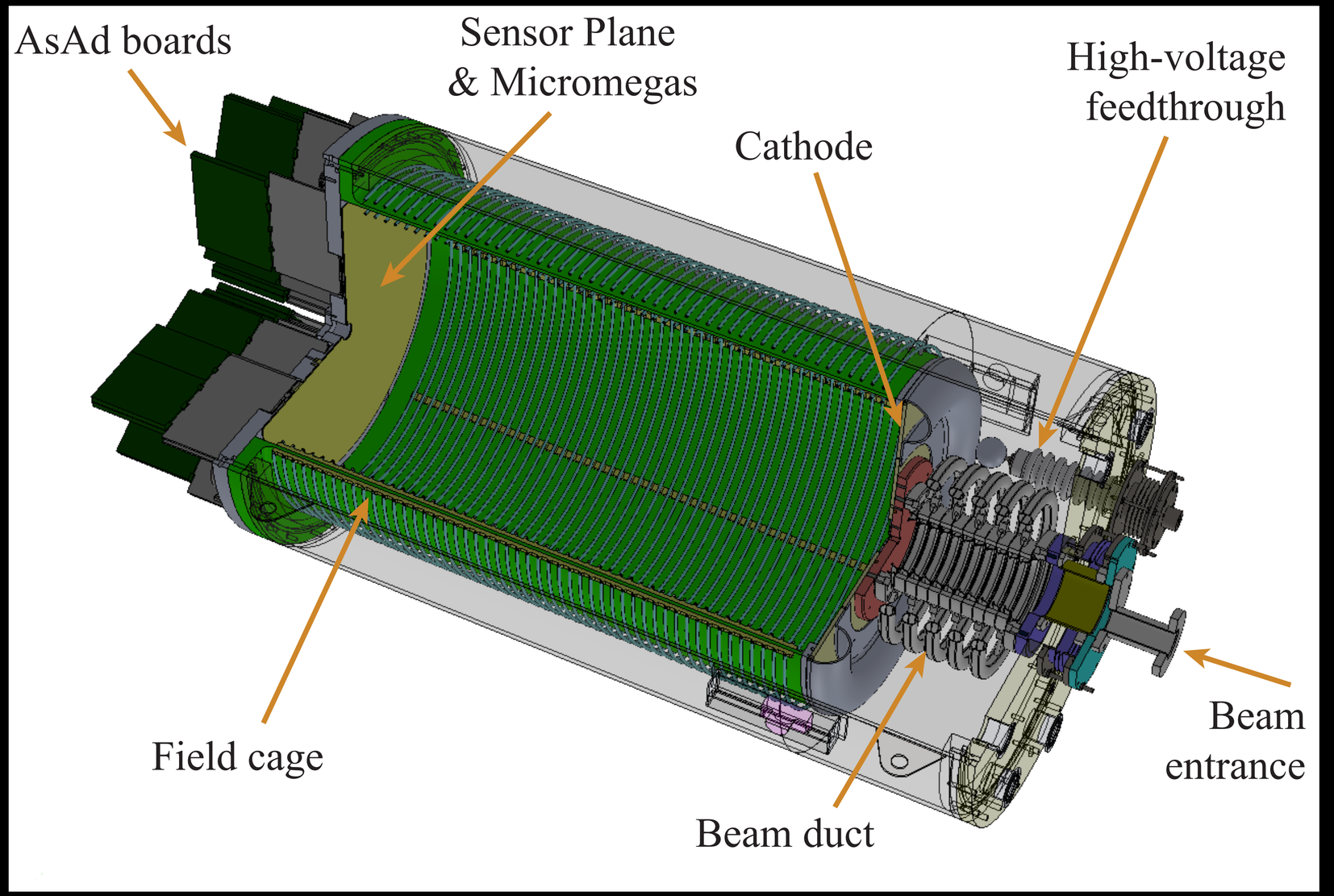
D. BAZIN
NATIONAL SUPERCONDUCTING CYCLOTRON LABORATORY
FACILITY FOR RARE ISOTOPE BEAMS
MICHIGAN STATE UNIVERSITY

PRESENT AND FUTURE OF THE GET SYSTEM AT NSCL/FRIB

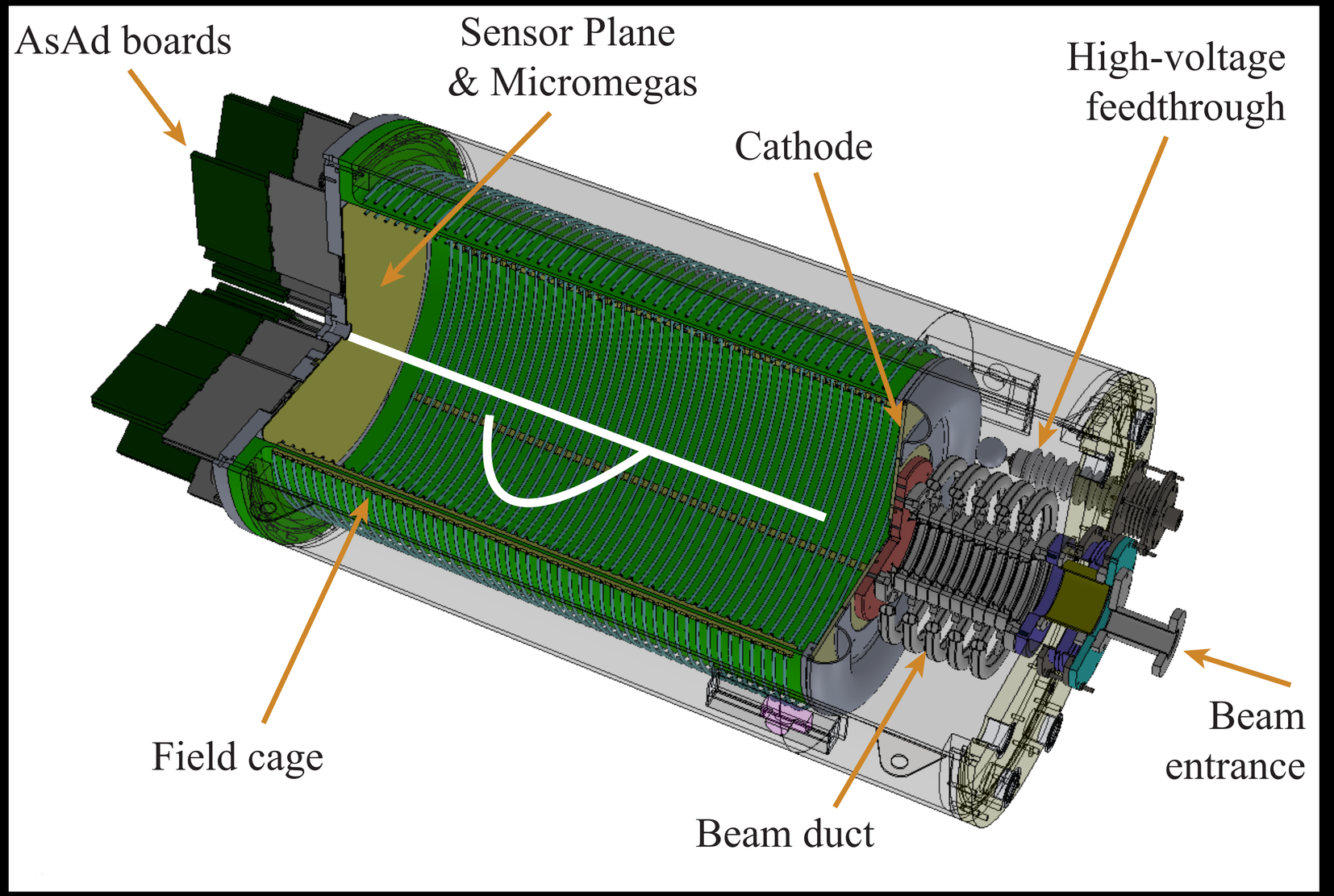
THE AT-TPC AT NSCL

- Cylindrical volume
  - 250 liters (1 m long by 55 cm wide)
  - Oriented on beam axis
  - Electrons produced in gas drift towards sensor plane parallel to beam direction
  - Surrounding volume filled with insulator gas such as N_2



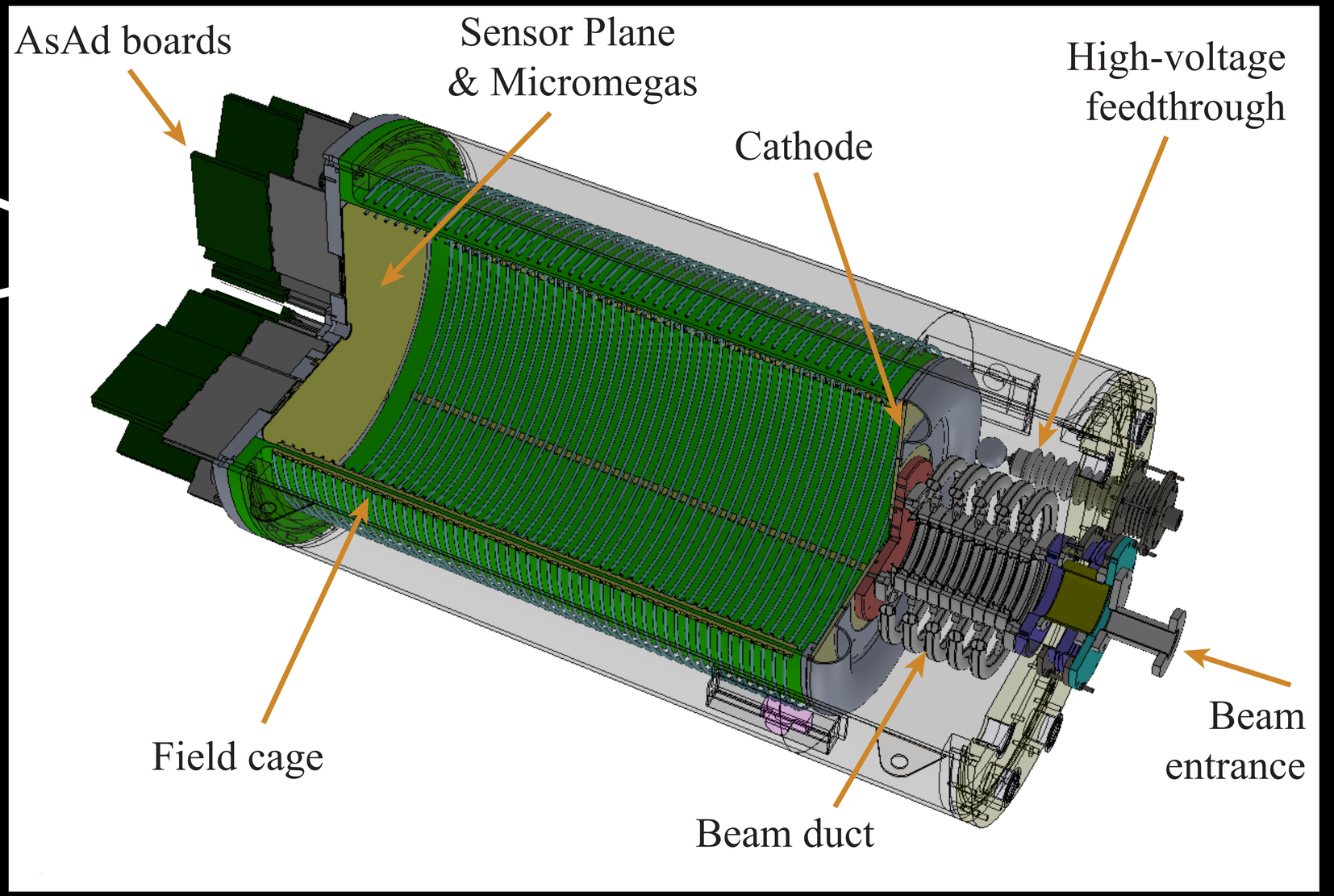
THE AT-TPC AT NSCL

- Cylindrical volume
  - 250 liters (1 m long by 55 cm wide)
  - Oriented on beam axis
  - Electrons produced in gas drift towards sensor plane parallel to beam direction
  - Surrounding volume filled with insulator gas such as N_2



