The nptool framework: new opportunities for simulation and analysis of gaseous detector (and system!)

Adrien MATTA, [a] for the nptool collaboration

[a]LPC Caen, ENSICAEN, UNICAEN, CNRS-IN2P3

ENSAR2 GDS workshop,
Thursday 24th January 2019

Simulation and analysis landscape

Root

- CERN supported
- Standard for data analysis
- Tree / MVA
- Physics Class

Geant4

- CERN supported
- Standard for MC simulation
- Geometry / Material
- Matter Interaction / Transport

Simulation and analysis landscape

Root

- CERN supported
- Standard for data analysis
- Tree / MVA
- Physics Class

Geant4

- CERN supported
- Standard for MC simulation
- Geometry / Material
- Matter Interaction / Transport

Usual approach in the Nuclear Physics community

- Purpose made code → almost one per experiment
- Separate Simulation and Analysis → hard to validate
- Poorly modular
- Not maintained

Simulation and analysis landscape

Root

- CERN supported
- Standard for data analysis
- Tree / MVA
- Physics Class

Geant4

- CERN supported
- Standard for MC simulation
- Geometry / Material
- Matter Interaction / Transport

Usual approach in the Nuclear Physics community

- Purpose made code → almost one per experiment
- Separate Simulation and Analysis → hard to validate
- Poorly modular
- Not maintained

a few exceptions (not exhaustif)

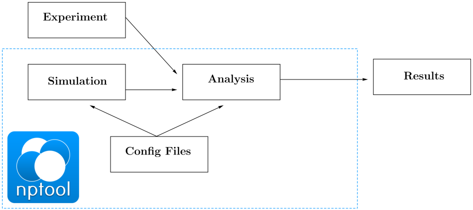
- Kaliveda (Indra / Fazia)
- FAIRRoot (FAIR)
- nptool (no string attached)

What is nptool?

Key Concept

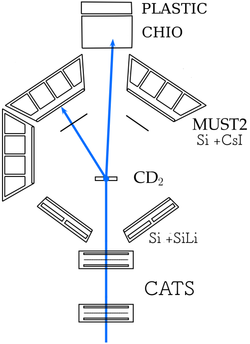
- A common framework for low energy nuclear physics experiment
- By and for the community: Open source, everybody is welcome!
- Modular and scalable → Any detector, any setup, any physics
- Promote good practices:
  - Framework philosophy → best use of Root and Geant4, readable input, ...
  - Implementation → Well commented, documented, readable code, ...
  - Physics → Validate simulation and analysis together

Basic workflow

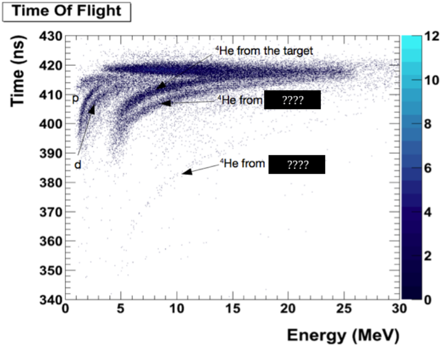


Study case: P. Morfouace's PhD

Setup



Problem

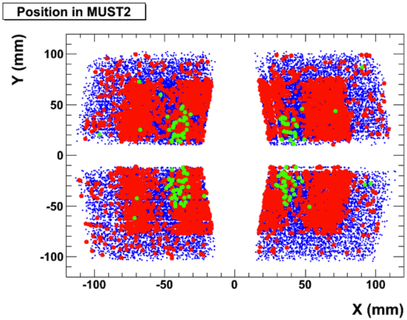


Problem

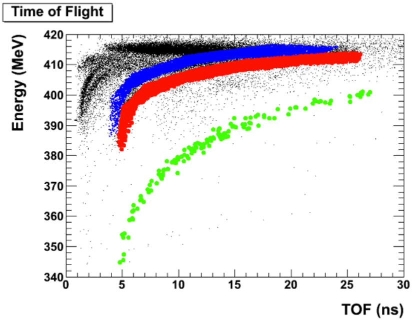
- Additional line in E-TOF ID plot
- Calibration? Corrupted Data? Real Physics?

