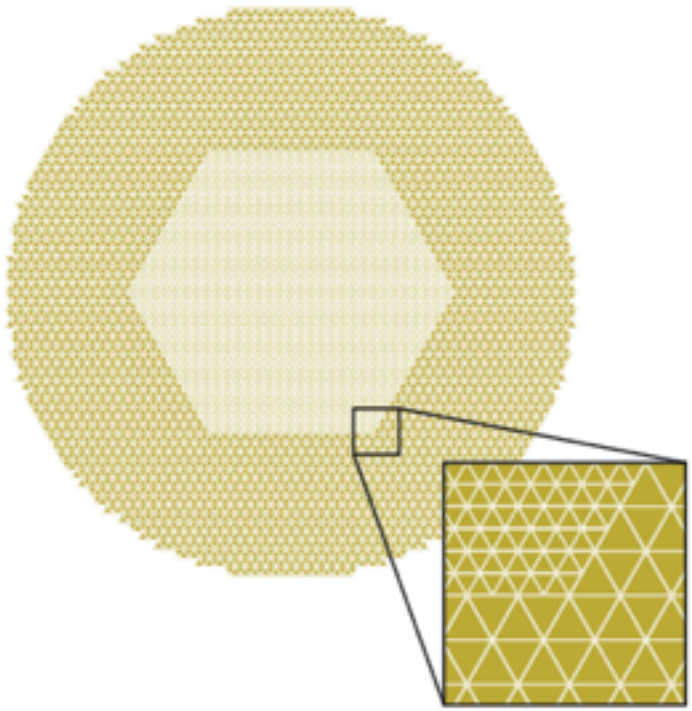
AT-TPC Tracking Software and Detector Development

Clementine Santamaria (NSCL)

January 17th, 2018

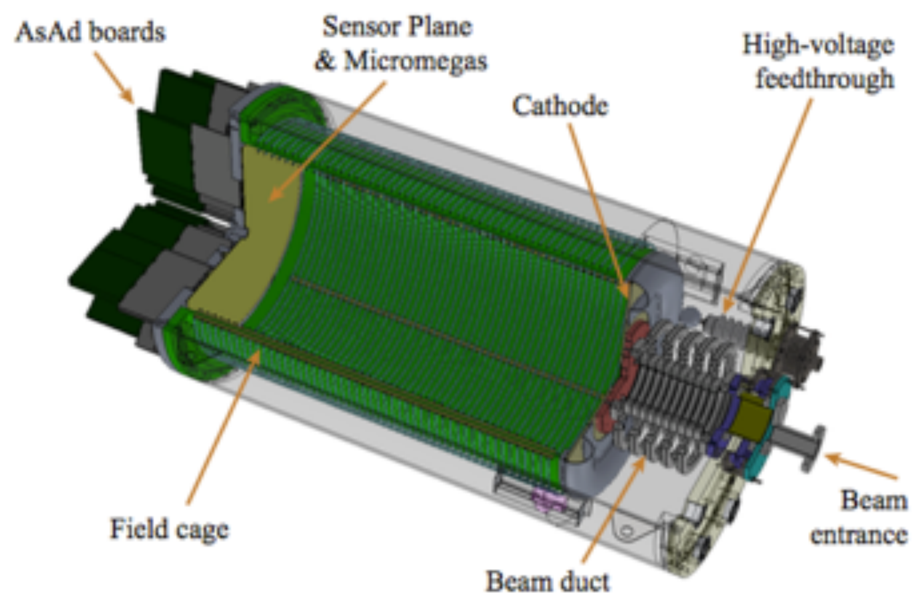
AT-TPC



- Active Target of 1 m length, 55 cm diameter

➡ Thick target, good resolution, 4π detection

- MicroMegas detection pad plane
- 10,240 pads, equilateral triangles
- GET electronics with internal trigger
- Coupling with magnetic field



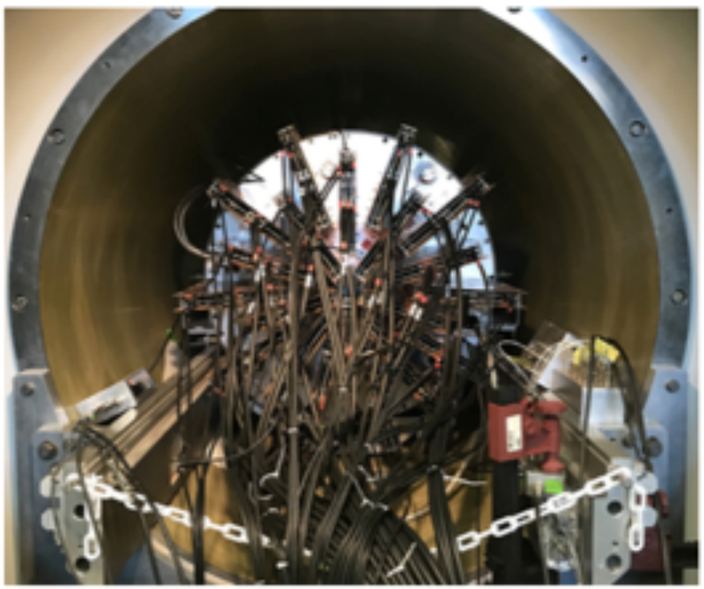
Resolution capabilities

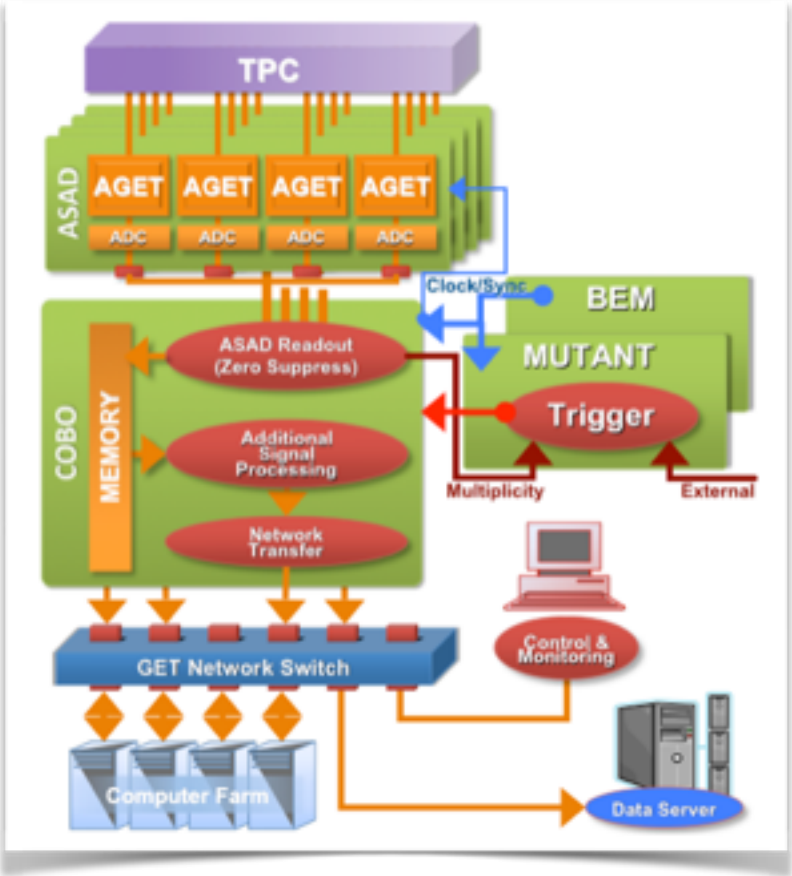
- Scattering angle = 1° for (α, α')
- Energy resolution of 30-40 keV/u in c.m. despite phasing issues

