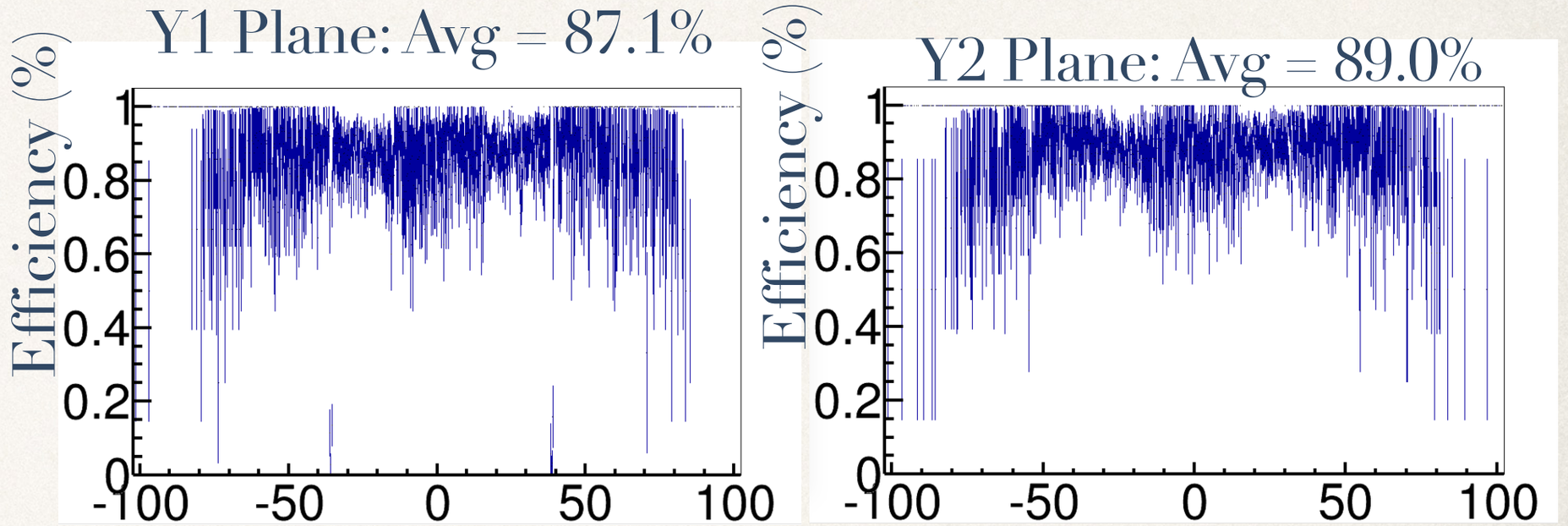
Wire tension results using a pulse generator to vibrate wires under a magnetic field