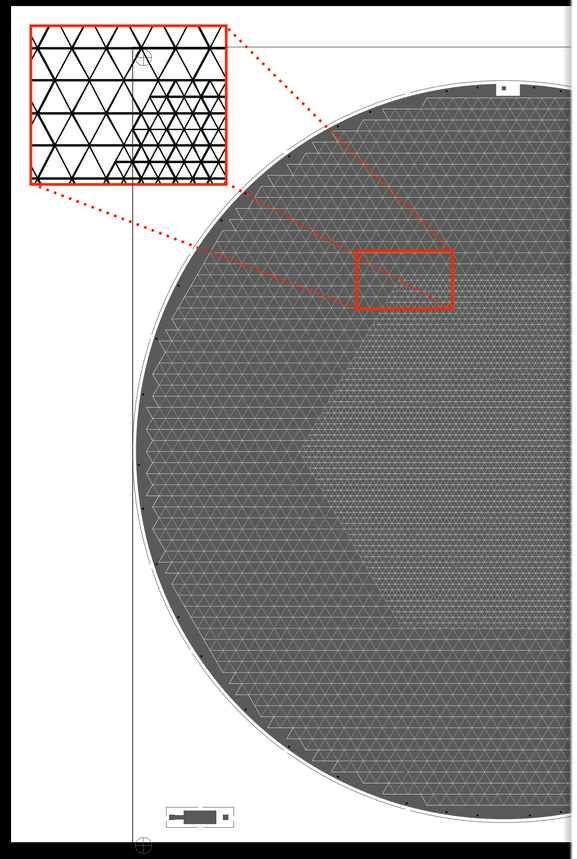
THE AT-TPC AT NSCL

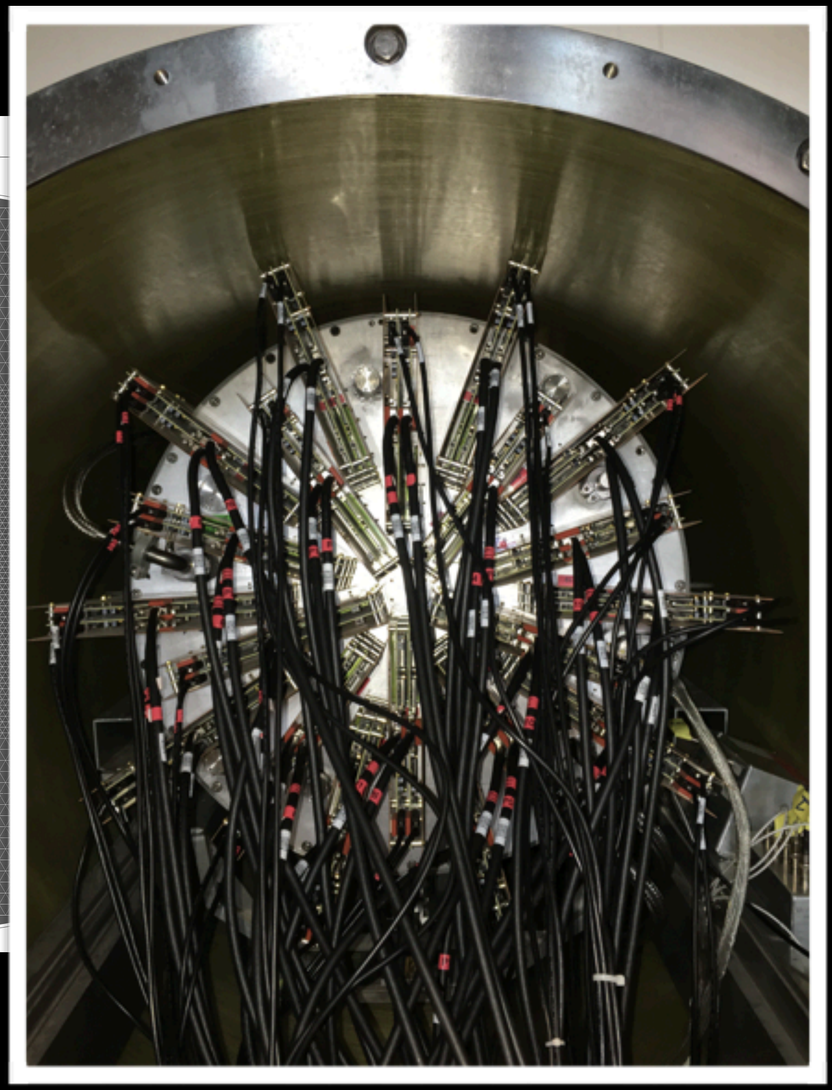
- Cylindrical volume
  - 250 liters (1 m long by 55 cm wide)
  - Oriented on beam axis
  - Electrons produced in gas drift towards sensor plane parallel to beam direction
  - Surrounding volume filled with insulator gas such as N_2



SENSOR PLANE & ELECTRONICS

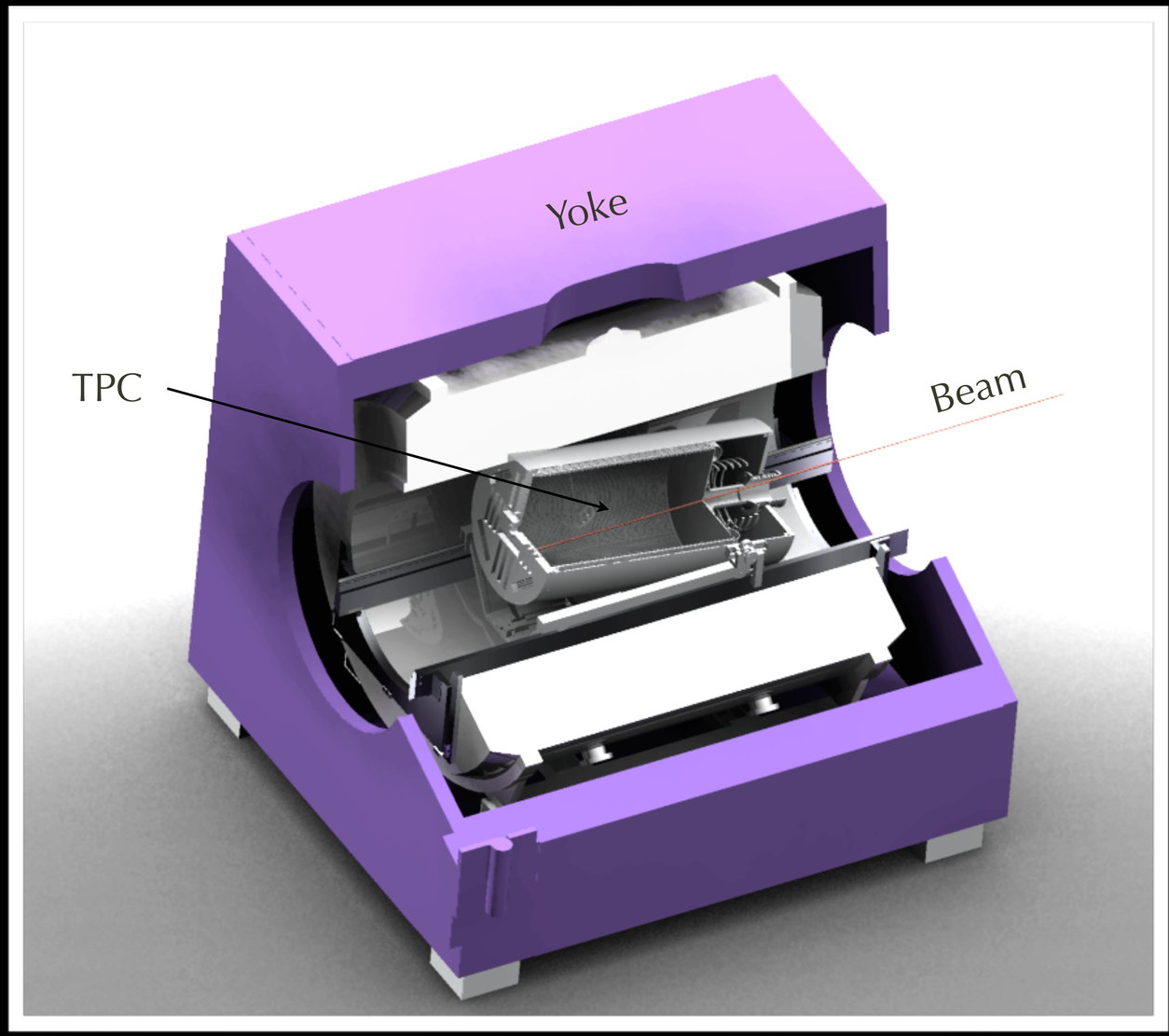
- Mosaic composed of 10,240 triangular pads
  - Smaller size triangle region in center to increase granularity
  - Pad sizes of 0.5 and 1 cm
- Front-end electronics
  - Directly mounted on the back of sensor plane to avoid cables and minimize capacitive noise



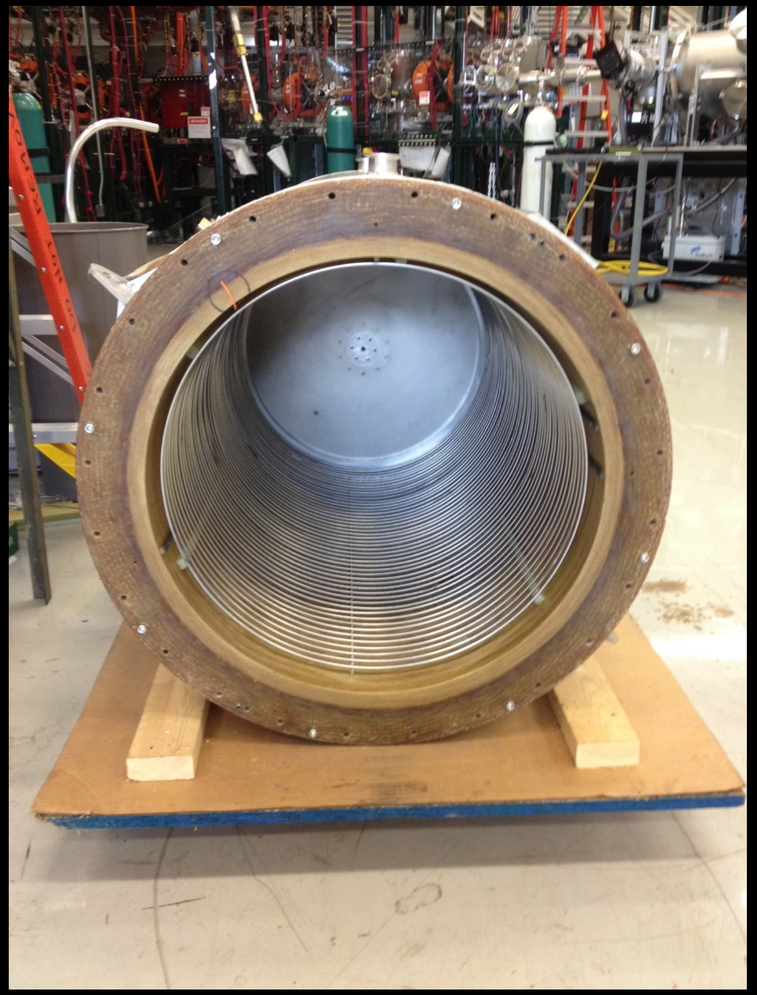


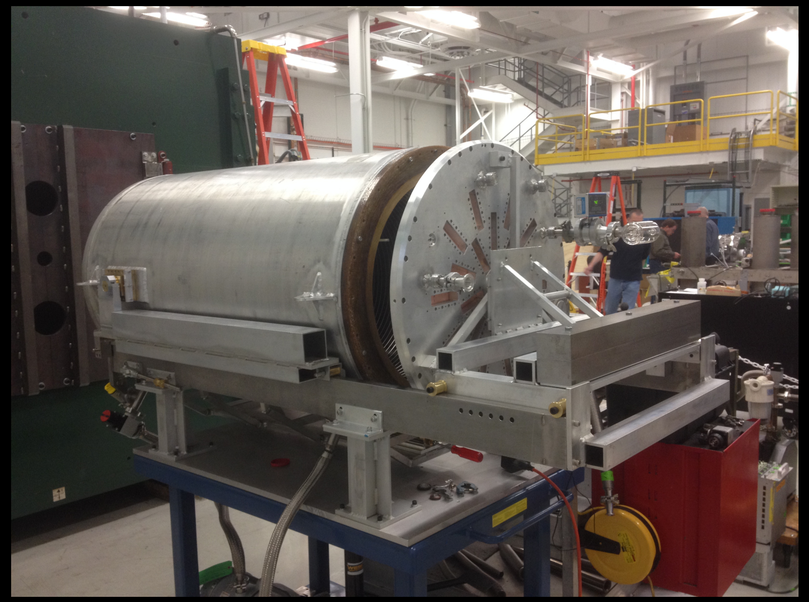
AT-TPC DEVICE

- AT-TPC detector placed inside large bore MRI solenoid
  - Curve trajectories of scattered particles
    - Increase their trajectory length and measure their range
    - Measure their magnetic rigidity
  - Tilt AT-TPC volume by up to 7°
    - Spread image of beam tracks over larger number of pads