GET ELECTRONICS

★Trigger needs to filter out unreacted beam events

- GET electronics provides discriminators on each pad
- Running multiplicities of each AsAd routed to MuTanT through CoBos
- Trigger configuration can be programmed





★AGET front-end chips provide various gains and shaping times

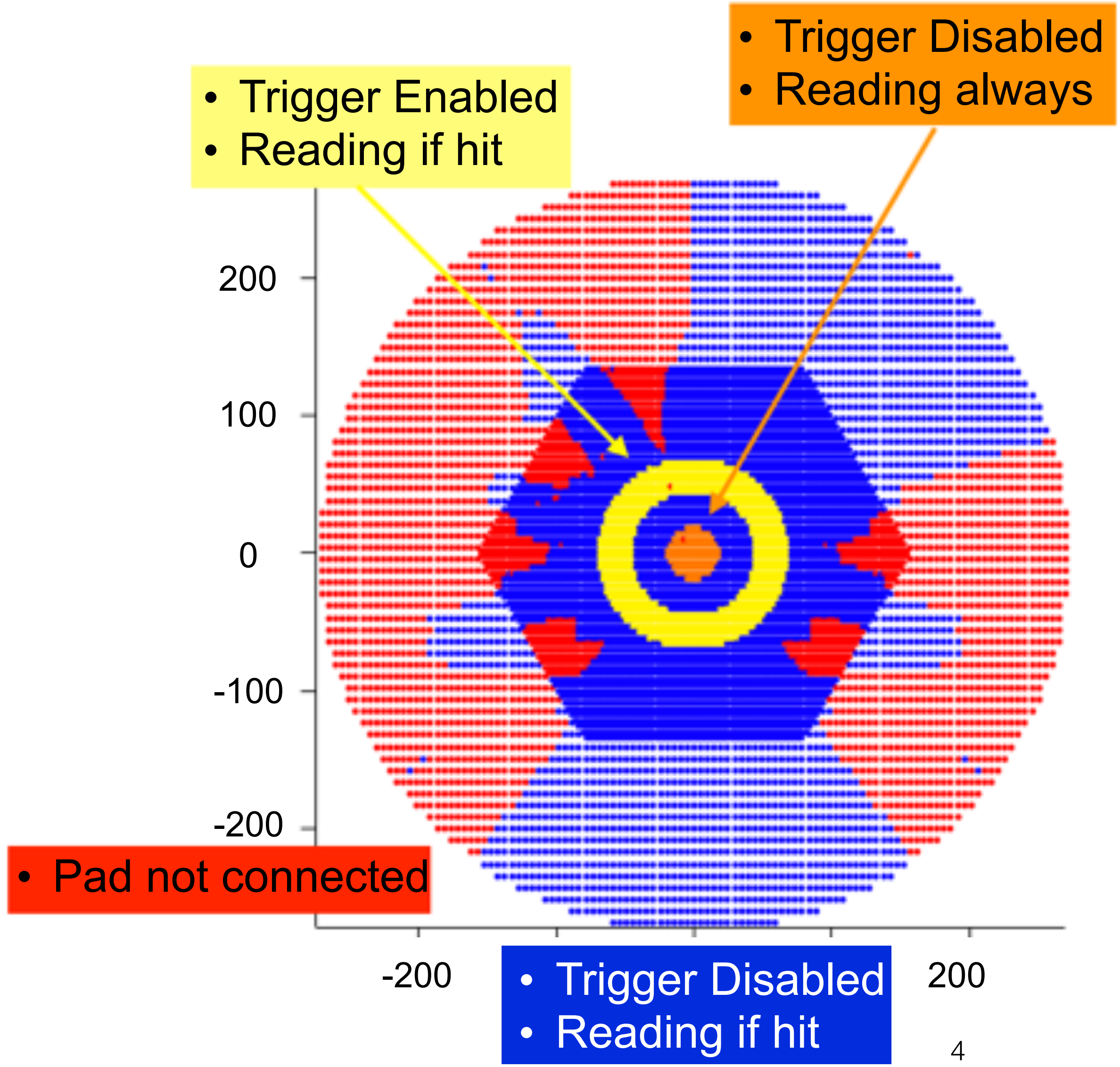
★GET: CEA-Saclay, CENBG- Bordeaux, GANIL-Caen, NSCL

TRIGGER GENERATION

★Define pad regions with different trigger attributes

★Example shows configuration for elastic scattering

★More complex pattern triggering can be programmed



AT-TPC EXPERIMENTS

NSCL

Stable beam commissioning of the AT-TPC (D. Bazin): α + α scattering
Commissioning of the AT-TPC with radioactive beam (D. Bazin): ^{46}Ar experiment
Capture cross sections and fusion barrier measurements with the AT-TPC (S. Beceiro-Novo)
Fusion with neutron-rich rare isotope beams (S. Beceiro-Novo)
Measurement of the fission barriers for heavy exotic nuclei (Z. Chajecki)
Direct measurement of a key reaction for the rp-process with the AT-TPC (Y. Ayyad)
Spectroscopy of chlorine isotopes at the proton-drip line (R. Kanungo)
Death of first stars. Measurement of ANC of 12N(p,g)13O relevant for the rap process (J. Pereira)

Notre Dame (pAT-TPC)

^{10}Be+α (D. Suzuki) + higher energy (3-body analysis)
D. Suzuki *et al.*, Phys. Rev. C **87**, 054301 (2013)
A. Fritsch *et al.*, Phys. Rev. C **93**, 014321 (2016)
^{10}Be + ^{40}Ar fusion barrier (J. Kolata)
F.D. Bechetti *et al.*, NIM B **376**, 397 (2016)
^{12}C Hoyle state decay
^{10}C + α , mirror of ^{10}Be

Talk by Yassid Ayyad

TRIUMF (pAT-TPC)

Investigation of nuclear forces, nucleon correlation and resonances in ^{8}He (R. Kanungo) ^{8}He+α
Search for cluster structures in ^{16}C through resonant alpha scattering (Y. Ayyad, W. Mittig) ^{12}Be+α

LBNL (pAT-TPC) => Campaign in Spring 2018 ?