Study case: P. Morfouace's PhD

Setup



Hypothesis

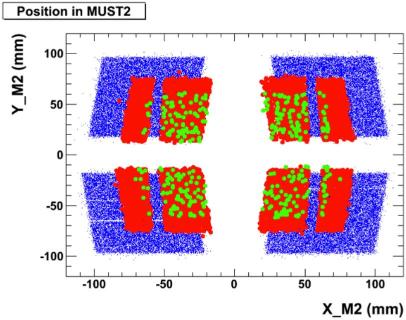


Hypothesis

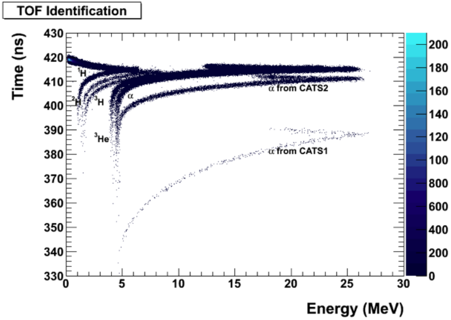
- Spatial distribution of the problematic particles
- Have to do with geometry of the setup!

Study case: P. Morfouace's PhD

Setup



Simulation



Simulation

- Done in 5 mins
- Final plots in 15 mins

What is nptool?

Concrete implementation

- Detectors are plugin library
- Event Generator are plugin library
  - → Dynamic loading at run time
  - → User focus on what matters
  - → Increased stability and performances
- All executables are Physics and Setup agnostic
- Wizard script and template to add new detector and event generator
  - → Get to work on your detectors/physics within minutes
  - → Homogeneity across detectors/physics
  - → Learn one detector, understand all of them

What is nptool?

Information sources

Publication	J. of Phys. G, Volume 43, Number 4
Project website	nptool.org
Project repository	github.com/adrien-matta/nptool

Main Contributors

- Adrien Matta (LPC)
- Nicolas de Sereville (IPNO)
- Pierre Morfouace (CEA/DAM)
- Marc Labiche (STFC/Dares. Lab)
- Freddy Flavigny (IPNO)
- Robert Shearman (NPL)
- Greg Christian (Texas A&M)
- D. Cox (Lundt)

Other lab users

- University of Surrey
- CEA
- Triumf
- GANIL
- Texas A&M
- Bose Institute
- MSU/NSCL
- University of Liverpool

nptool in numbers

The collaboration

- 16 contributors, around 25 users
- 15 PhD, 1 dedicated paper, 10 citations
- 14 laboratory involved

Code repository

- 2500+ commits
- 50 000 line of code (mainly C++)
- 50+ detectors
- 14 minutes to build and test each commit with TravisCI

#10yearsChallenge

nptool is 10!

NPTool
dec. 2008

nptool
dec. 2018

nptool in numbers

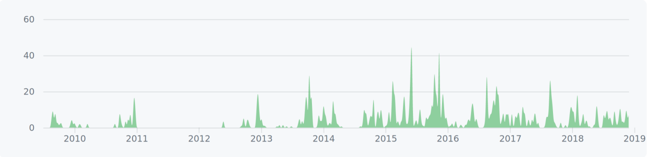
The collaboration

- 16 contributors, around 25 users
- 15 PhD, 1 dedicated paper, 10 citations
- 14 laboratory involved

Code repository

- 2500+ commits
- 50 000 line of code (mainly C++)
- 50+ detectors
- 14 minutes to build and test each commit with TravisCI

#10yearsChallenge



nptool in numbers

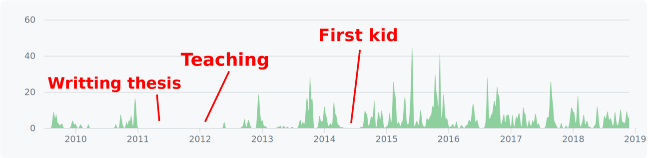
The collaboration

- 16 contributors, around 25 users
- 15 PhD, 1 dedicated paper, 10 citations
- 14 laboratory involved

Code repository

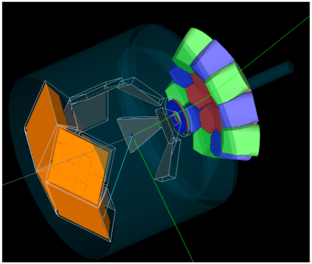
- 2500+ commits
- 50 000 line of code (mainly C++)
- 50+ detectors
- 14 minutes to build and test each commit with TravisCI