A FEW PICTURES…

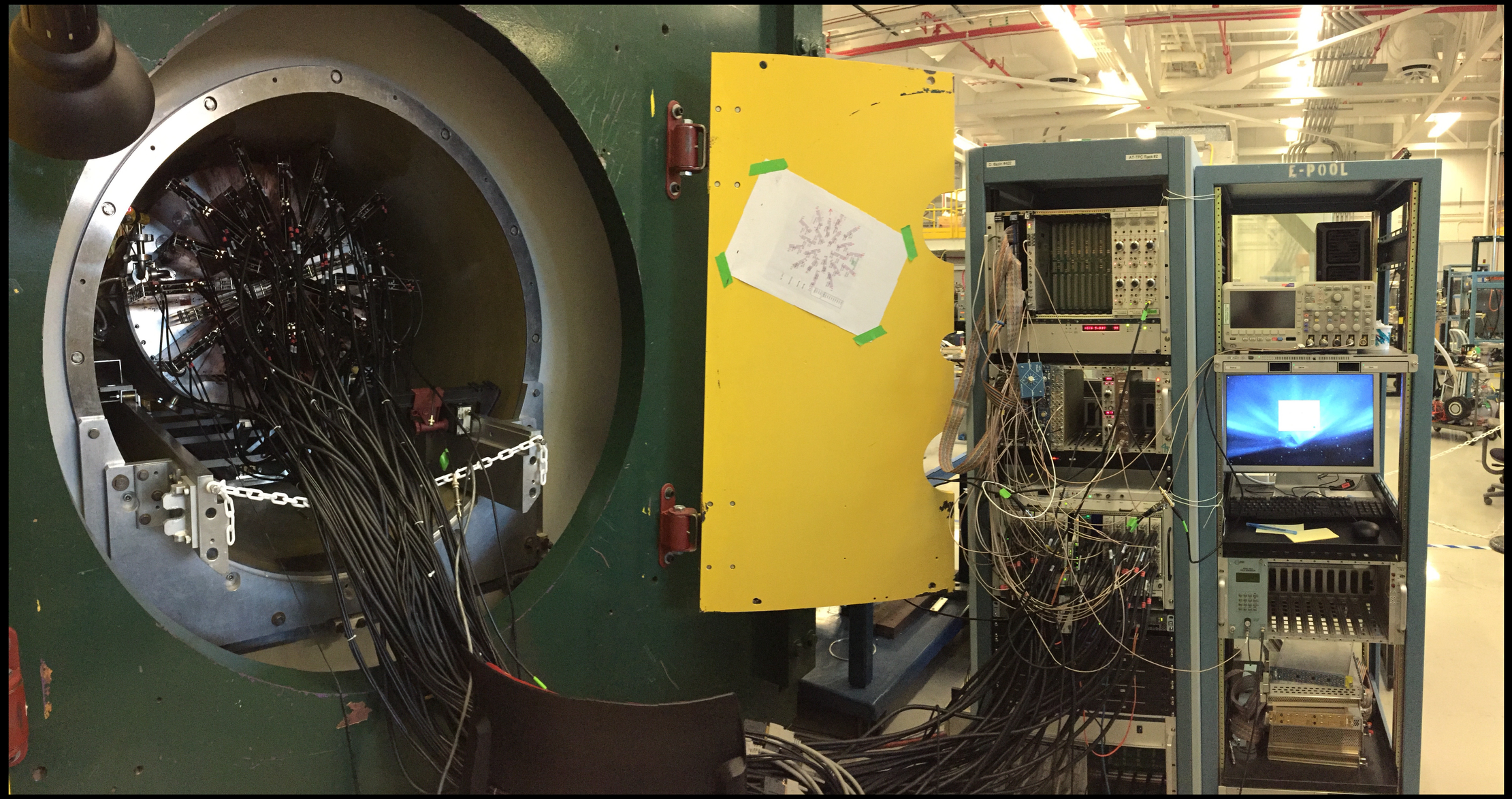




GET ELECTRONICS AND THE AT-TPC

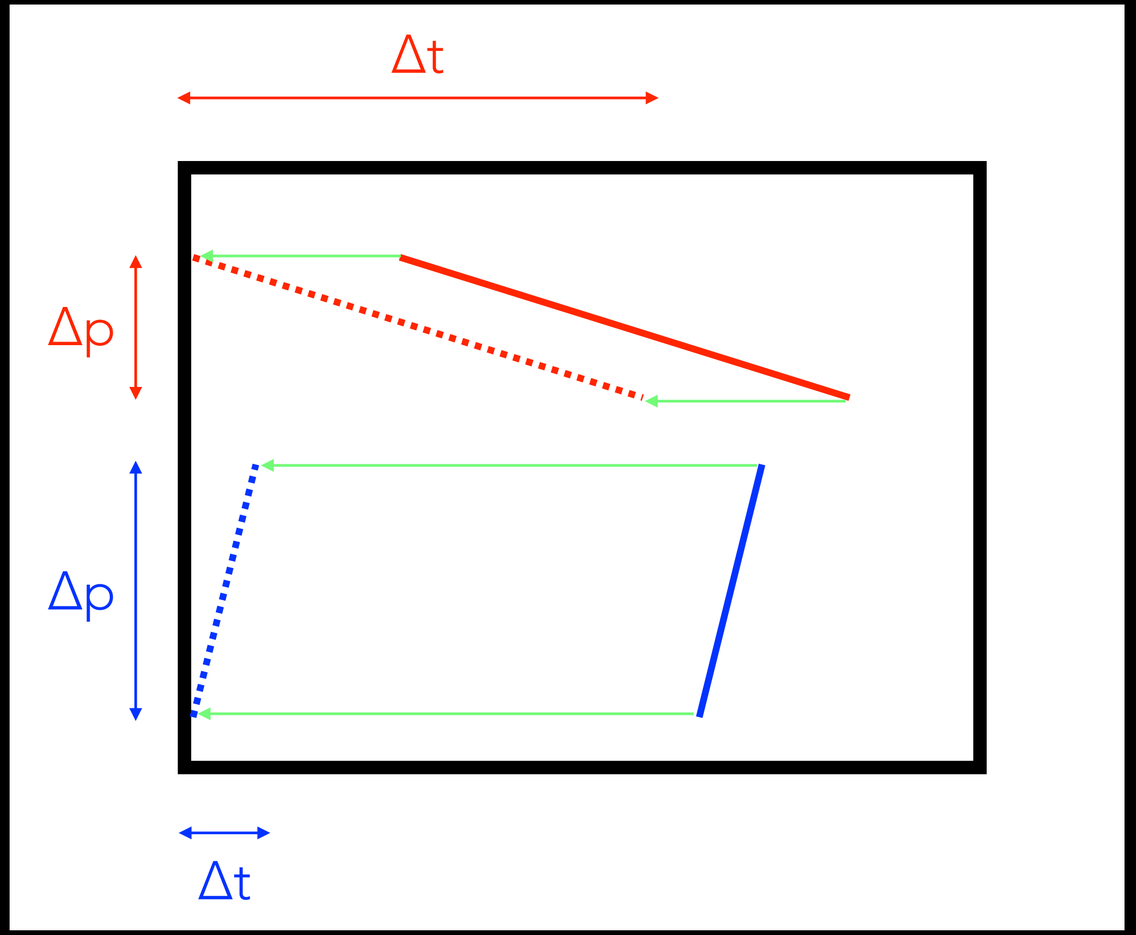
- The special features of the GET electronics are essential to the AT-TPC
  - Only ancillary detectors are Ion Chamber or MCP upstream of AT-TPC
  - No ancillary detector to be used as trigger source
  - AT-TPC has to rely on internal (self) trigger generated from its pad plane
- Trigger generation of the AT-TPC
  - Define beam exclusion region corresponding to pads hit by beam tracks
  - Generate signal for multiplicities larger than a threshold outside exclusion region
  - Set trigger timing to entrance window using upstream beam detector

ELECTRONICS SETUP



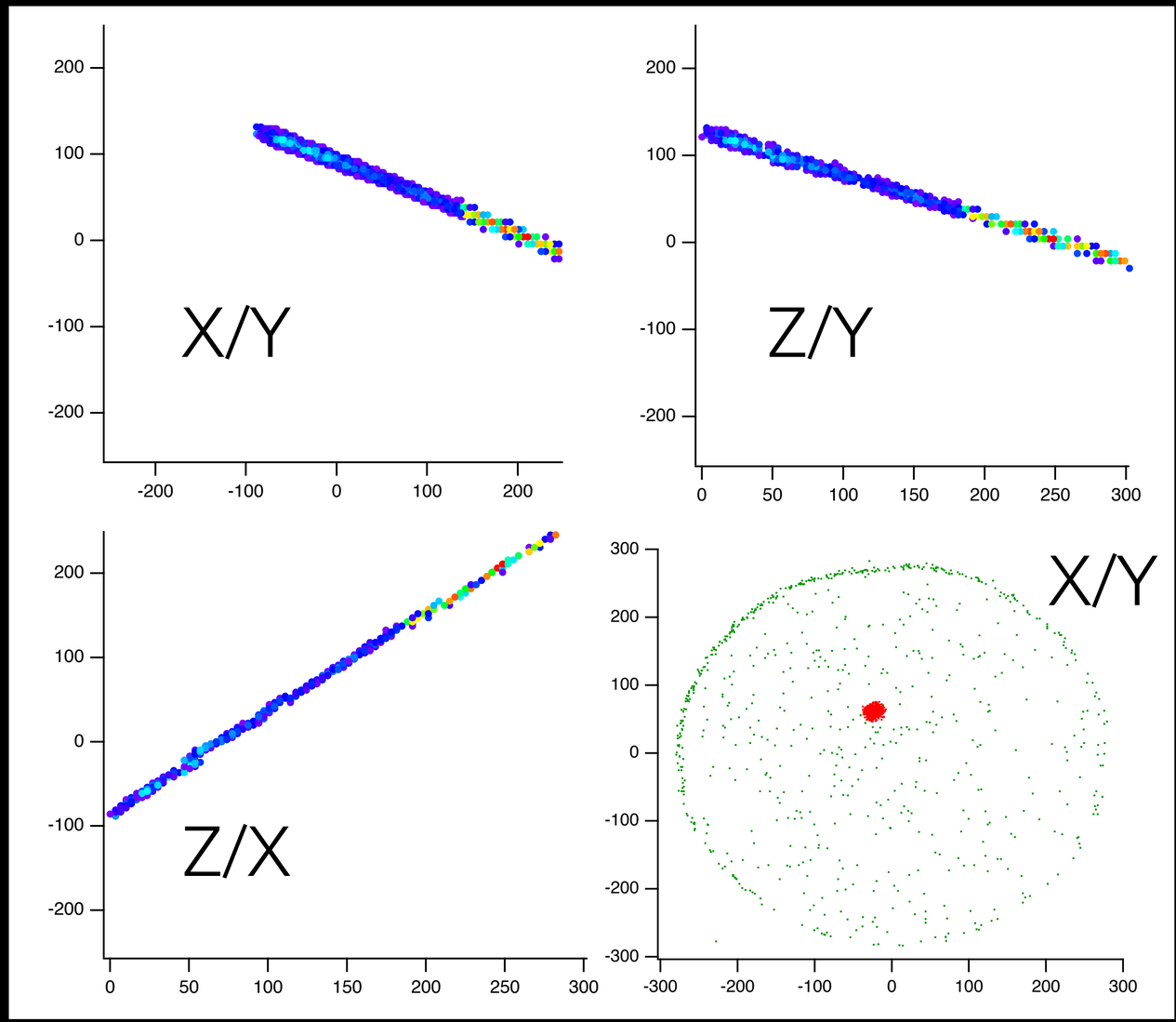
THE MULTIPLICITY BASELINE ISSUE

- Multiplicity sliding window
  - Must be long enough to cover maximum electron drift time
  - Running average subtracted to multiplicity to remove baseline
  - Problem: running average follows slowly rising multiplicity more than fast rising
  - Tracks with small scattering angle are more suppressed from triggering
  - Solution: use fixed baseline subtraction



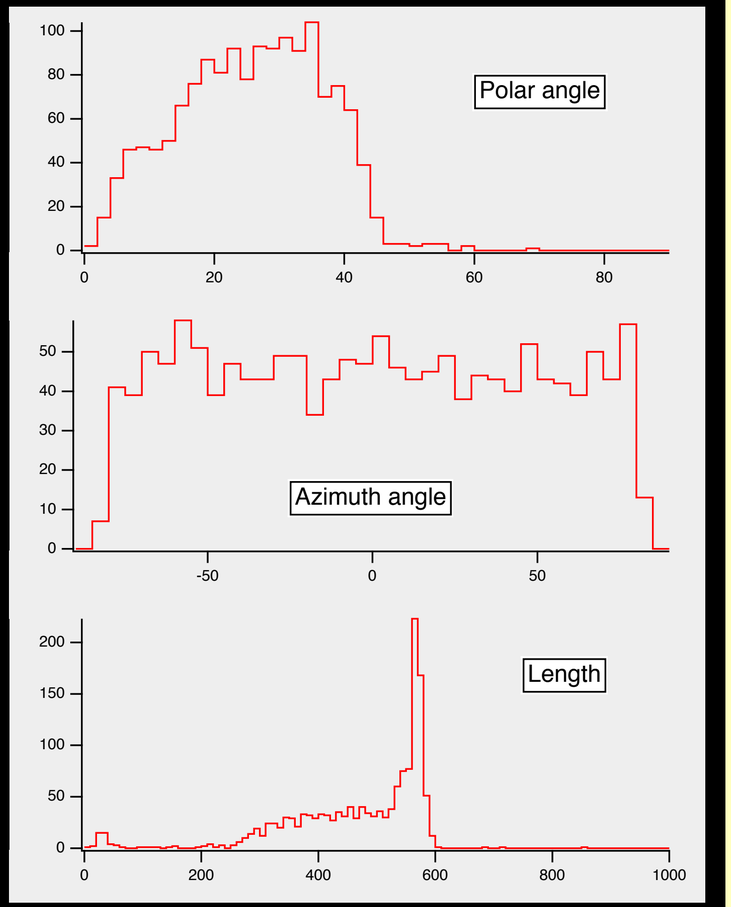
MULTIPLICITY TRIGGER TEST

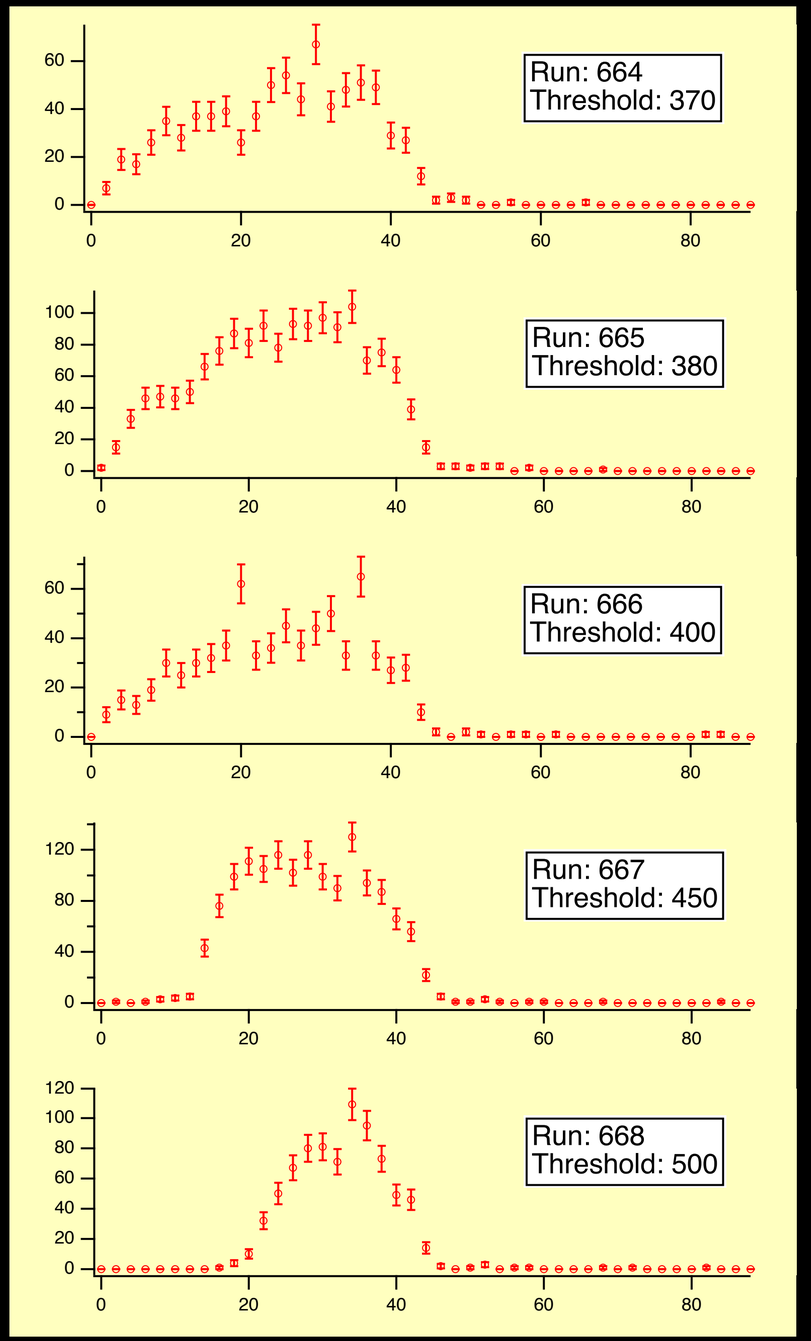
- Fixed baseline determination
  - Different for each AGET chip
  - Can be calibrated from data frame header information
  - New firmware parameters set to baseline plus fixed threshold
- Test using alpha source in AT-TPC
  - Source place on high voltage cathode
  - Red: track start, green: track stop