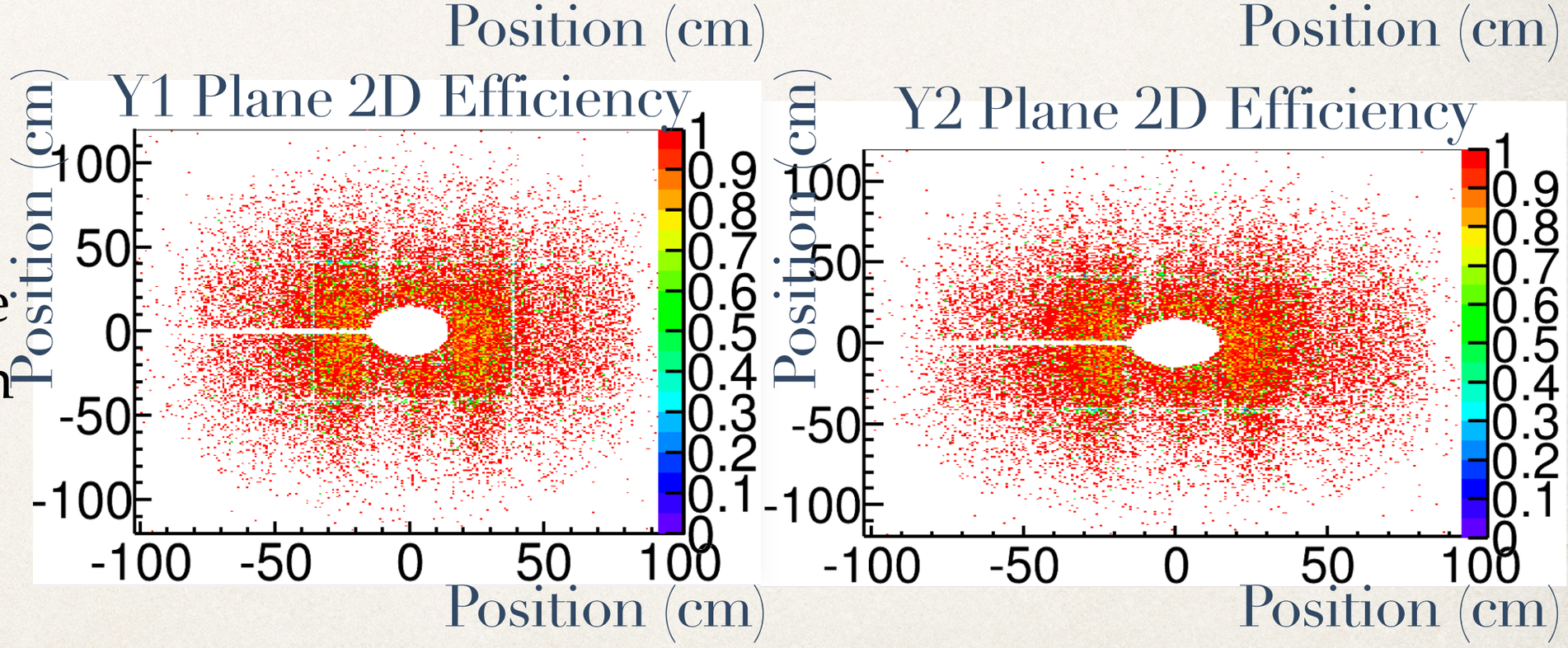
Amplification counts per view with the source placed at the top

2015 Efficiency

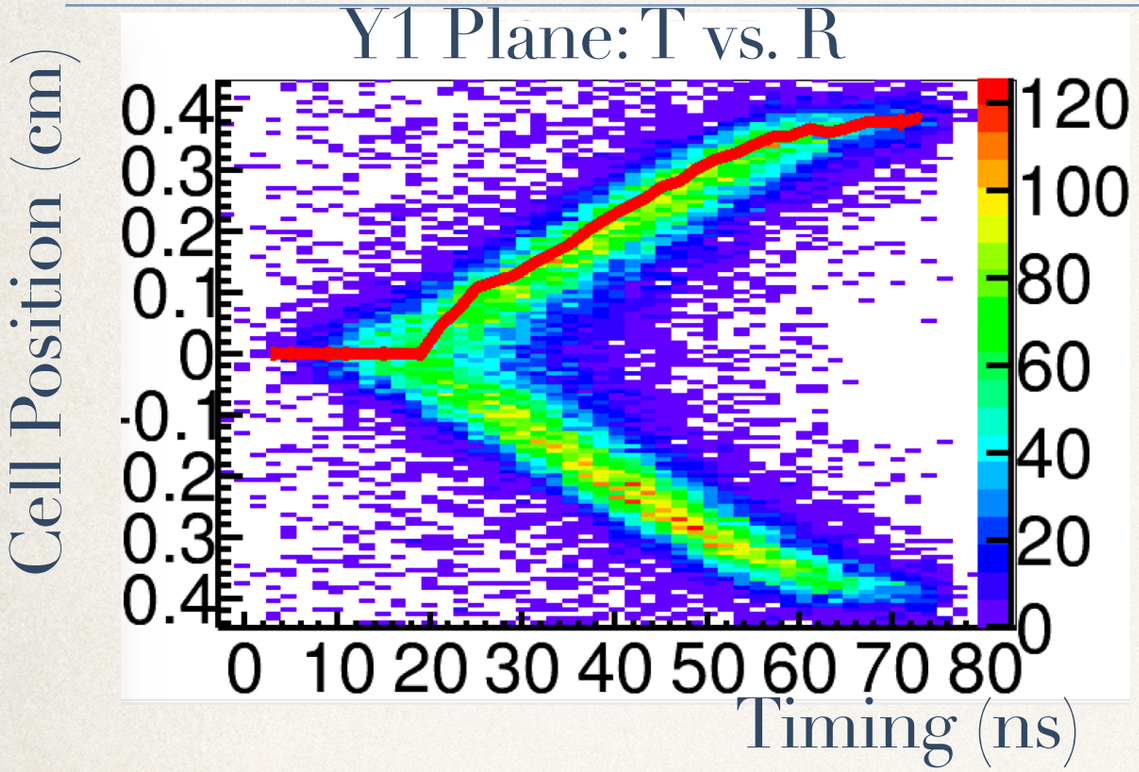
- The efficiency was studied by excluding the plane of interest from the reconstruction