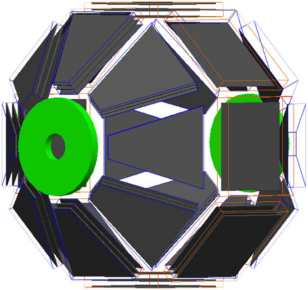
#10yearsChallenge

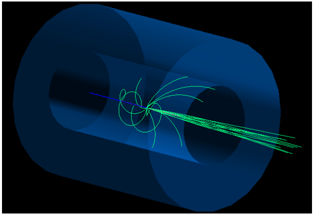


A lot of detectors to choose from

- Silicon (MUST2, HIRA, Sharc, TREX, GRIT, S1, ...)
- Ge (AGATA, MINIBALL)
- Scintillator (PARIS,FATIMA,NANA,DALI,NEUTRON WALL,...)
- Magnetic (HELIOS/ISS, VAMOS)
- Gas (IC, ACTAR, MINOS)





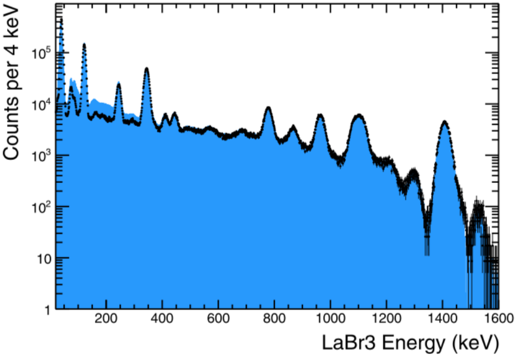


Modular Physics List

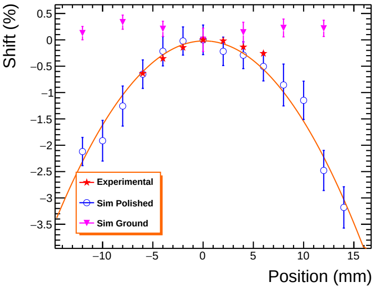
- Interactive change of the physics list
- Support for inflight decay
- Support for neutron
- Support for optical photon

```
EmPhysicsList Option4
DefaultCutOff 1000000
DriftElectronPhysics 0
IonBinaryCascadePhysics 0
NPIonInelasticPhysics 0
EmExtraPhysics 0
HadronElasticPhysics 0
StoppingPhysics 0
OpticalPhysics 0
HadronPhysicsINCLXX 0
HadronPhysicsQGSP_BIC_HP 0
Decay 1
```

Modular Physics List



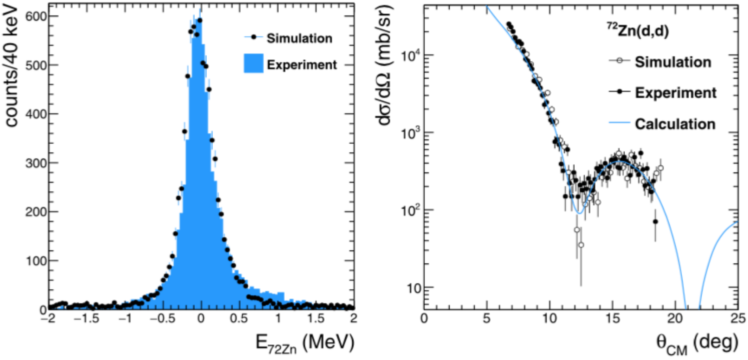
LaBr3 (R. Shearman)



CsI (P. Morfouace)

Event Generator

- Beam and source → Emmitance, energy distribution,...
- Two body reaction → angular distribution, beam energy dependence, ...
- Decay → Particle and γ, angular distribution
- Cosmic ray

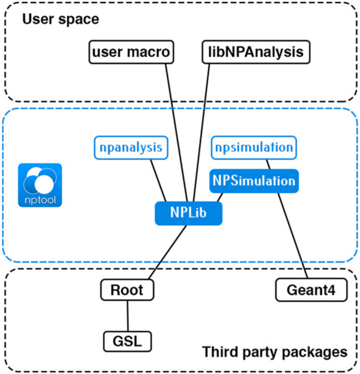


User space

Philosophy

- Experiment specific
  → Analysis Project
- Detector generic
  → NPLib, NPSimulation
- Separate Framework from plugin
  → Focus on what matters
- Best of ROOT and Geant4
  → More on physics