MULTIPLICITY TRIGGER TEST

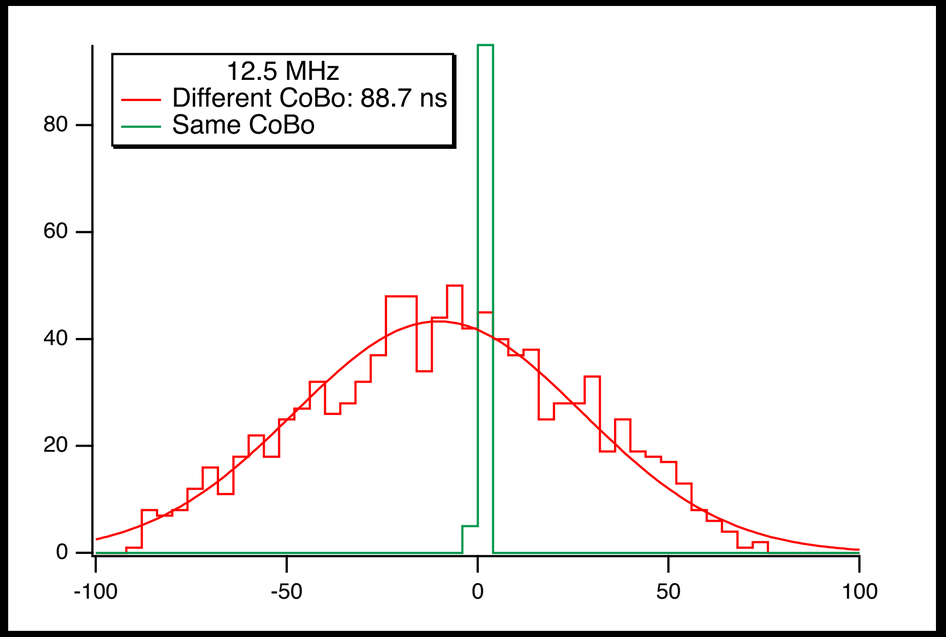
- Alpha tracks analysis
  - Polar angle limited to <40° due to source collimator
  - Length distribution shows peak at range of alphas
- Trigger threshold analysis
  - Global multiplicity threshold on MuTanT
  - Minimum at around 350
  - Clear cut of small polar angles with rising threshold

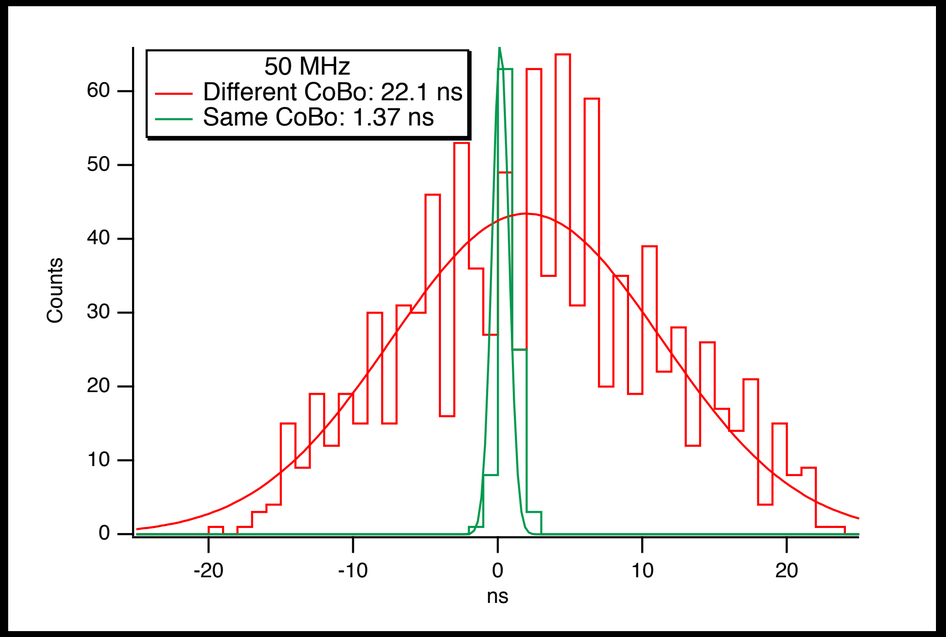




CLOCK PROBLEMS...

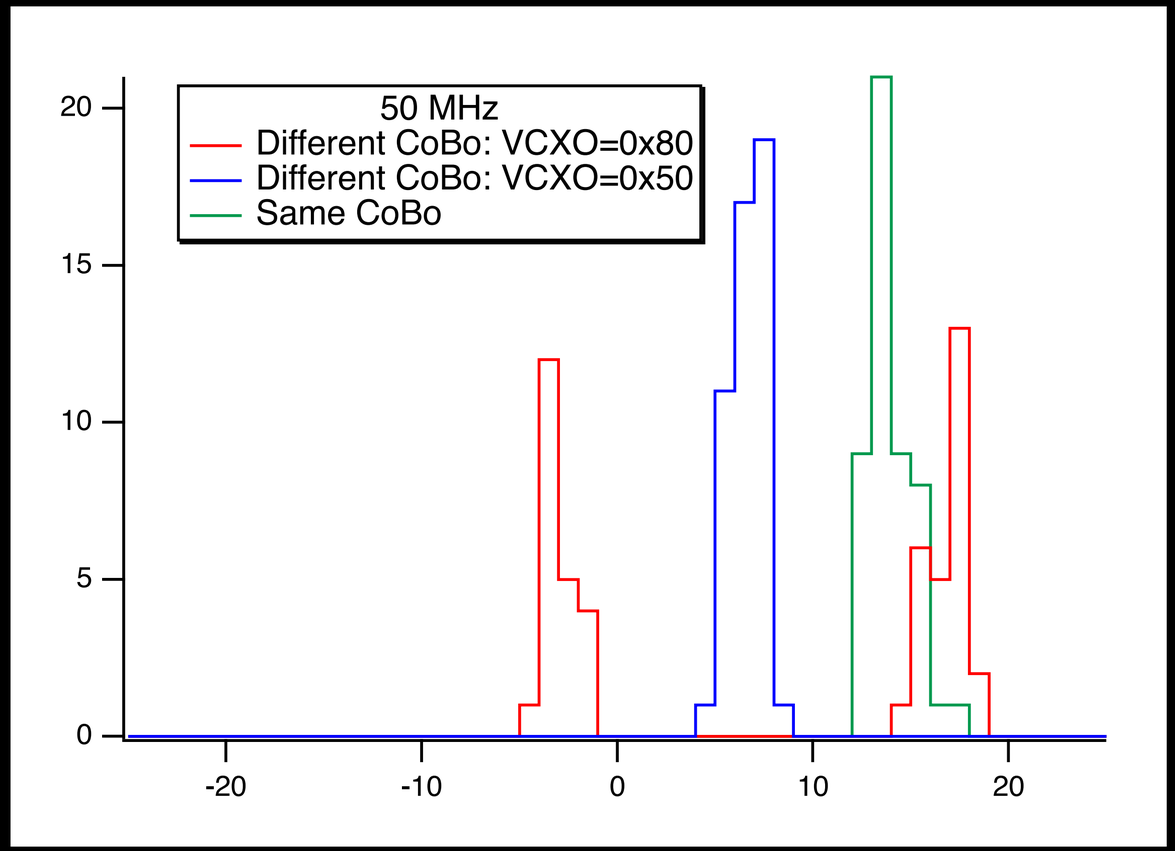
- Green histograms show timing between 2 channels from the same CoBo: good resolution
- Red histograms show timing between 2 channels from different CoBos: resolution lost
- Bad timing histograms follow triangular distributions expected from 2 independent clocks
- Explanation: Mutant clock frequency outside working range of CoBo PLL circuit





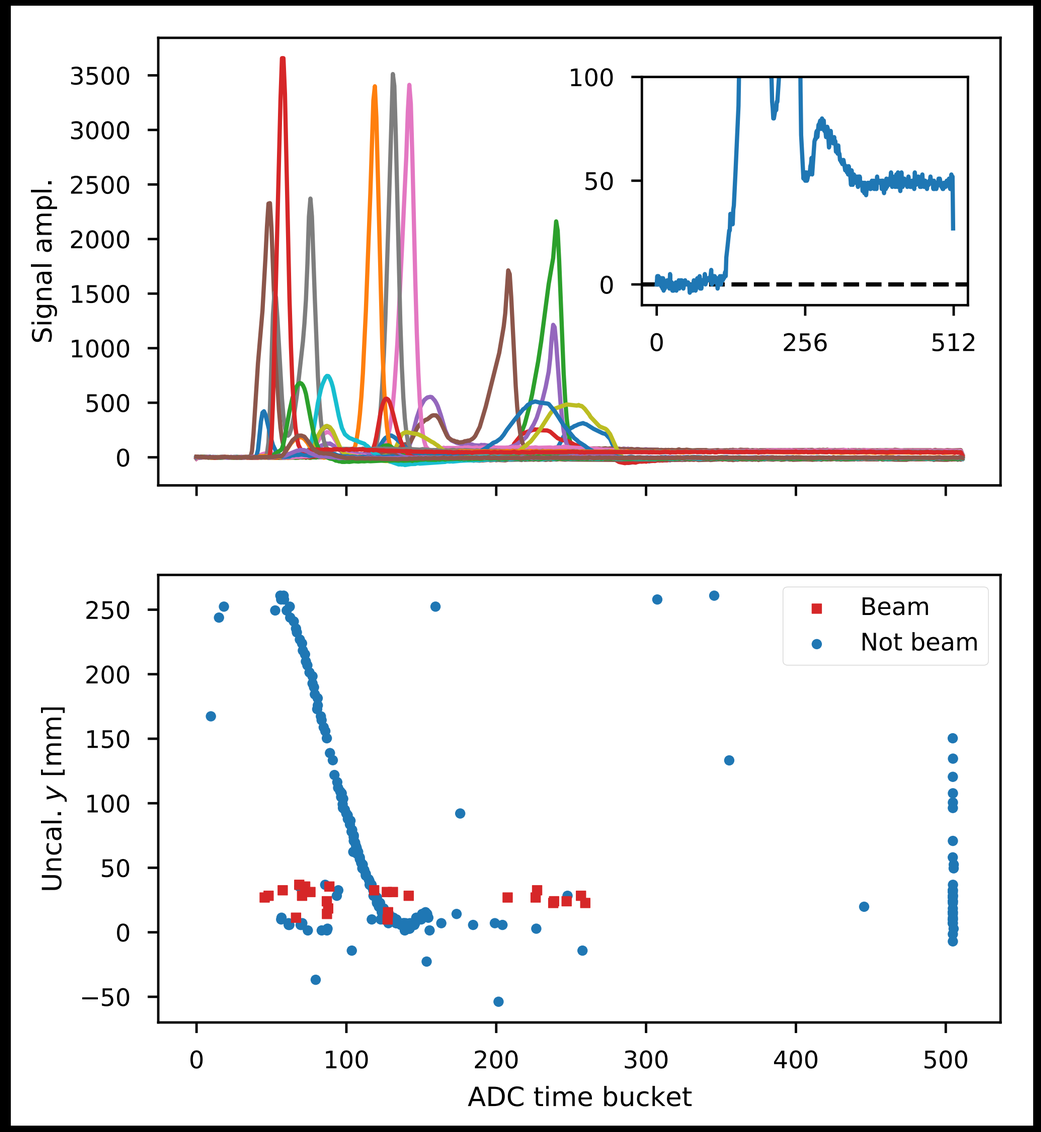
CLOCK PROBLEMS...

- Fix: add parameter to set frequency of Mutant GMC clock within range of CoBo PLL
- VCXO parameter at 0x50: one peak identical to same CoBo peak
- VCXO parameter at 0x80: two peaks separated by period (20 ns)
- Effect of CKW flip on AsAd2+3?



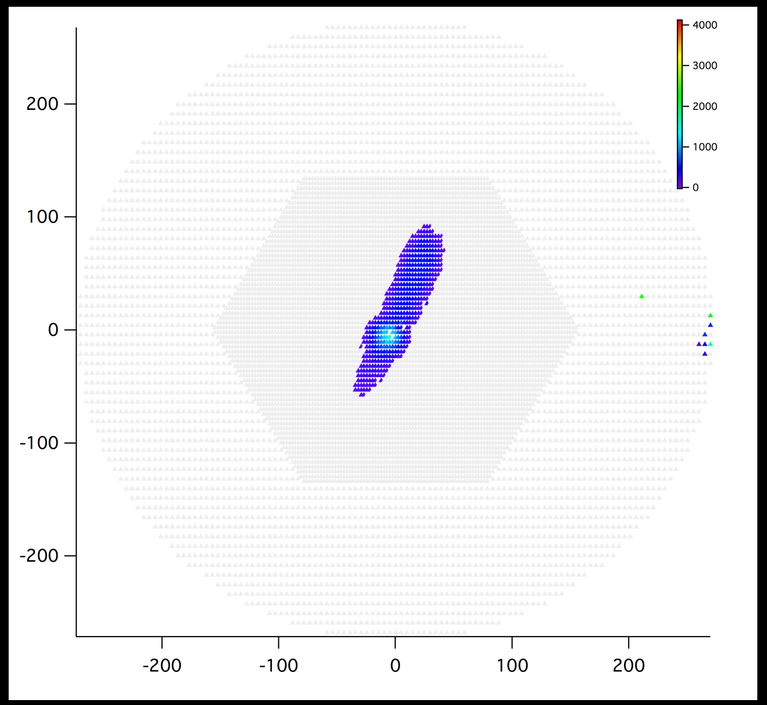
DYNAMIC RANGE ISSUE

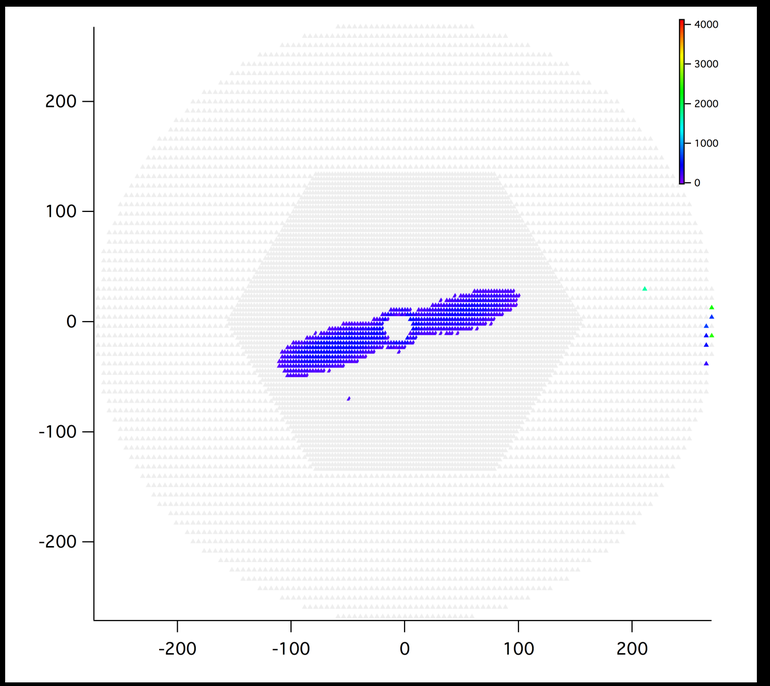
- Rate and energy loss of beam particles
  - Much higher and larger than scattered recoils
  - Even with lowest gain (10 pC) beam region preamplifiers saturate
  - Large amount of electrons in multiplication device (Micromegas) induce significant current and fluctuations of high voltage
  - Large number of positive ions can distort electric field and suppress primary electrons



HOLE IN THE BEAM!