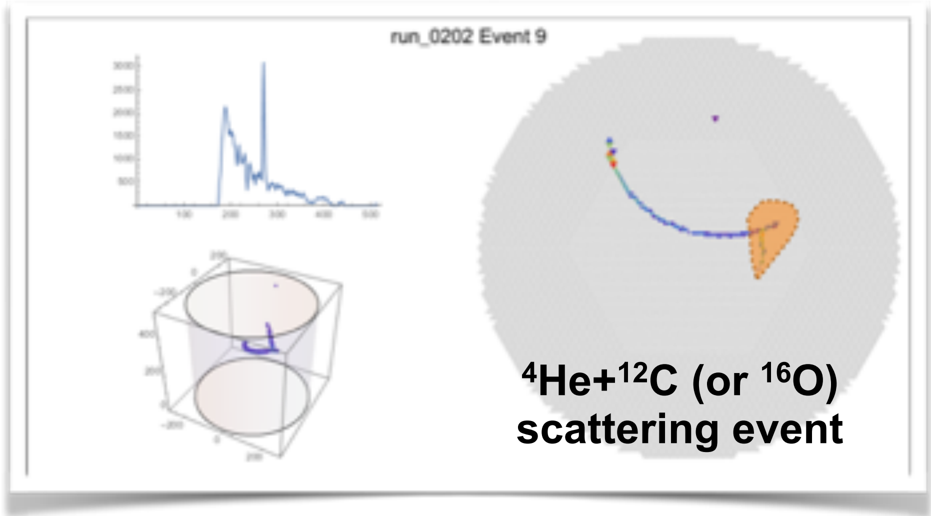
RCNP (AT-TPC)

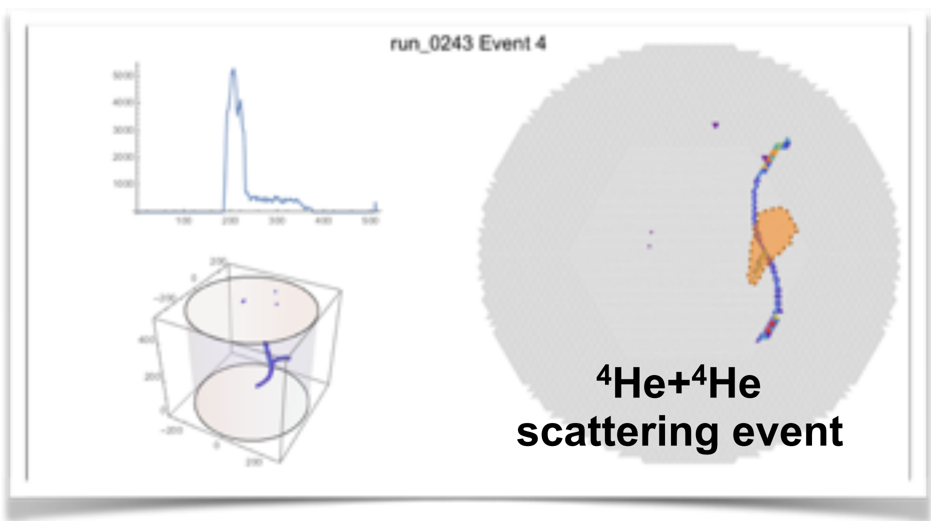
^{17}C (d,p) (B. Fernandez Dominguez)

EVENT EXAMPLES

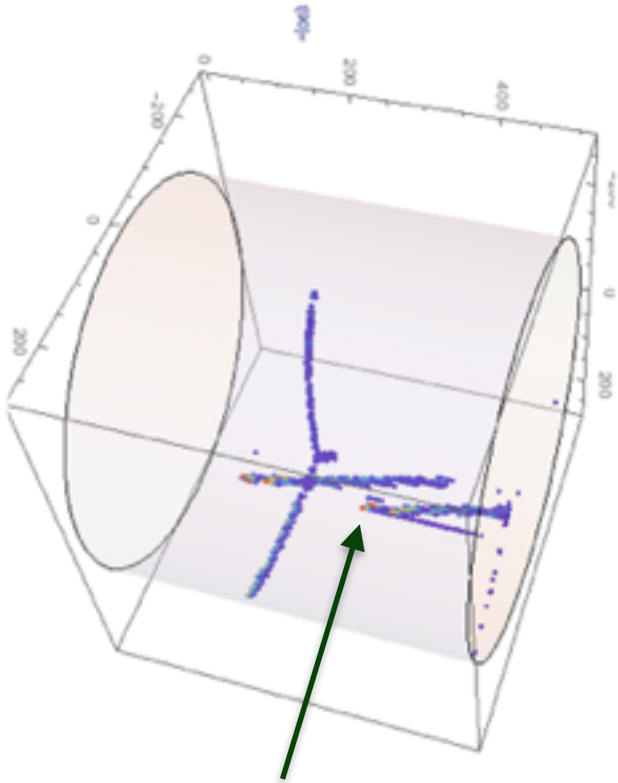
★ Commissioning in December 2014
- Beam: 4He at 3 MeV/u
- Target: He(90%) + CO2(10%) @ 100 torr
- Magnetic field: 1 Tesla

★ Event displays
- Right: hit pattern on pad plane, orange region is trigger exclusion zone
- Top Left: integrated time projection
- Bottom Left: 3D reconstruction of the event

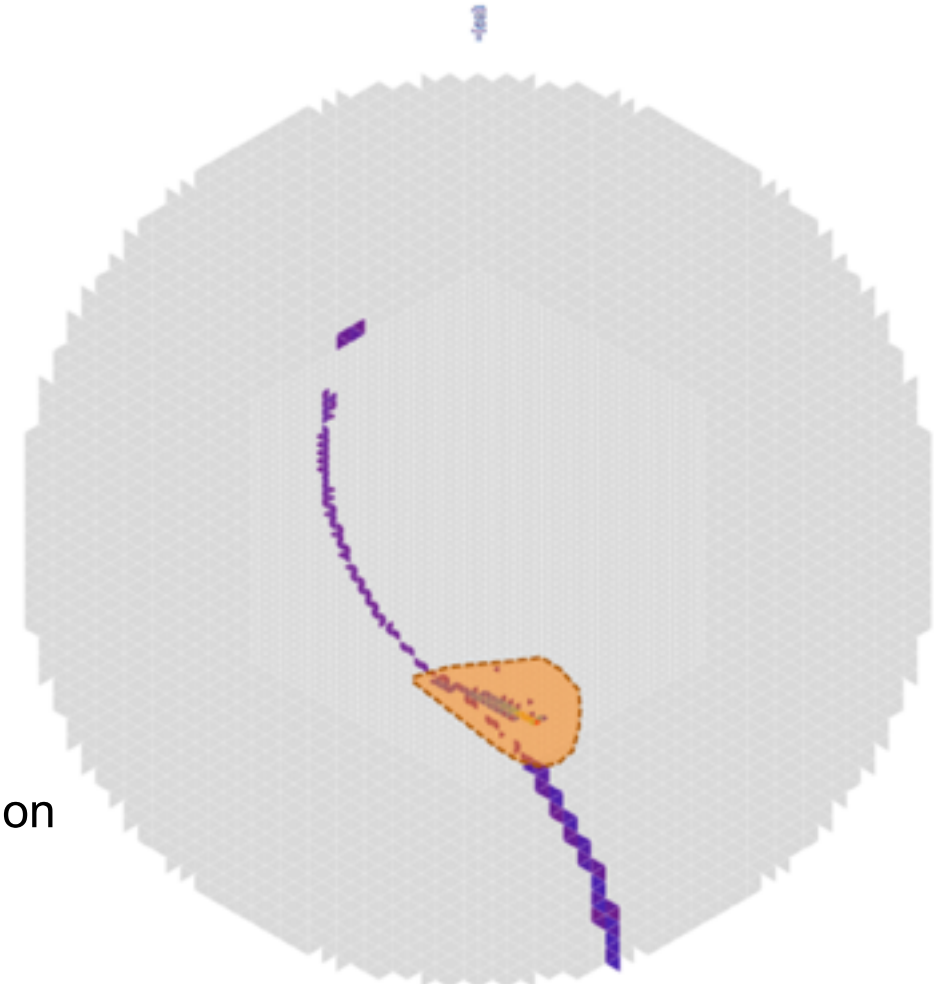




PILE UP REJECTION



7° tilt angle creates time-position correlation for the beam



Track reconstruction more complex as B and E field not aligned

AT-TPC ANALYSIS FRAMEWORK

★ Two analysis frameworks developed in parallel:
- ATTPCROOT (C++, ROOT, and FairROOT)
- pyTPC (Python)