Layout



Toolbox

Energy loss, Calibrations, Kinematics, Online ...

nptool for cryogenic target

Input File

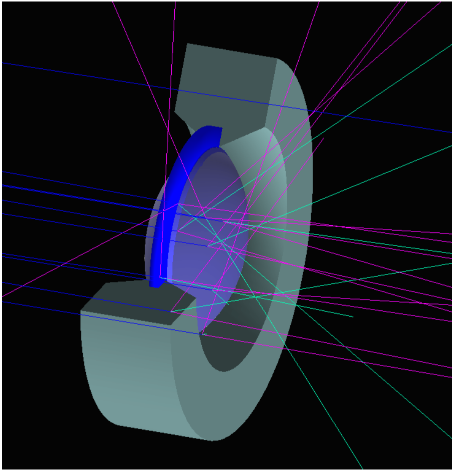
```
CryogenicTarget
  NominalThickness= 10 mm
  Material= LH2
  Density= 8 mg/cm3
  Radius= 10 cm
  Angle= 0 deg
  X= 0
  Y= 0
  Z= 0
  FrontDeformation= 10 mm
  FrontThickness= 10 micrometer
  FrontRadius= 8 cm
  FrontMaterial= Mylar
  BackDeformation = 3 mm
  BackThickness= 10 micrometer
  BackRadius= 8 cm
  BackMaterial= Mylar
  FrameRadius= 12 cm
  FrameThickness= 5 cm
  FrontCone= 45 deg
  BackCone= 45 deg
  FrameMaterial= Al
  ShieldInnerRadius= 30 cm
  ShieldOuterRadius= 31 cm
  ShieldBottomLength= 20 cm
  ShieldTopLength= 20 cm
  ShieldFrontRadius= 15 cm
  ShieldBackRadius= 10 cm
  ShieldMaterial= Al
```

Input File

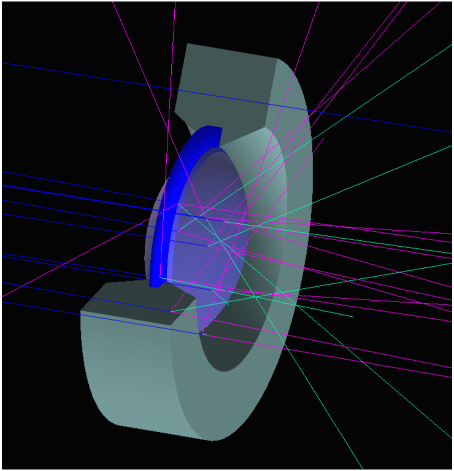
```
CryogenicTarget
  NominalThickness= 10 mm
  Material= LH2
  Density= 8 mg/cm3
  Radius= 10 cm
  Angle= 0 deg
  X= 0
  Y= 0
  Z= 0
  FrontDeformation= 10 mm
  FrontThickness= 10 micrometer
  FrontRadius= 8 cm
  FrontMaterial= Mylar
  BackDeformation = 3 mm
  BackThickness= 10 micrometer
  BackRadius= 8 cm
  BackMaterial= Mylar
  FrameRadius= 12 cm
  FrameThickness= 5 cm
  FrontCone= 45 deg
  BackCone= 45 deg
  FrameMaterial= Al
  ShieldInnerRadius= 30 cm
  ShieldOuterRadius= 31 cm
  ShieldBottomLength= 20 cm
  ShieldTopLength= 20 cm
  ShieldFrontRadius= 15 cm
  ShieldBackRadius= 10 cm
  ShieldMaterial= Al
```