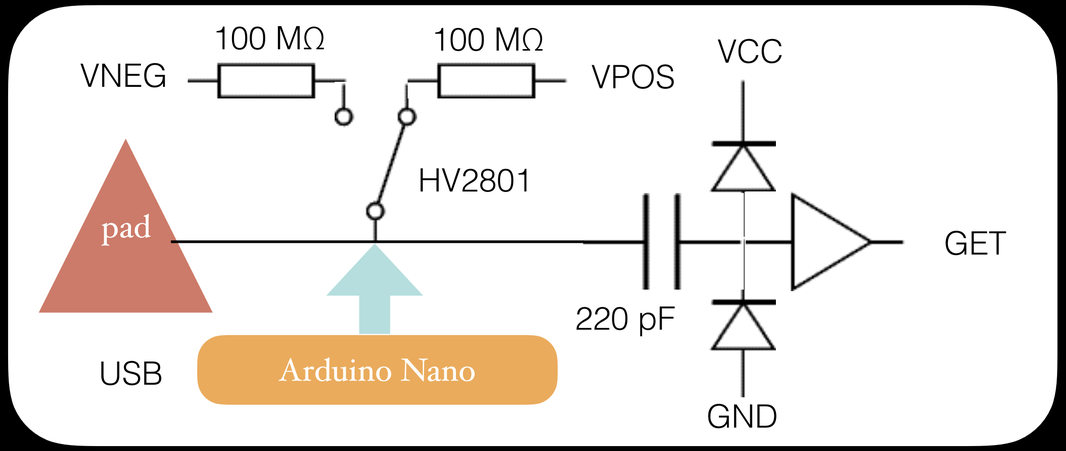
- Elastic scattering of ^{46}K in P10 ($Ar+CH_4$) gas
- Upper figure shows scattering event at low beam intensity (10-100 pps)
- Lower figure shows similar event at rate 1,000-10,000 pps (instantaneous)
- Primary electrons from beam ionization recombine with large amount of positive ions drifting in opposite direction
- Positive ions distort electric field in beam region

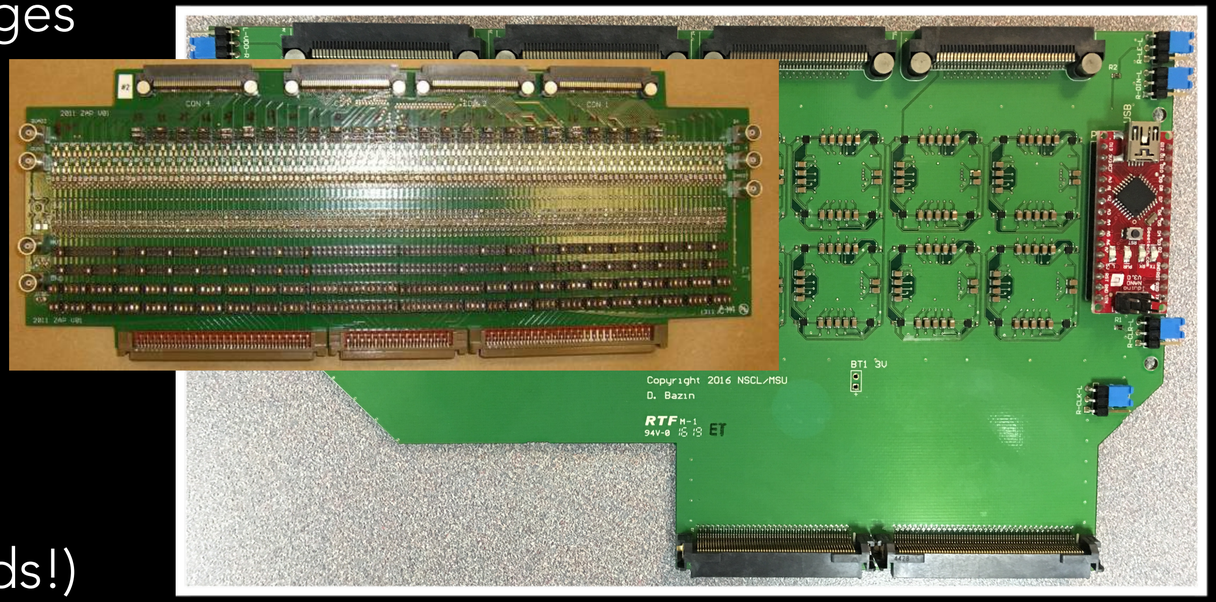




INDIVIDUAL PAD POLARIZATION

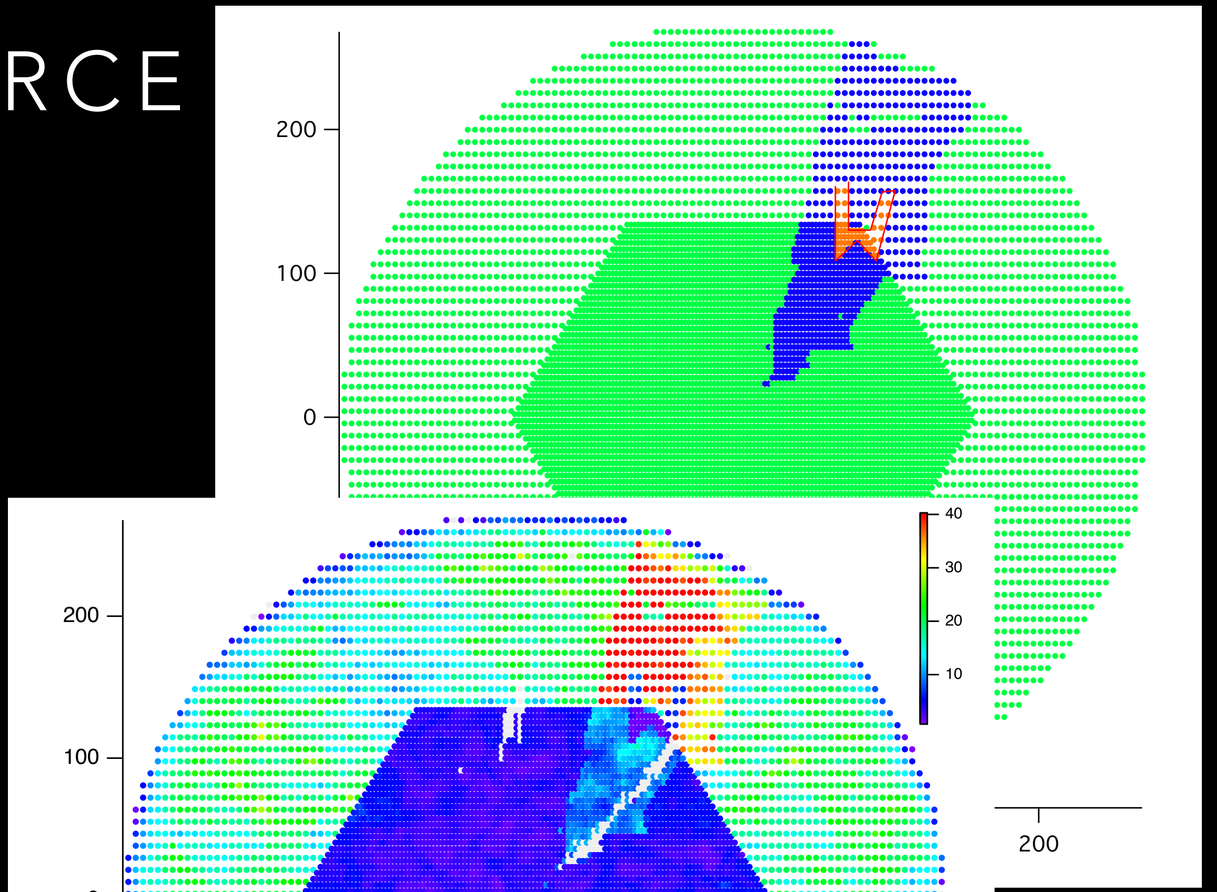
- Micromegas avalanches are localized
  - Very small gap (100 µm)
  - Gain depends on field gradient between each pad and the mesh
  - Varying the potential on a given pad changes the gain for that pad only
- Implementation
  - Protection circuit of electronics equipped with jumpers (256 pads) …
  - … or programmable HV switch (10,000 pads!)

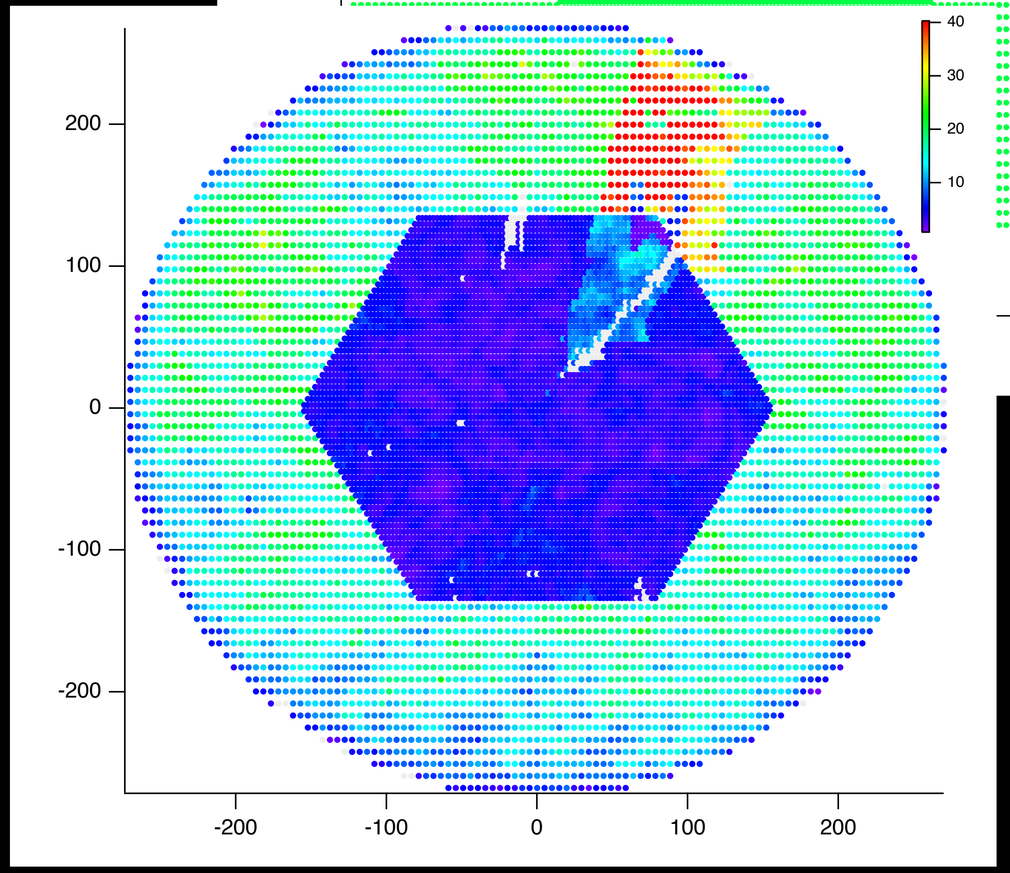




TEST USING ALPHA SOURCE

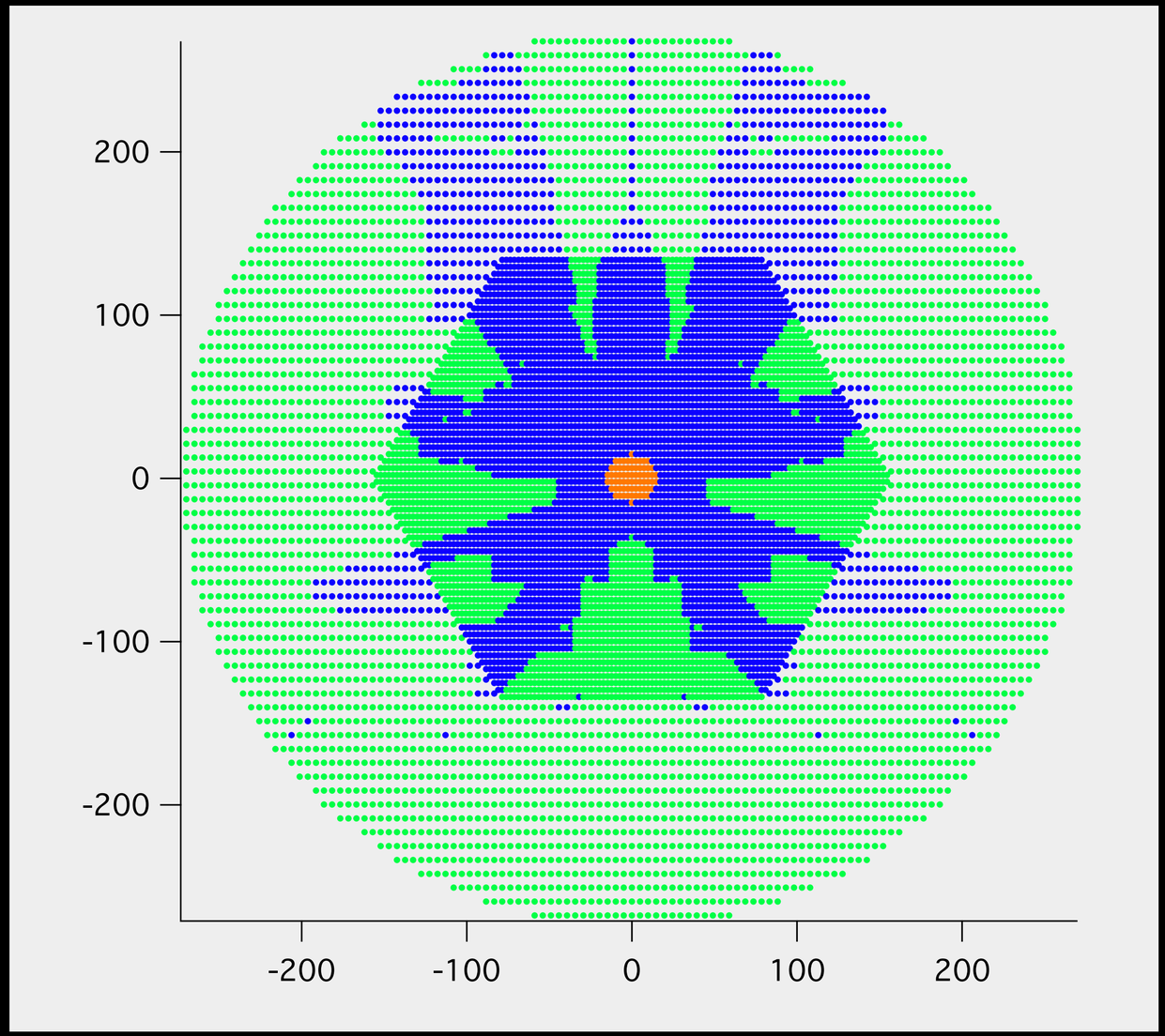
- Alphas emitted from sputtered ^{248}Cm on walls of field cage from fission source
- Micromegas polarized at -300V
  - Orange region: +40V (lower gain)
  - Blue region: -40V (higher gain)
  - Green region: 0V
- All channels have the same electronics gain