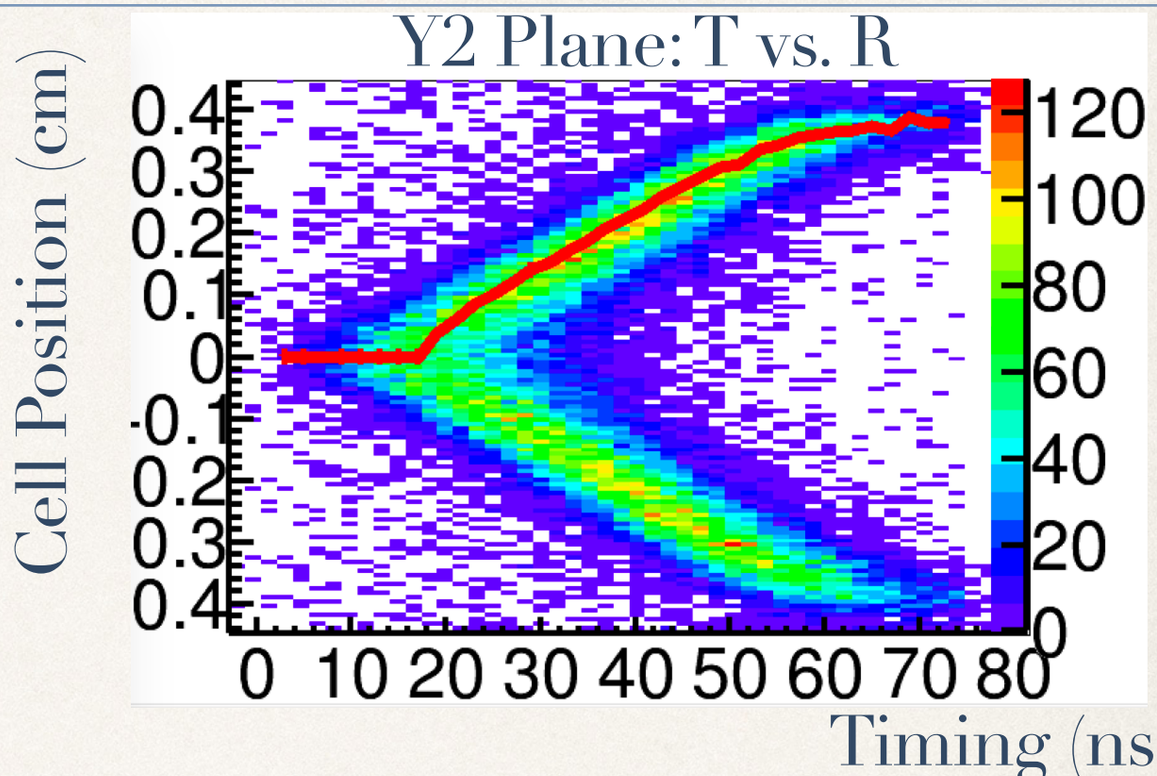


- Tracks from the spectrometer are used to determine where hits should be on a plane