Simulation

Target cell in details



Target cell in details



Windows deformation

$$f(x) = (x_0 + b + 1) - cosh(\frac{x}{(R/acosh(b+1)})$$

b = window maximum deformation

x_0 = offset

R = windows radius

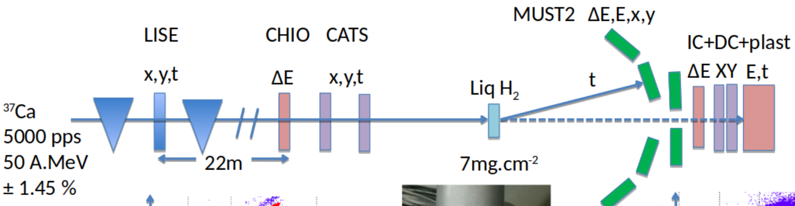
Simulation

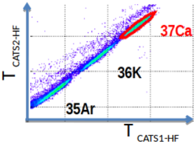
- Generate volumes
- Beam X Target

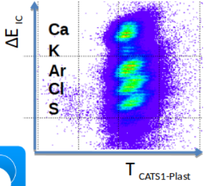
Analysis

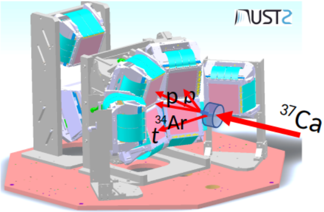
- Beam X Target
- Position dependend E_{Loss}

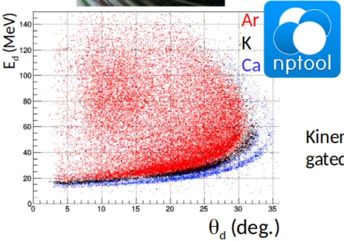
Study case: MUST2 (p,t) campaign (2018)





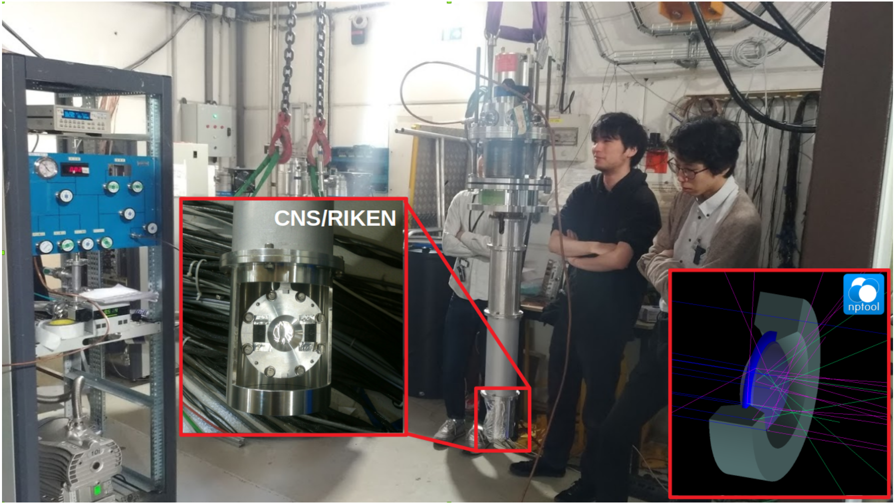






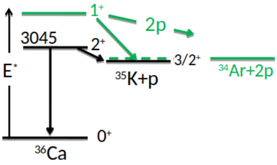
Kinematics in MUST2 gated on outgoing Z

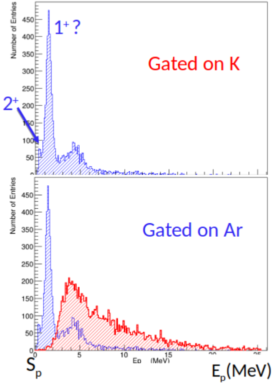
Study case: MUST2 (p,t) campaign (2018)

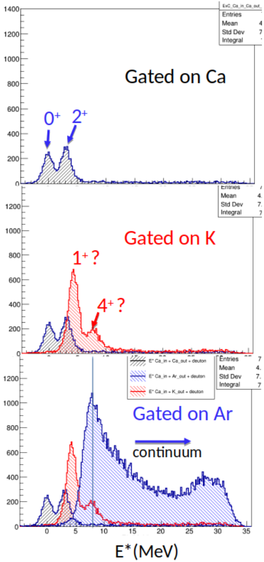


CryPTa (CNS/RIKEN)