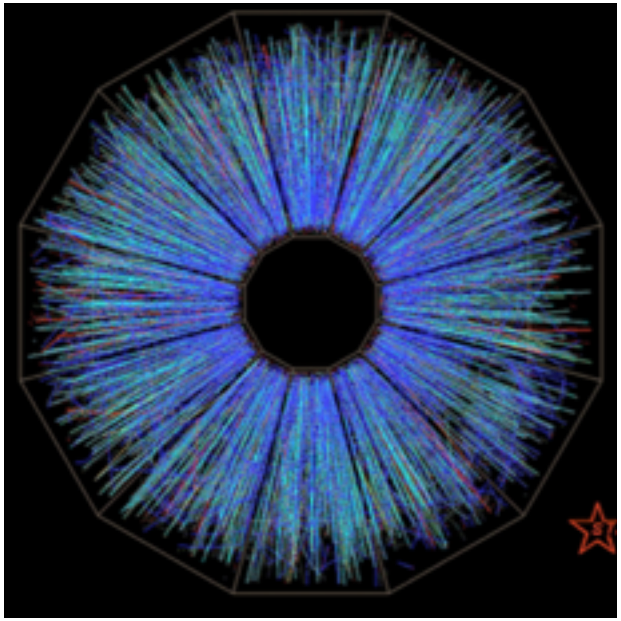
★ Provides tools for analysis & simulation in the same framework:
- Merger of raw data taken by GET electronics (hdf5 or ROOT files)
- Pulse Shape Analysis of signals on pads + calibration (time, charge)
- Transforms (Hough, RANSAC…) to distinguish tracks & get starting points for the fitting procedure
- Fitter (MC fitting) to get final parameters for the tracks

★ Development of cross-platform libraries INDEPENDENT of framework

★ Maintenance of those libraries by the AT-TPC group, with the availability to use the 2 frameworks (no maintenance for them)

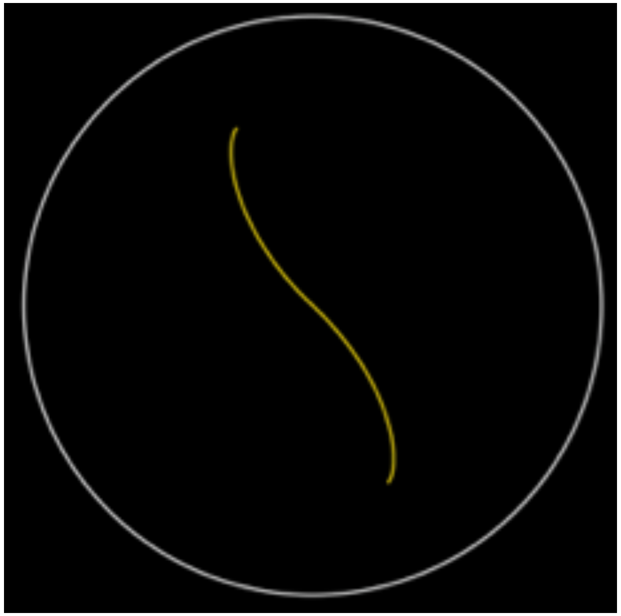
TRACKING

High Energy Physics



- Many tracks
- Tracks leave volume
- Constant curvature

AT-TPC



- Few tracks
- Tracks stop in volume
- Changing curvature
- Tracking protons to fission products
- With & without B field

FairSoft

- ★ All the necessary packages collected to run FairRoot
- ★ Designed to be installed on both Linux and OS X
- ★ Included packages:
- ★ gtest, gsl, boost, Pythia6, Pythia8, HepMC, GEANT3, GEANT4, XRootD, Pluto, ROOT, VGM, VMC, Millepede, ZeroMQ, Protocol Buffers, nanomsg
- ★ RAVE, CLHEP, and GENFIT2 packages added for SπRITROOT

Talk by Genie Jhang

FairRoot

- ★ A framework containing base classes for running simulation, reconstruction and analysis

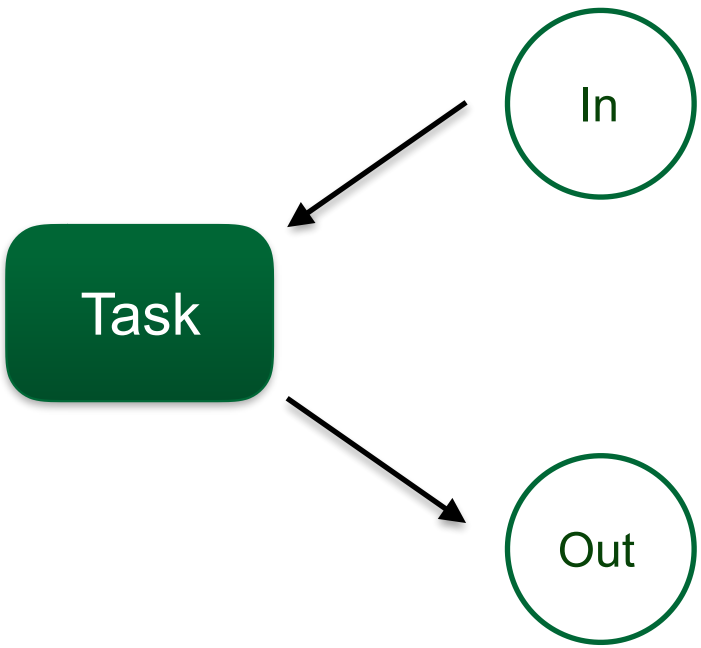
ATTPCROOT

- ★ Based on the SπRIT analysis framework SpiRITROOT
- ★ A framework containing specific modules for AT-TPC experiment on top of FairRoot
- ★ Composed of task-based modules, TGeo geometry and steering macro
- ★ Written by following the structure of FOPIROOT

. M. Ball et al., Technical Design Study for the PANDA Time Projection Chamber, http://arxiv.org/abs/1207.0013

ATTPCROOT: A TASK BASED MODULE

★ Easy to turn on and off
★ Analysis separated in steps
★ Easy to debug and maintain