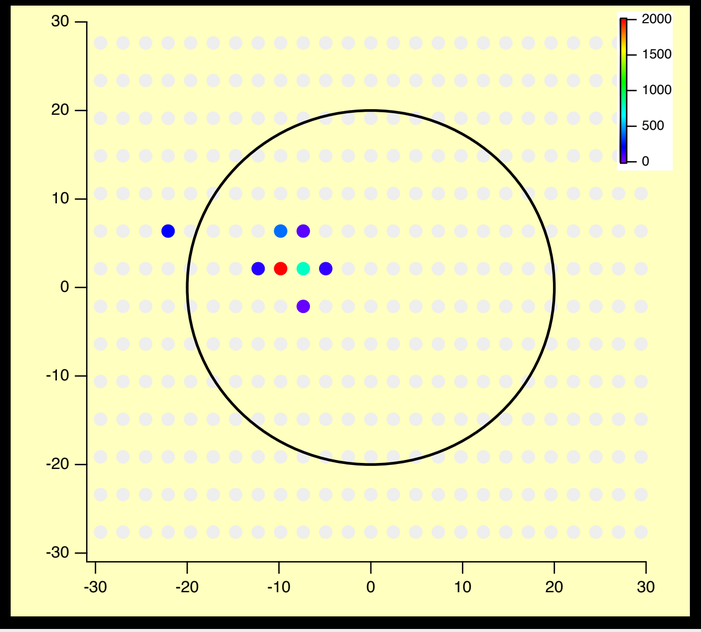
REAL EXPERIMENT: ^{22}MG(ALPHA,P)

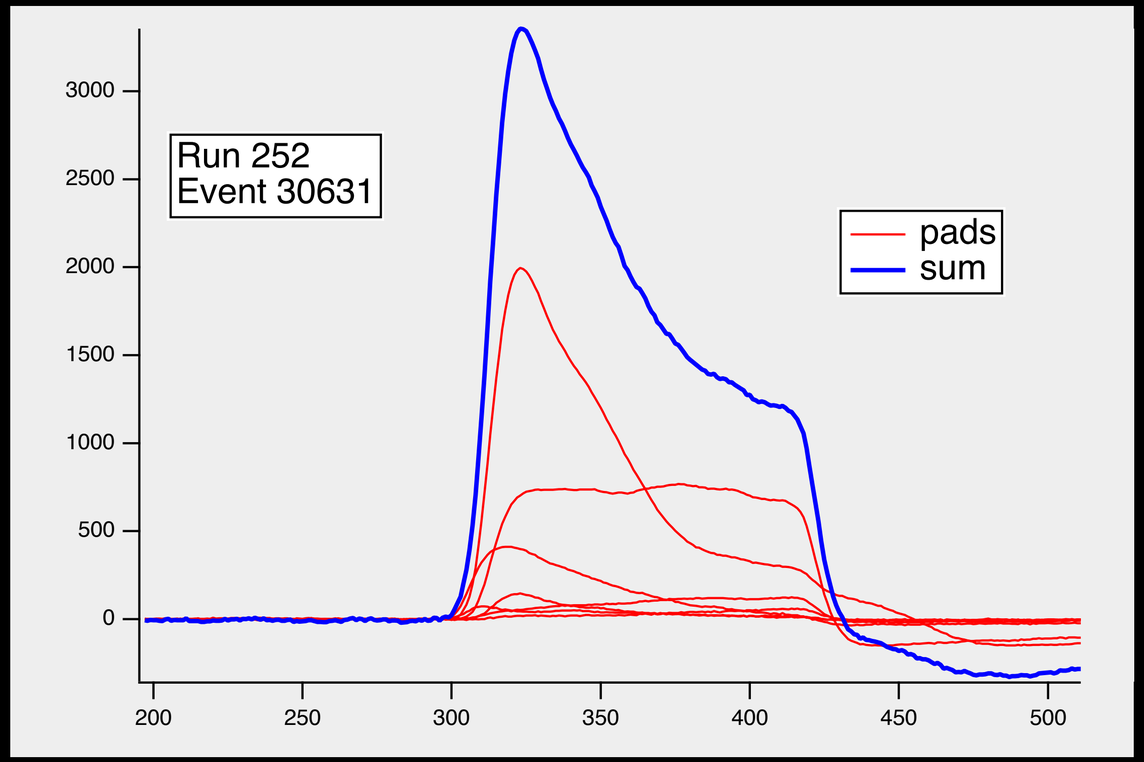
- Central region (orange)
  - Polarized at +100V
  - Lowest electronics gain (10 pC)
- Only blue region equipped with individual pad polarization
- Kill two birds with one stone
  - Avoid saturation of beam pads and their electronics channels
  - Avoid loss of primary electrons from beam tracks



BEAM EVENT

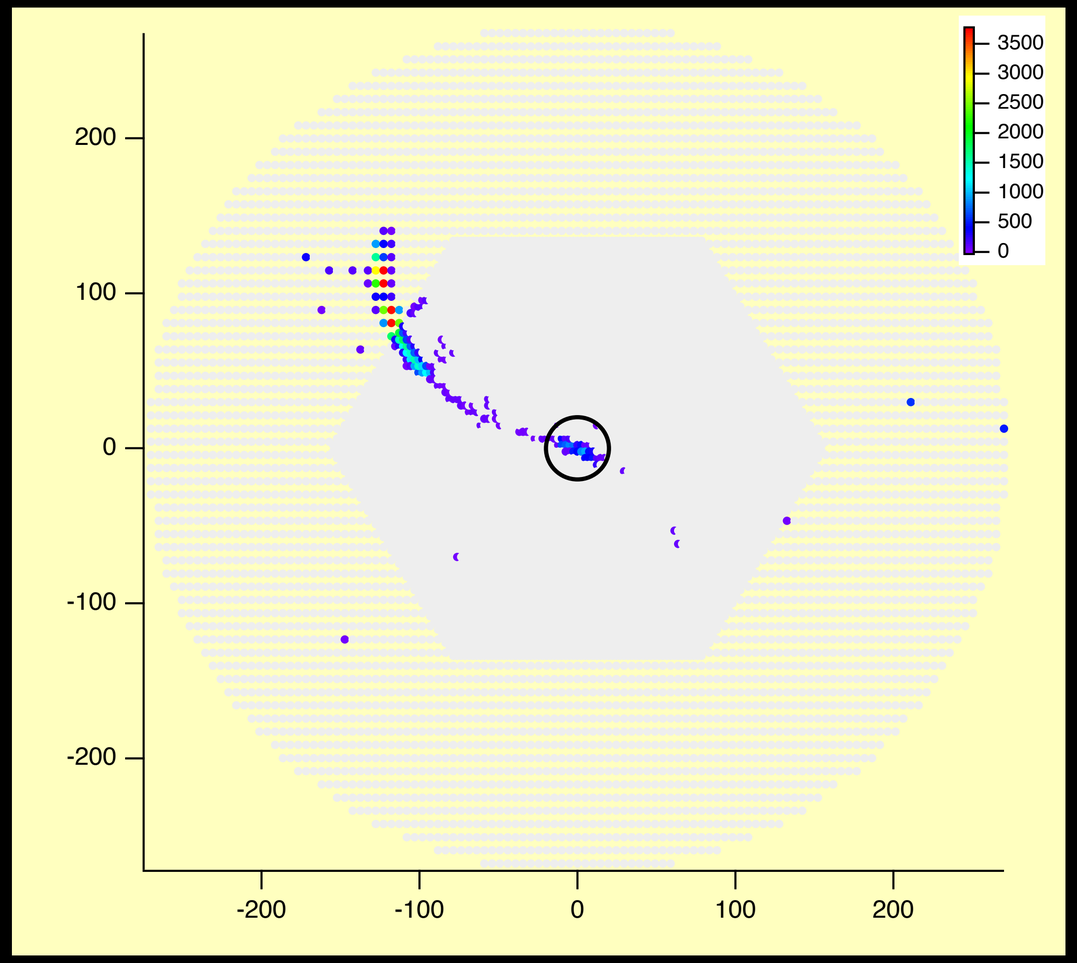
- ^{22}Mg beam stops in gas
  - Range ~ 50 cm
  - Only 7 pads registered a hit
- Signals in beam region
  - No saturation of preamplifiers
  - Slight undershoot due to shape of signal and transfer function of shaper
  - Bragg profile of ^{22}Mg measured