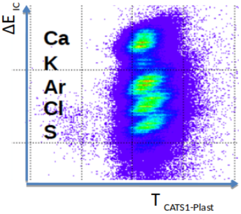
Preliminary results







Gated on
- deuterium in MUST2
- outgoing Z in IC



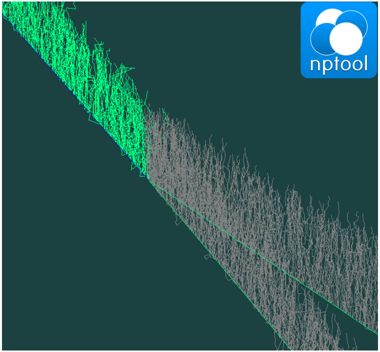
PhD Louis Lalanne
Start Oct 2018

nptool for TPC and Gas based detection

Geant4 Physics list for TPC (A. Matta & P. Morfouace)

To be submitted to Geant4:

- Inspired by Optical Photon
- New particle: Drift electrons
- Weigthed track system
- Ionization with DE
- Transport
  → Realistic or Simplified
- Amplification/Absorption
- Drift/Diffusion
  → Properties of Material



Example4 (nptool.org)

Geant4 Physics list for TPC (A. Matta & P. Morfouace)

To be submitted to Geant4:

- Inspired by Optical Photon
- New particle: Drift electrons
- Weigthed track system
- Ionization with DE
- Transport
  → Realistic or Simplified
- Amplification/Absorption
- Drift/Diffusion
  → Properties of Material

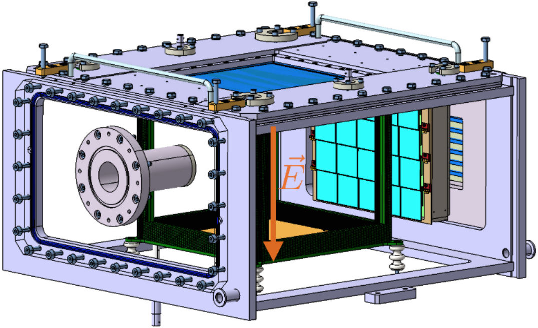
```
G4MaterialPropertiesTable* MPT = new G4MaterialPropertiesTable();
MPT->AddConstProperty("DE_PAIRENERGY",20*eV);
MPT->AddConstProperty("DE_YIELD",3e-1);
//MPT->AddConstProperty("DE_AMPLIFICATION",2);
MPT->AddConstProperty("DE_ABSLENGTH",1*pc);
MPT->AddConstProperty("DE_DRIFTSPEED",0.8*cm/microsecond);
MPT->AddConstProperty("DE_TRANSVERSALSPREAD",2e-5*mm2/ns);
MPT->AddConstProperty("DE_LONGITUDINALSPREAD",7e-5*mm2/ns);
```

Tool box for TPC (P. Morfouace)

Part of NPLib:

- Track reconstruction
- Vertex detection
- RANSAC
- Hough transformation

Study case: ACTAR TPC



GANIL spiral2 laboratoire commun CEA/DRF CNRS/IN2P3

erc European Research Council Established by the European Commission

cf J. Giovinazzo's talk

ACTive TARget and Time Projection Chamber

Gas-Filled active target and TPC

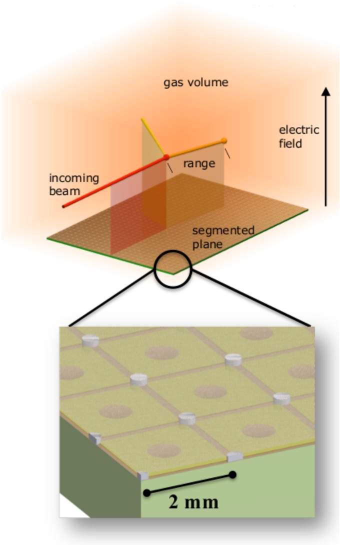
- Gas = Target AND Detector
- Vertexing = reso. $\sim$ thin solid target
- High effective thickness $\sim$ x1000

Major advantages over conventional approaches

- Detection efficiency $\sim 4\pi$
- Low threshold: particle stop in the gas
- Event-by-event 3D reconstruction
- Compact, portable and versatile detector

Physics Programs

- Resonant Scattering
- Inelastic scattering and giant resonances
- Transfer reactions
- Rare and exotic decays ($2p$,$\beta-2p$,..)
- Transfer-induced fission,...