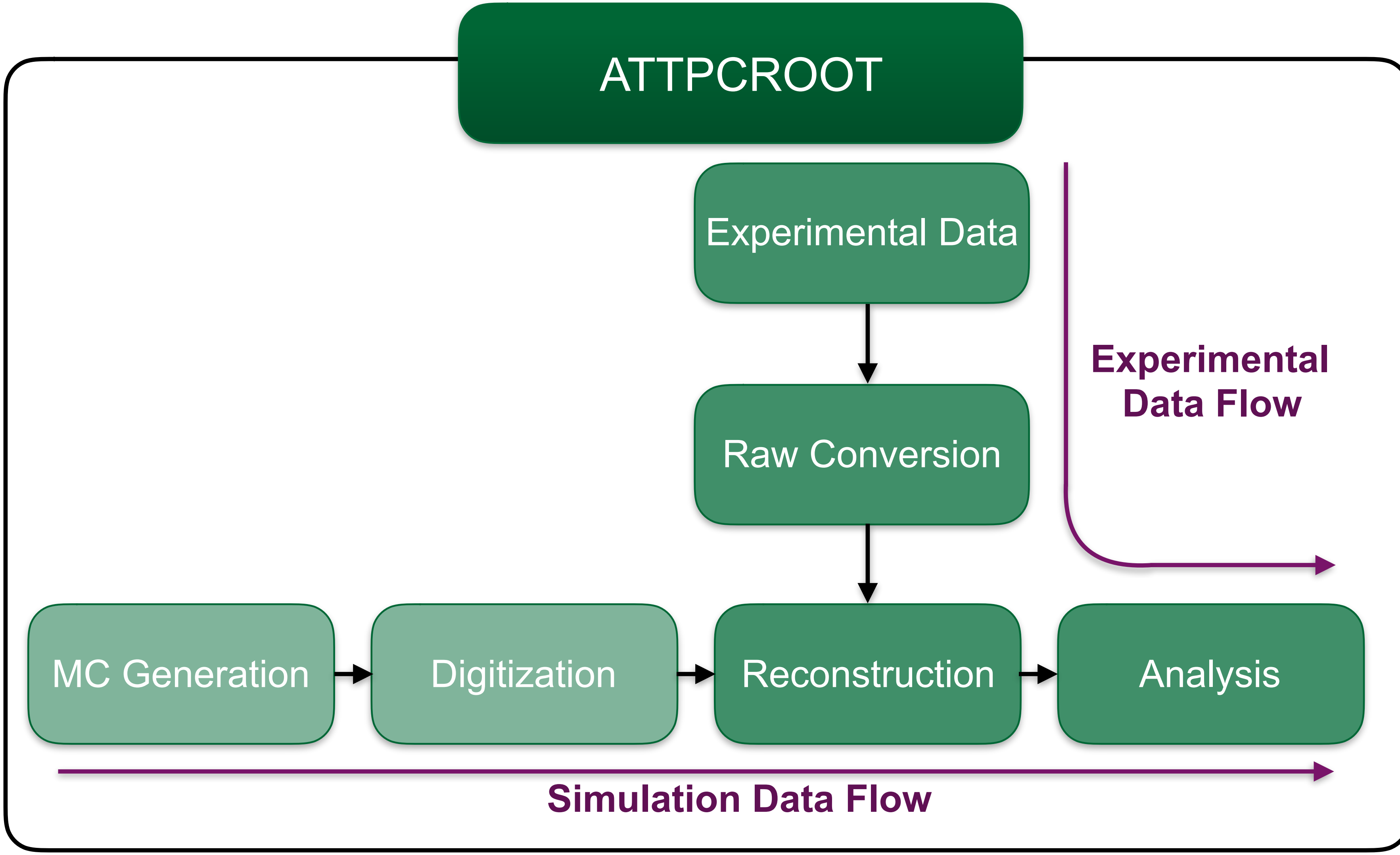


- ASCII
- GRAW
- ROOT
- An object on memory (TClonesArray*)

- ROOT
- An object on memory (TClonesArray*)

*TClonesArray is a container class provided in ROOT which can be stored in ROOT file.

SCHEMATICS OF ATTPCROOT



TRACKING RECONSTRUCTION

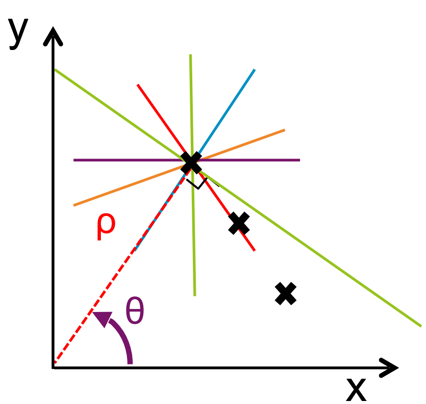
Initial fit of tracks
- Hough transform for lines (without B field) and for circles (with B field)
- RANSAC= RANdom SAmple Consensus algorithm for line detection
- Hierarchical clustering
- 3D Hough Transform
- Neural network ?

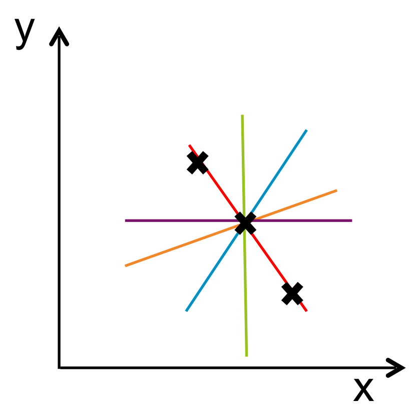
Final fit of the tracks
- Monte Carlo iterative procedure to correctly fit the tracks
- Starting point of the parameters from the initial fit