2015 RT Relation

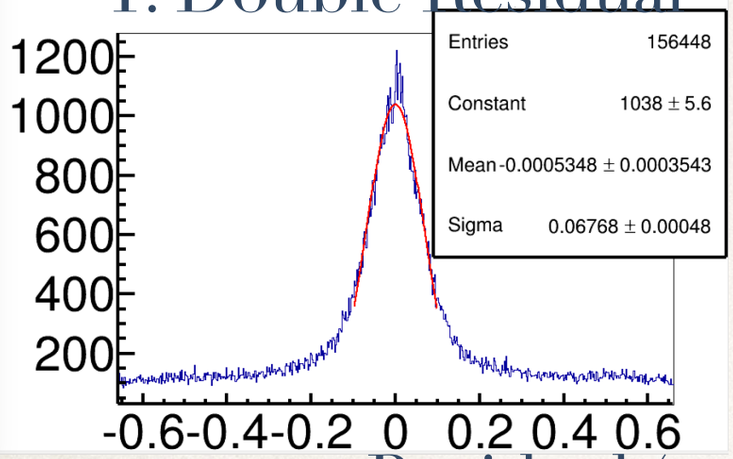




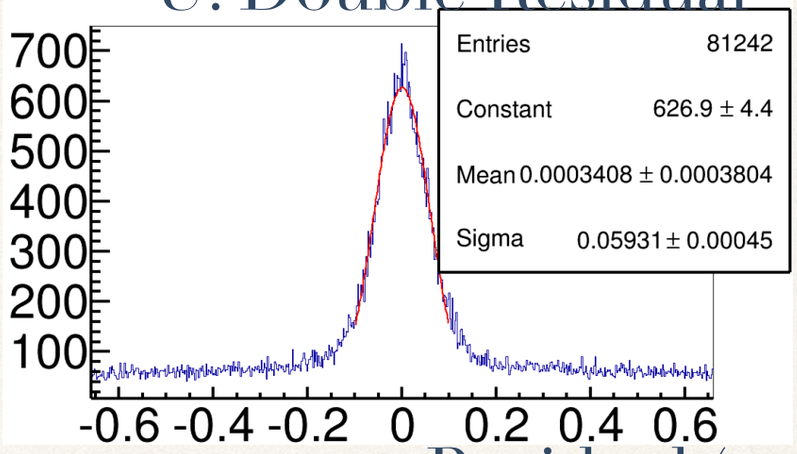
- The RT relation accurately gives the position of a hit within a drift cell.
- This relation is determined from the reconstructed track times and reconstructed track positions.
- Drift speed within a cell ~80 μm/ns

2015 Position Resolution

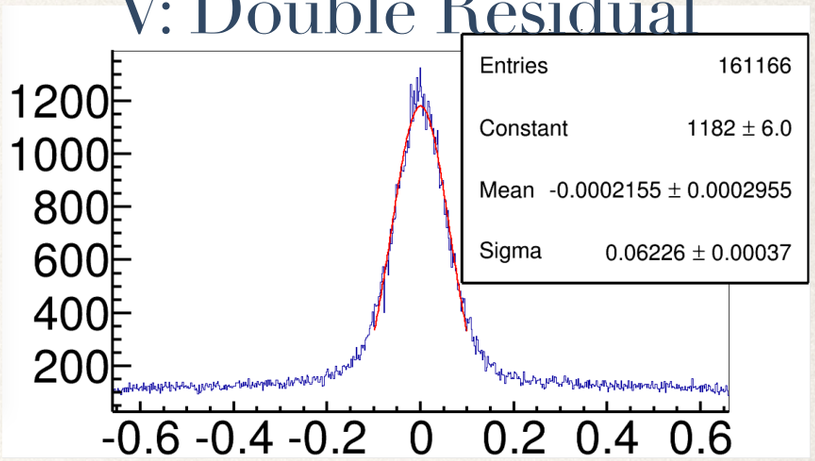
Y: Double Residual



U: Double Residual



V: Double Residual



$$\sigma^2_{total} = \sigma^2_{Y1} + \sigma^2_{Y2}$$

$$\sigma_{Y1} = \sigma_{Y2} = \frac{\sigma_{total}}{\sqrt{2}}$$

- Differences in residuals between views (double residuals) should be correlated
- Double residual is independent of track resolution and less prone to alignment errors
- In 2015 a position resolution of 430 microns was achieved

Conclusion

- Large-area drift chamber, DC05, was made at Illinois, Old Dominion University and CERN
- Drift Chamber 05 is a stable, efficient detector that will useful for years to come
- Successfully implemented in 2015 Drell-Yan reconstruction and currently taking data at COMPASS