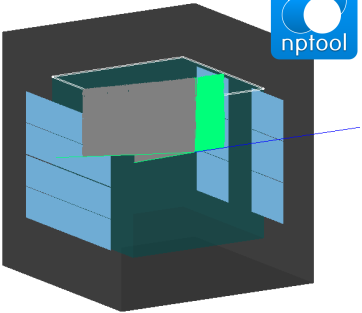


Morfouace Matta Mauss

ACTAR simulation with nptool

Key features

- Output data in "raw" format
  - → Test existing analysis
- One step simulation
- Modular ancillary
- Human readable input file
- Simulation with other detectors
- Reproduce ID Plot
- Reproduce Resolution

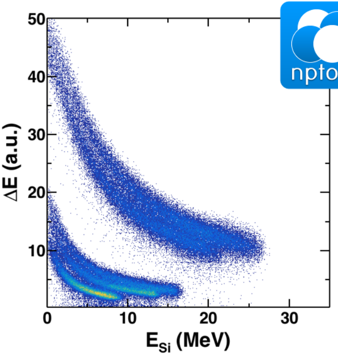


Morfouace Matta Mauss

ACTAR simulation with nptool

Key features

- Output data in "raw" format
  - → Test existing analysis
- One step simulation
- Modular ancillary
- Human readable input file
- Simulation with other detectors
- Reproduce ID Plot
- Reproduce Resolution

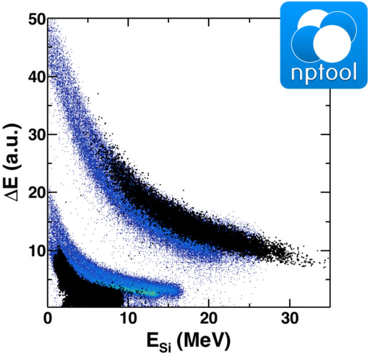


Morfouace Matta Mauss

ACTAR simulation with nptool

Key features

- Output data in "raw" format
  - $\rightarrow$ Test existing analysis
- One step simulation
- Modular ancillary
- Human readable input file
- Simulation with other detectors
- Reproduce ID Plot
- Reproduce Resolution

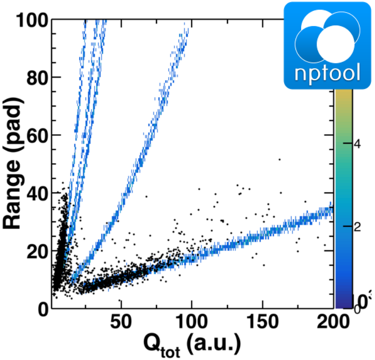


Morfouace Matta Mauss

ACTAR simulation with nptool

Key features

- Output data in "raw" format
  - → Test existing analysis
- One step simulation
- Modular ancillary
- Human readable input file
- Simulation with other detectors
- Reproduce ID Plot
- Reproduce Resolution



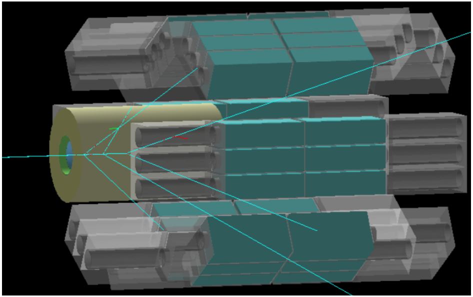
Conclusion

Gaseous detector and system

- Offers new tool for Geant4 simulation of Gaseous detector
- Offers out of the box tool for TPC analysis
- Cryogenic target simulation facility
- Cryogenic target analysis facility

Comming up

- Dali-Minos-Nebula
- Spede (D. Cox)
- Resonant scattering
- Multifragmentation
- Triggerless simulation



UNIVERSITY OF SURREY

cea

RIKEN NiSHiNA CENTER

UNIVERSITY OF LIVERPOOL

Grand Accélérateur National d'Ions Lourds
GANIL
Laboratoire commun CEA / DSM - CNRS / IN2P3

UNIVERSITAS STUDII PADUANI MCCXXII

IPN INSTITUT DE PHYSIQUE NUCLÉAIRE ORSAY

NPL National Physical Laboratory

Thank You

TRIUMF

LUND UNIVERSITY

lpc caen

IPHC Institut Pluridisciplinaire Hubert CURIEN STRASBOURG

INFN Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Legnaro

Science & Technology Facilities Council
Daresbury Laboratory

ATM