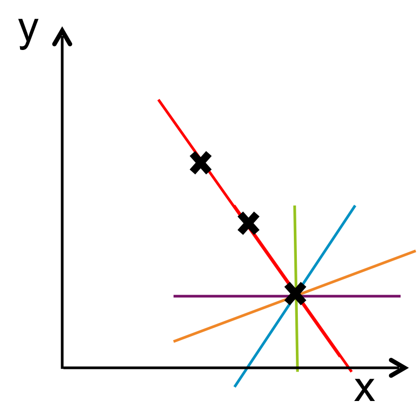
2D HOUGH TRANSFORM

2D Hough transform

Real space line ⟺ Hough space (ρ,θ) point





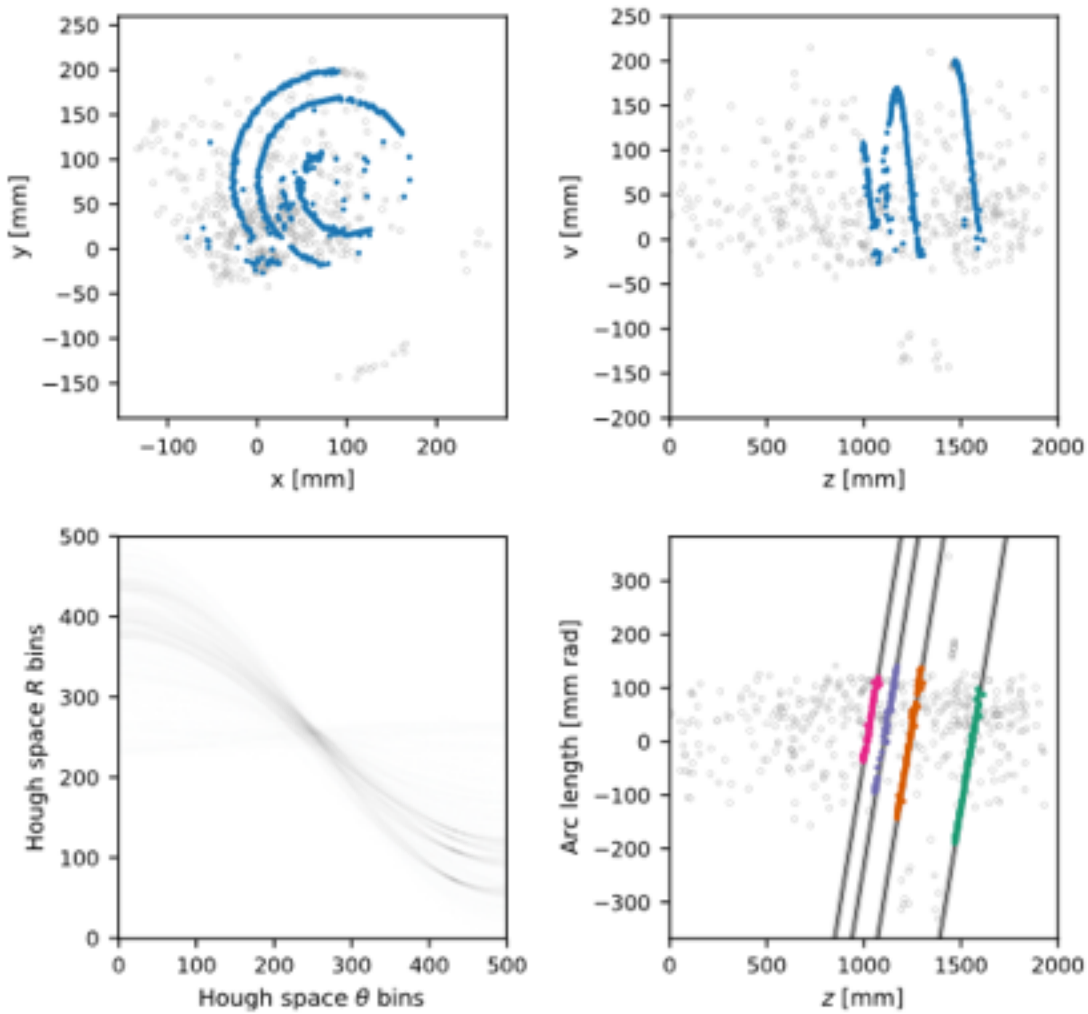


ρ	θ
ρ_1	θ_1
ρ_2	θ_2
ρ_3	θ_3
ρ_4	θ_4
ρ_5	θ_5

ρ	θ
ρ_6	θ_6
ρ_7	θ_7
ρ_8	θ_8
ρ_9	θ_9
ρ_5	θ_5

ρ	θ
ρ_{10}	θ_{10}
ρ_{11}	θ_{11}
ρ_{12}	θ_{12}
ρ_{13}	θ_{13}
ρ_5	θ_5

TRACKING: HOUGH TRANSFORM (^{46}Ar)

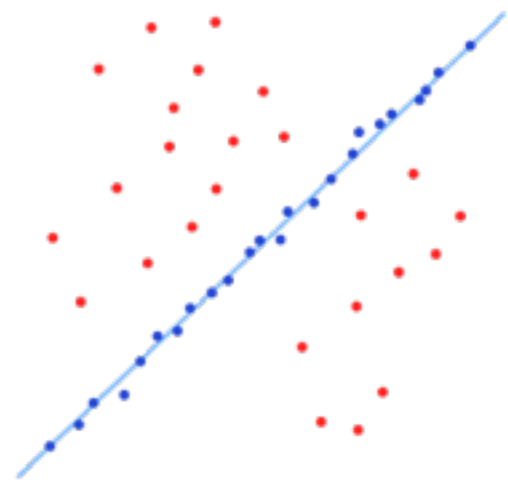


Random sample consensus (RANSAC):

- iterative method
- estimate parameters of a mathematical model
- from a set of observed data that contains outliers (noise)

- sample subset chosen at random
- fitting model computed
- algorithm checks which elements are outliers from a threshold applied

Data set with outliers



Fitted line with RANSAC

HIERARCHICAL CLUSTERING

Christoph Dalitz, Lukas Aymans, Jens Wilberg

Goal

find tracks without assumption of particular shape:

Ayyad et al.: Novel particle tracking algorithm based on the Random Sample Consensus Model for the AT-TPC. NIM A 880, pp. 166-173 (2017)

Dalitz, Schramke, Jeltsch: Iterative Hough Transform for Line Detection in 3D Point Clouds. IPOL 7, pp. 184-196 (2017)

Problem formulation

Almost a classic clustering problem:

- partition points into tracks (= clusters)
- however:
  - points at collisions belong to more than one track
  - additional cluster “noise” (disjoint from other clusters)

Reformulation as a clustering problem:

① transform points into triplets
  - group of three points representing a line segment
  - points in same triplet approximately collinear
  - one point can belong to several (or no) triplets

② cluster these triplets instead of original points

③ points not in grouped triplets are noise

Christoph Dalitz, Lukas Aymans, Jens Wilberg

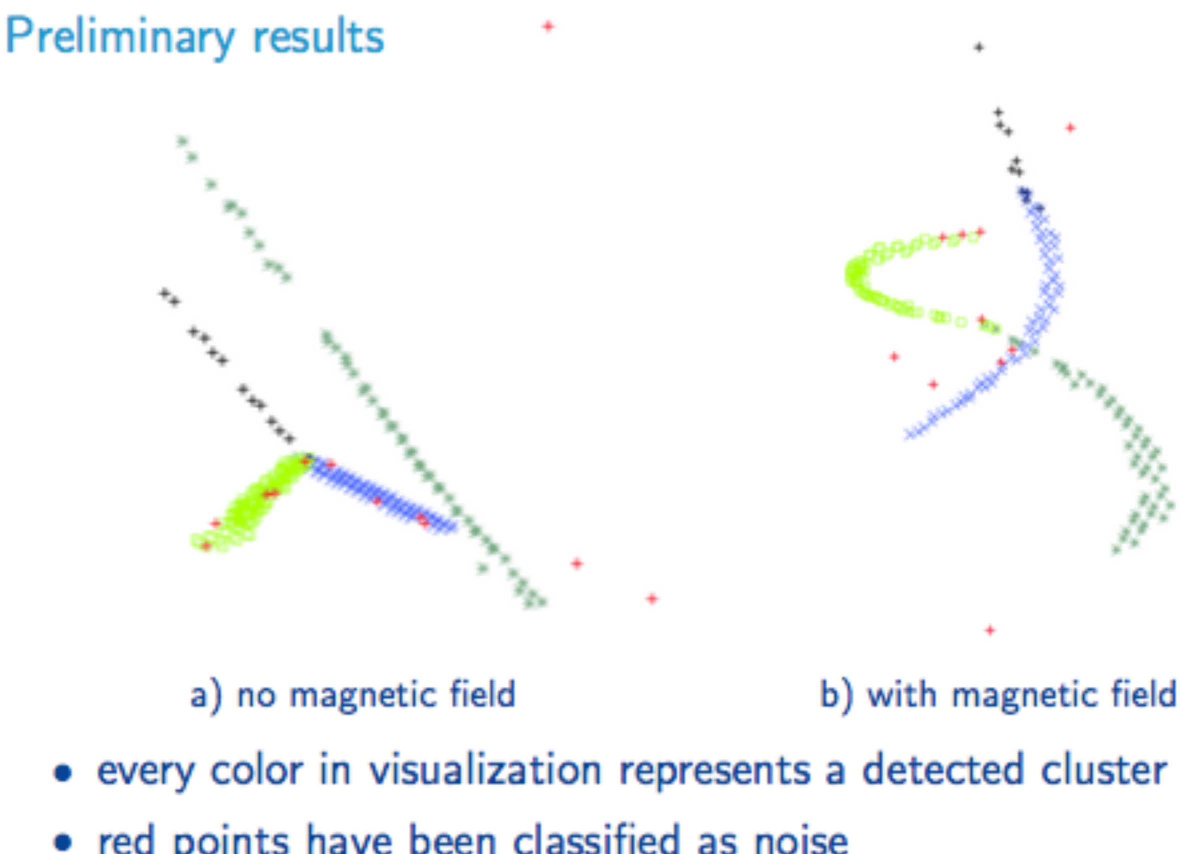
Rough idea

Triplet idea inspired by Lezama et al., 2017
- devised for 2D locally equidistant point patterns
- searches shortest path in weighted triplet graph