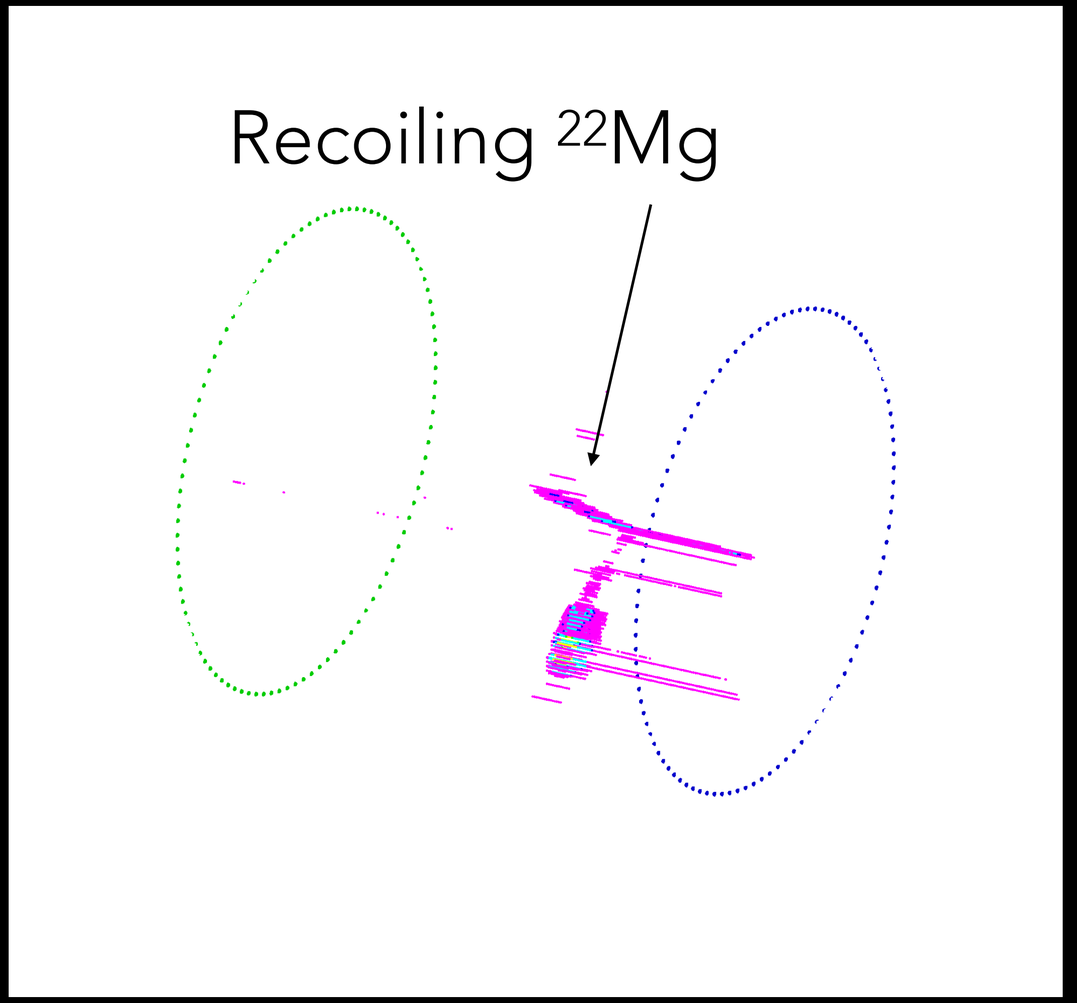




GALLERY

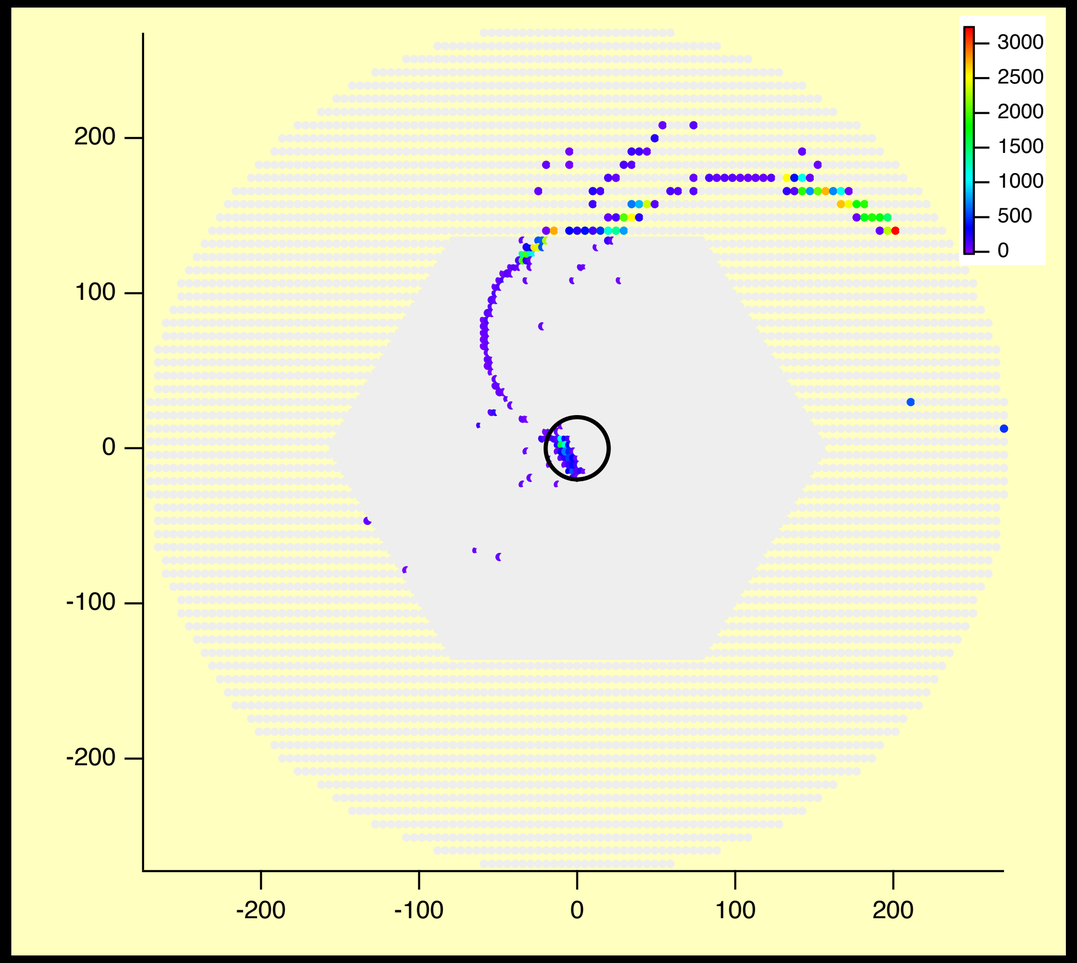
$^{22}Mg(\alpha,\alpha)$

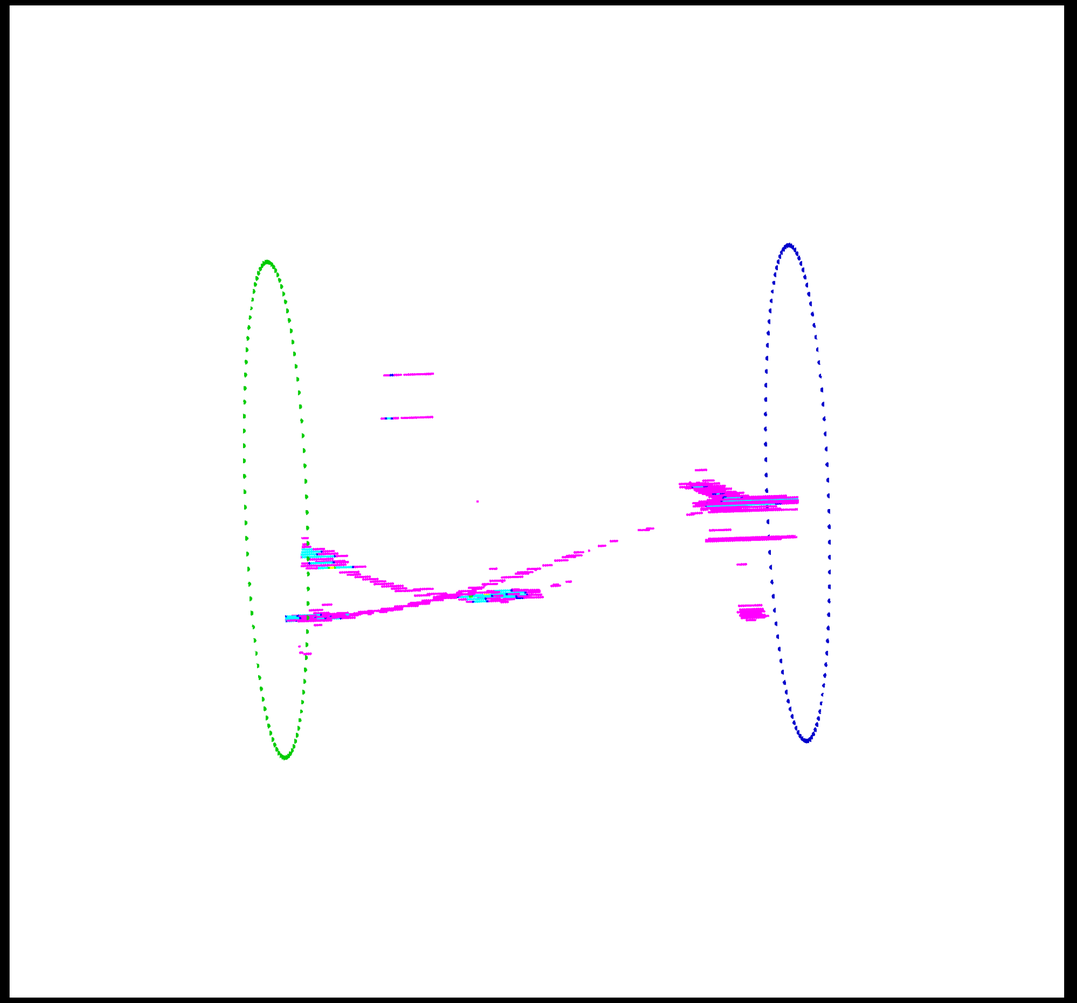




GALLERY

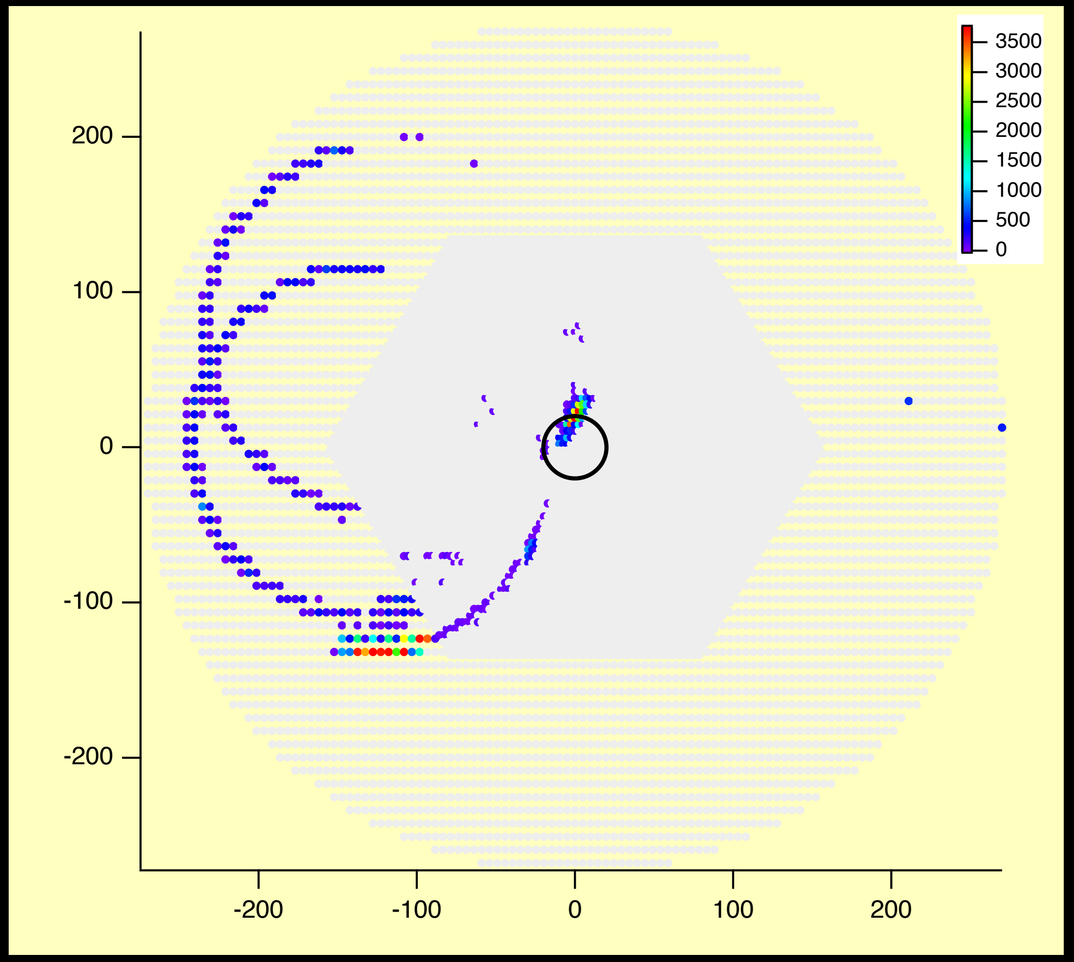
$^{22}Mg(\alpha,2p)$

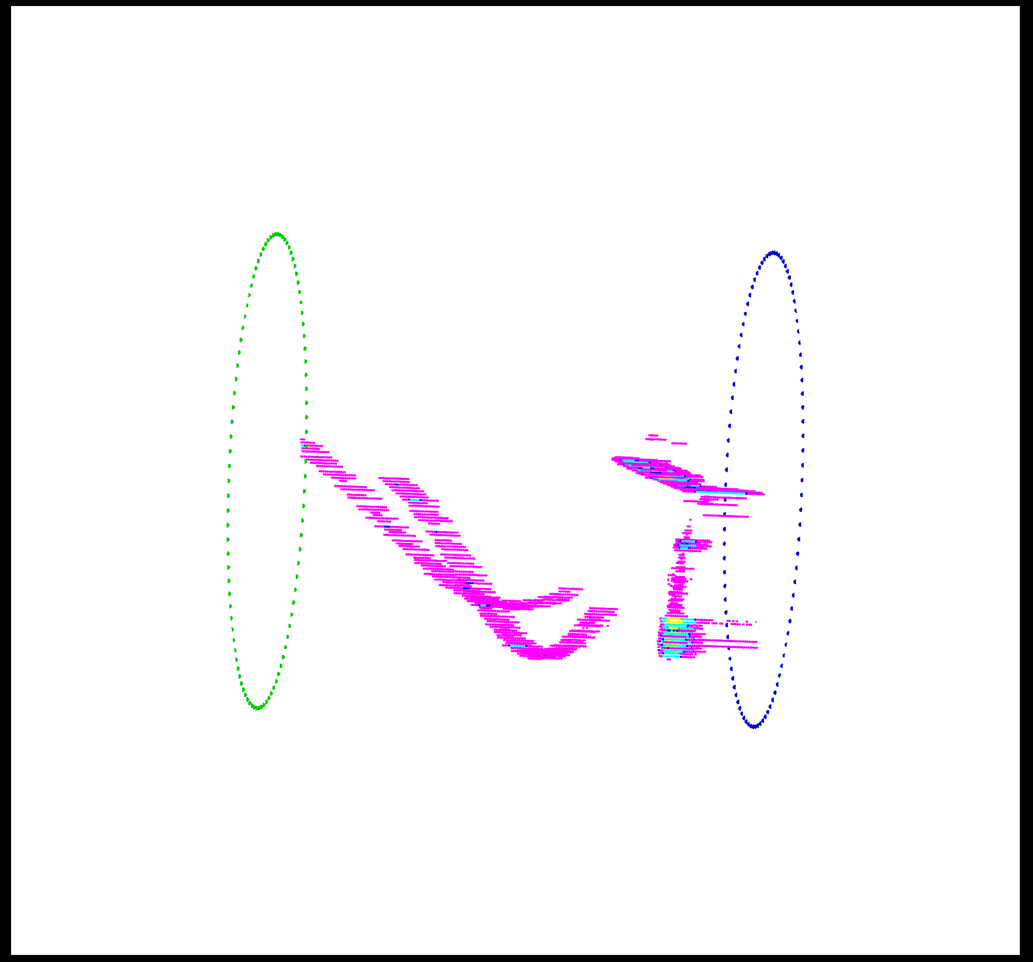




GALLERY

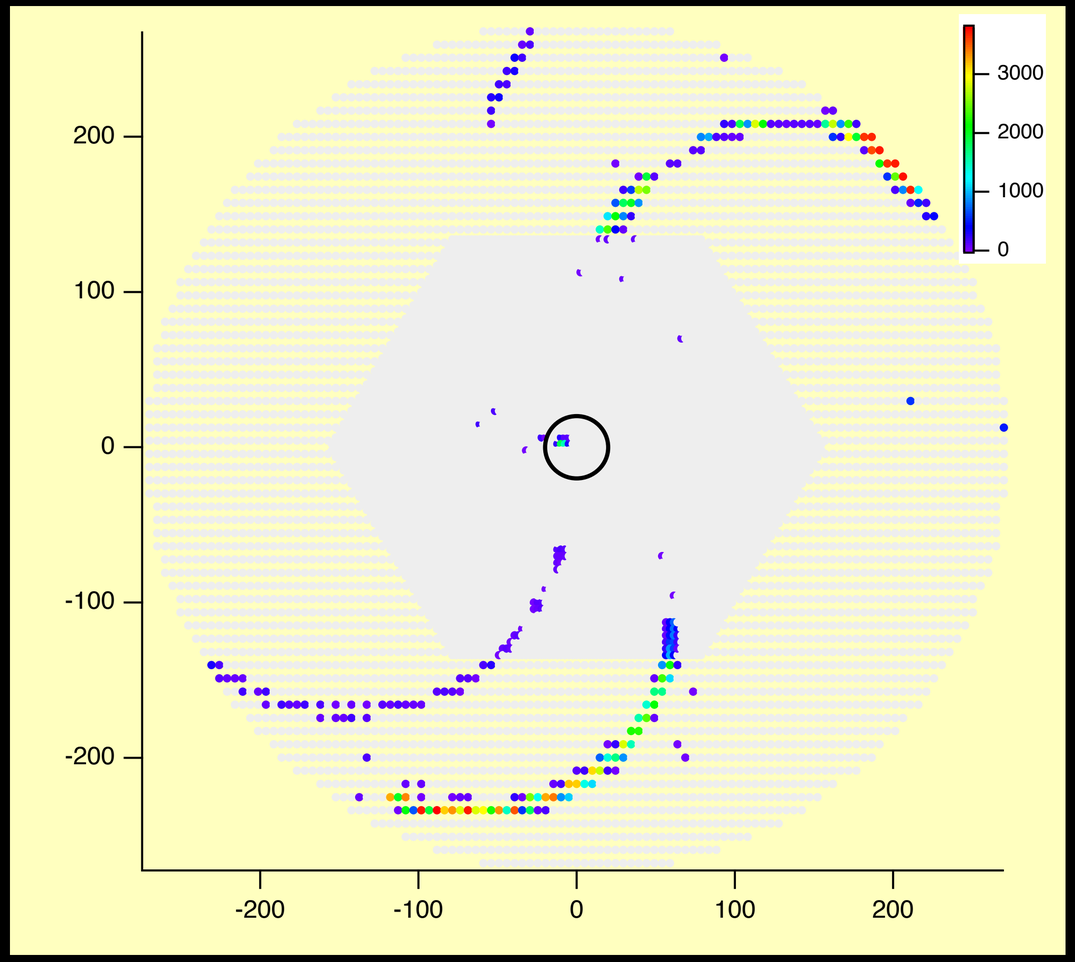
^{22}Mg(α,α2p)