Our algorithm is different and consists of the steps:
① smooth points by averaging
② find somewhat collinear triplets
③ hierarchical clustering
  (parameters: triplet distance & cutoff threshold)
④ remove too small clusters

Lezama et al.: An Unsupervised Algorithm for Detecting Good Continuation in Dot Patterns. IPOL 7 (2017), pp. 81–92

Christoph Dalitz, Lukas Aymans, Jens Wilberg



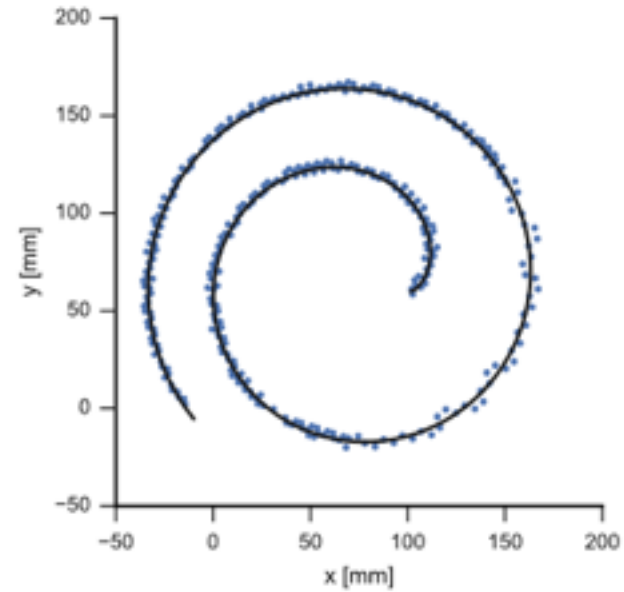
- Implementation with ATTPCROOT
- Testing of $^4He+^4He$ scattering data
- Comparison with Hough and RANSAC

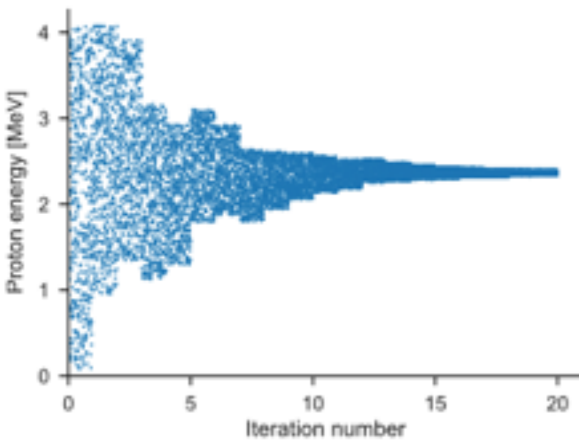
TRACKING: MONTE CARLO FIT (^{46}Ar)

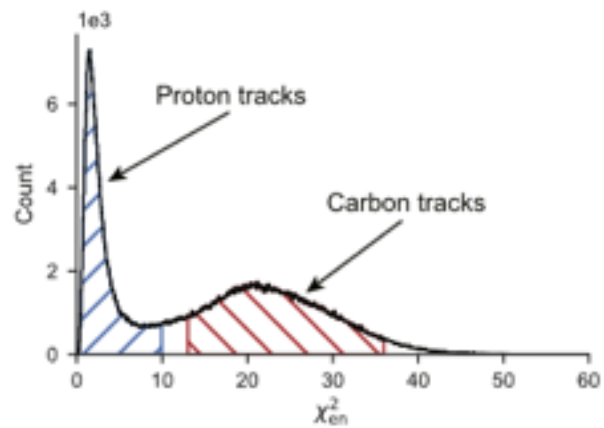
★ Right: Sample event from ^{46}Ar run, result of the MC fit with line, proton energy reconstructed at 2.081 MeV with a scattering angle of 63.5° (lab frame)

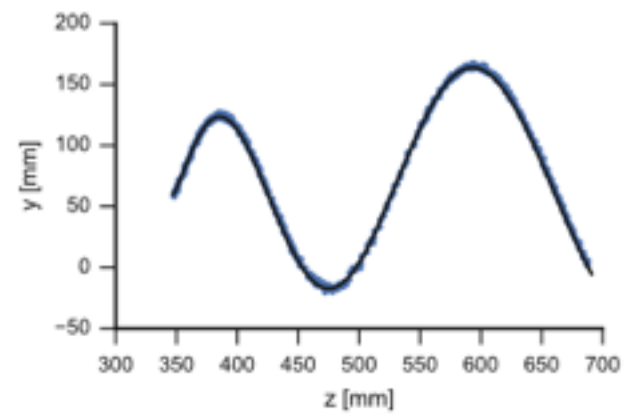
★ Bottom Left: Monte Carlo fitted energy for proton track with respect to iteration

★ Bottom Center: χ^2 energy fit, we can distinguish proton from carbon scattering



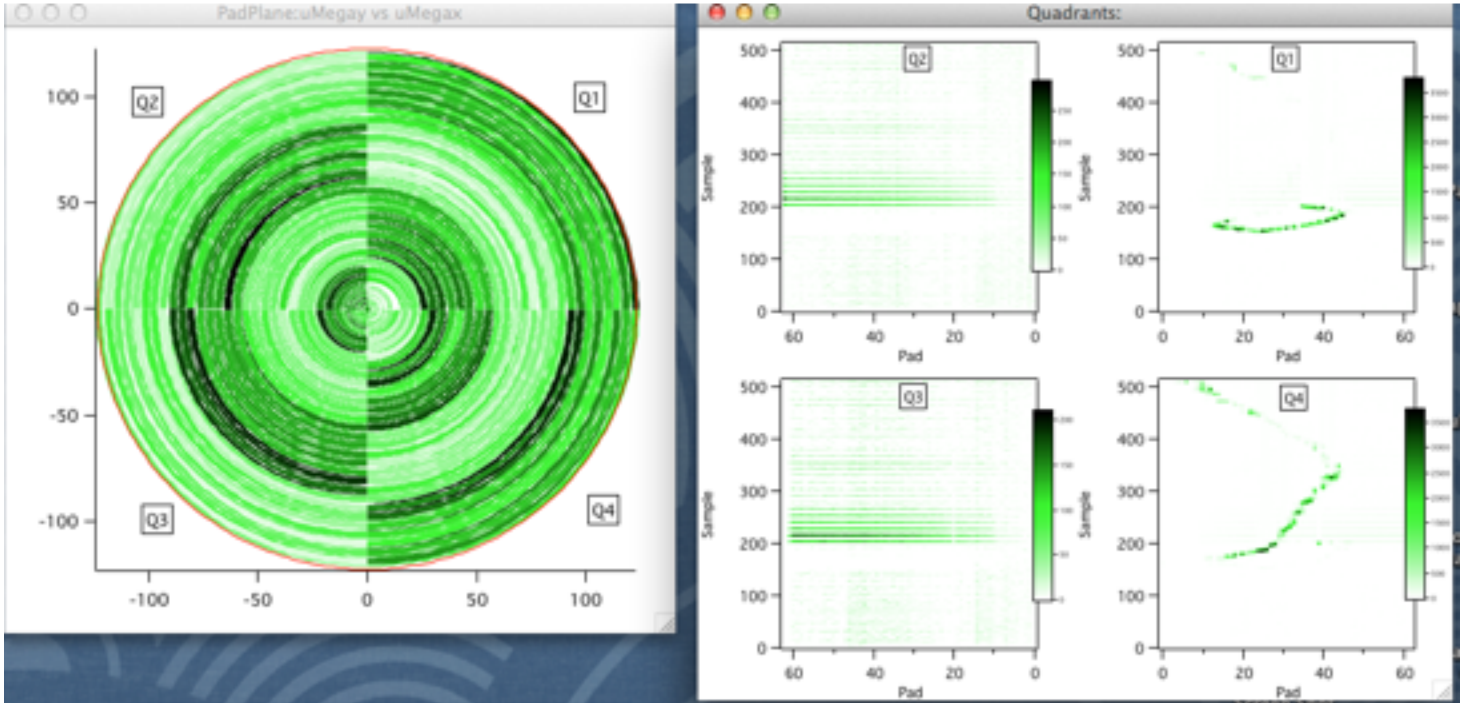






J. Bradt, NIM A **875**, 65-79 (2017)

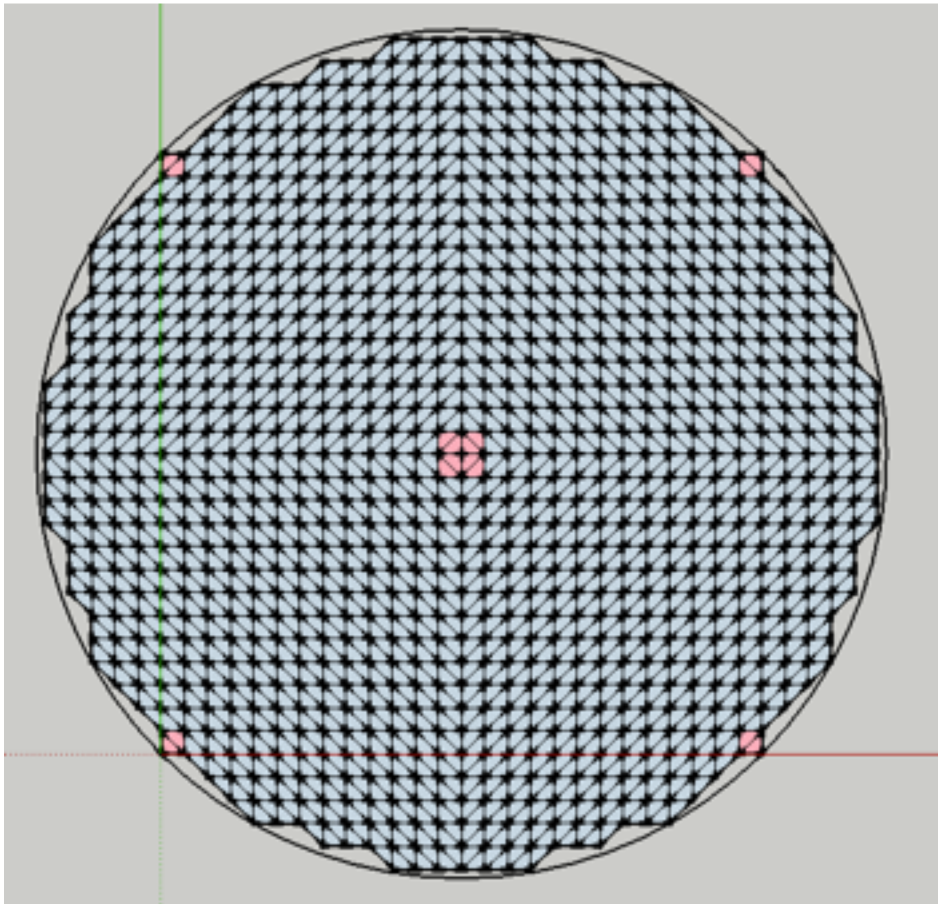
AT-TPC: LATEST DEVELOPMENTS



★ Single electron detection (delayed decay such as 2p disintegration)

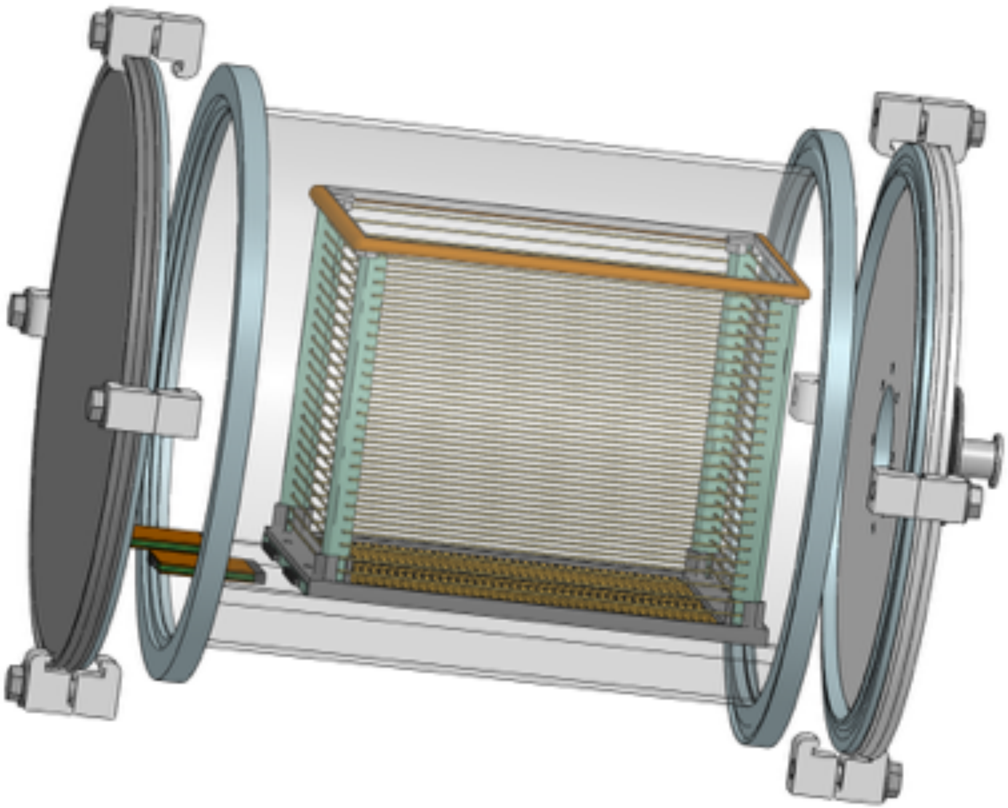
★ Dual gain on pads to measure light particles and heavier nuclei
★ MicroMegas Th-GEM detector for higher gains
★ ^{3}He gas, CD_4 gas in future TPC experiments

pAT-TPC UPGRADE



- ★ new pad plane
- ★ ~2000 pads
- ★ triangular pads
- ★ better granularity
- ★ smaller radius than AT-TPC
- ➡ coupling to other detectors

AT-TPC: FUTURE DEVELOPMENT



★ smaller TPC (200 mm diameter)
★ smaller drift time
➡ Higher count rates

★ Exit window possible in the design for higher beam energies

★ Different pad plane orientation for beam tracking
★ Coupling with gamma detection & neutron detection
★ example: (d,n) reactions

SUMMARY

★ ATTPCROOT in development using SpiRITROOT as basis

★ PyROOT development in parallel

★ Independent libraries for cross-platform programming

★ Upgrade of the pAT-TPC

★ New TPC design for the future

★ Physics campaigns at LBNL, NSCL, RCNP =>Y. Ayyad