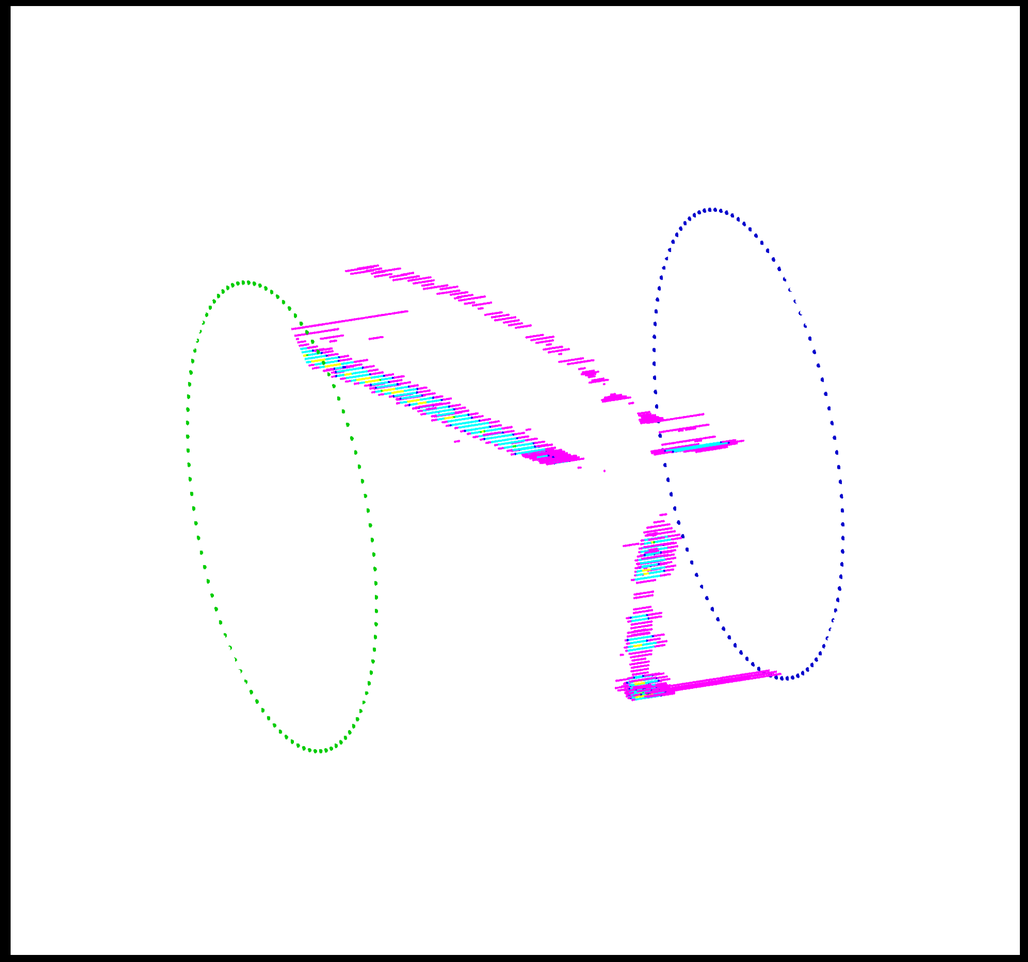




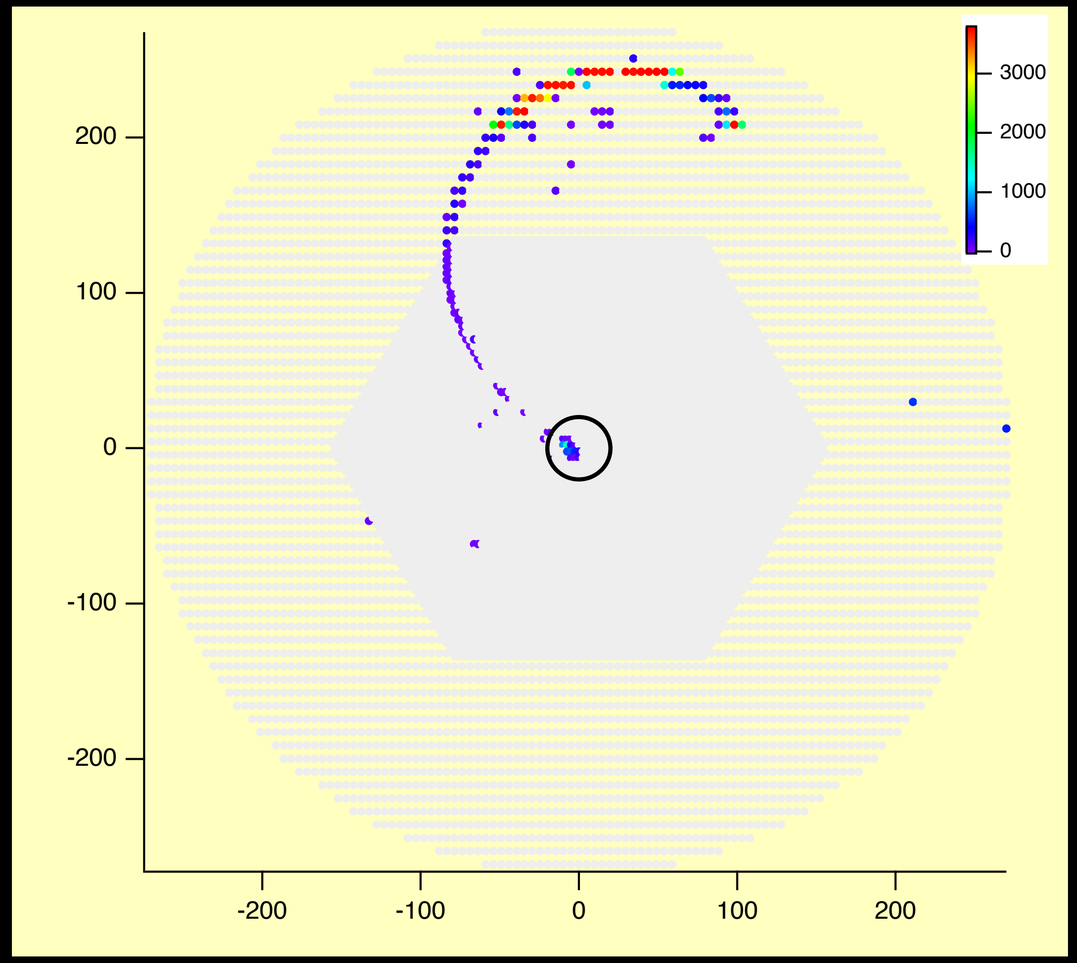
GALLERY

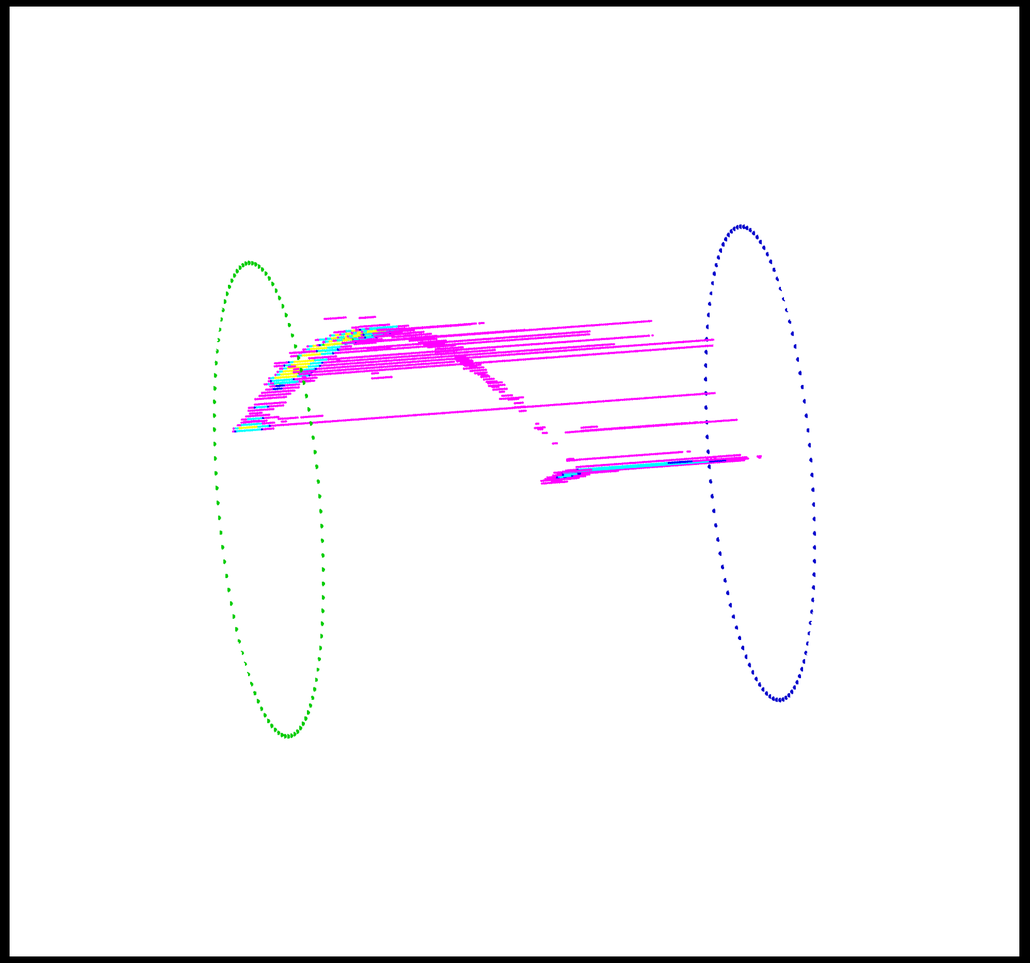
$^{22}Mg(\alpha,?)$





WHAT WE WERE LOOKING FOR...





Low energy ^{22}Mg(α,p)

COBO FIRMWARE ISSUES

- Source of most issues: resources of FPGA close to full utilization
  - Timing constrains difficult to meet: hit or miss behavior
  - CoBo has many clock domains to reconcile
  - Mutant-less firmware has no issues
- Symptoms of main issues
  - Bad AGET programming: some AGET registers are not correctly initialized
  - Bit flip: delay compensation between AsAd and CoBo not well optimized
  - CoBo stuck during Prepare phase

Device Utilization Summary:

Number of PLL_ADVs	2 out of 6	33%
Number of PPC440s	2 out of 2	100%
Number of RAMB18X2s	35 out of 228	15%
Number of RAMB18X2SDPs	18 out of 228	7%
Number of RAMB36SDP_EXPs	10 out of 228	4%
Number of RAMB36_EXPs	69 out of 228	30%
Number of TEMACs	1 out of 2	50%
Number of Slices	14124 out of 16000	88%
Number of Slice Registers	34535 out of 64000	53%

METHOD FOR BYPASSING ISSUES

- Present method to “fix” issues during experiment
  - Program all channels using “Prepare” and “Configure” phases
  - Identify CoBo/AsAd/AGET with issues taking pulser or baseline data
  - Reprogram ONLY the “bad” CoBo/AsAd/AGET using GetController
  - Check that data is good and do not touch any parameter before running
- Smarter slow control interface proposal
  - If p is probability of programming success for one CoBo, it becomes p^n for n CoBos
  - Slow control interface could identify changed parameters from current and only reprogram CoBo/AsAd/AGET that need to be

DIFFICULTIES FIXING FIRMWARE

- Xilinx doesn't help!
  - Virtex 5 not supported by latest software suite (Vivado)
  - Software used for Virtex 5 (ISE) no longer supported
  - Latest version of ISE not ported to Windows 10 (only for Spartan 6)
- Lengthy process
  - Both engineers who developed CoBo no longer work at NSCL
  - Recompiling firmware takes ~ 1 hour (on a good machine)
  - "Noodle syndrome": modifying one part can break another

FUTURE OF GET AT NSCL/FRIB

- Ideal electronics for drift chambers or multi-channel tracking detectors
  - Upgrade of CRDC (Cathode Readout Drift Chamber) of S800
  - Possible electronics for Optical PPAC using SiPM
  - See talk by M. Cortesi
  - Planned use for proton detector (see talk by M. Friedman)
- Integration of GET readout in NSCL DAQ system
  - Ongoing work by R. Fox and G. Cerizza
  - External triggering (no Mutant) but need for time stamp/clock synchronization

CONCLUSION

- GET is great!
  - Without the GET electronics, AT-TPC experiments would not be possible
  - Internal trigger based on live multiplicity is essential to AT-TPC
  - Quality of data competitive with flash ADC technology at fraction of cost
- The future of GET
  - Solving the remaining issues with CoBo firmware is desirable
  - Alternative to Reduced-CoBo for smaller Mutant-free systems
  - More discussions during this meeting…