The nptool framework: news and other excitment

Adrien MATTA, [a] for the nptool collaboration

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

GRIT workshop,
9-11th October 2019, Florence

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)

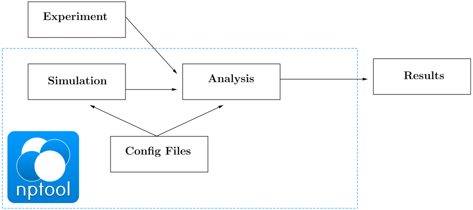
- Kaliveda (Indra / Fazia)
- FAIRRoot (FAIR)
- nptool (no string attached)

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



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 (new website in preparation!)
Project repository	gitlab.in2p3.fr/np/nptool (new!)

Main Contributors

- Adrien Matta (LPC)
- Nicolas de Sereville (IPNO)
- Pierre Morfouace (CEA/DAM)
- Marc Labiche (STFC/Dares. Lab)
- Freddy Flavigny (LPC)
- Valerian Alcindor (GANIL)
- 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 30 users
- 15 PhD, 1 dedicated paper, 8 citations
- 15 laboratory involved

Code repository

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

#10yearsChallenge

nptool is 10!

dec. 2008

dec. 2018

nptool in numbers

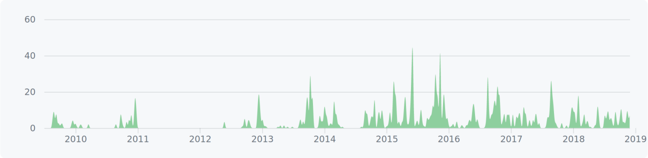
The collaboration

- 16 contributors, around 30 users
- 15 PhD, 1 dedicated paper, 8 citations
- 15 laboratory involved

Code repository

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

#10yearsChallenge



nptool in numbers

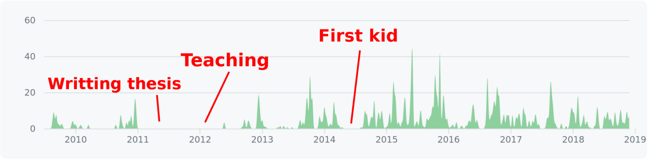
The collaboration

- 16 contributors, around 30 users
- 15 PhD, 1 dedicated paper, 8 citations
- 15 laboratory involved

Code repository

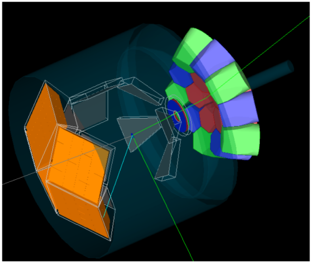
- 2500+ commits
- 50 000 line of code (mainly C++)
- 50+ detectors
- 10 minutes to build and test each commit with gitlab-CI

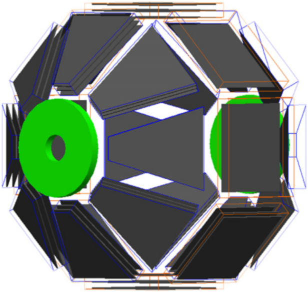
#10yearsChallenge

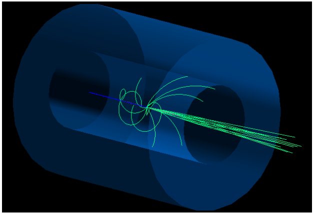


A lot of detectors to choose from

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





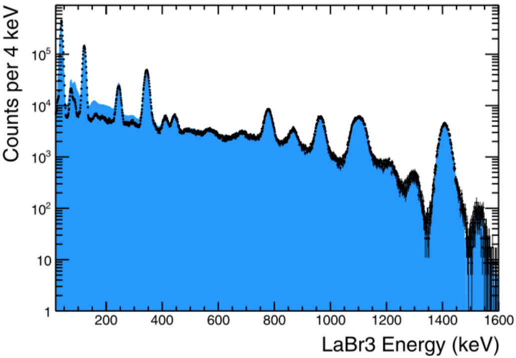


Modular Physics List

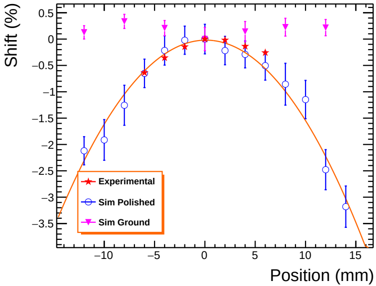
- Interactive change of the physics list
- Support for inflight decay
- Support for neutron
- Support for optical photon

```
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



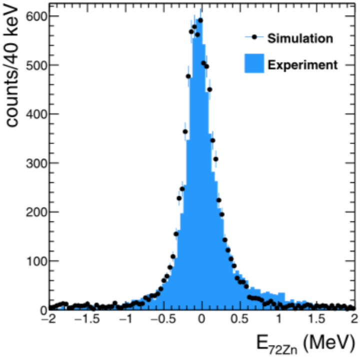
LaBr3 (R. Shearman)

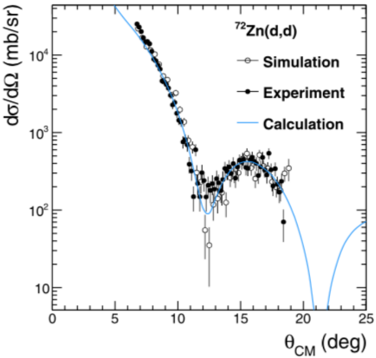


CsI (P. Morfouace)

Event Generator

- Beam and source → Emmitance, energy distribution,...
- Two body reaction → angular distribution, beam energy dependence, ...
- Decay → Particle and γ, angular distribution
- Cosmic ray
- Quasi-Free Scattering (coming soon!)



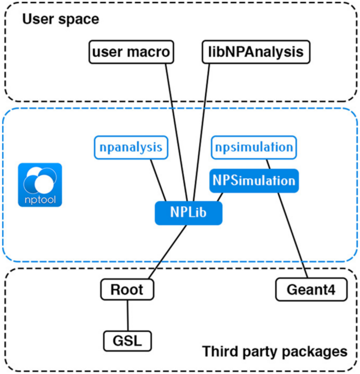


User space

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 ...

DSAM and cryogenic target

Input File

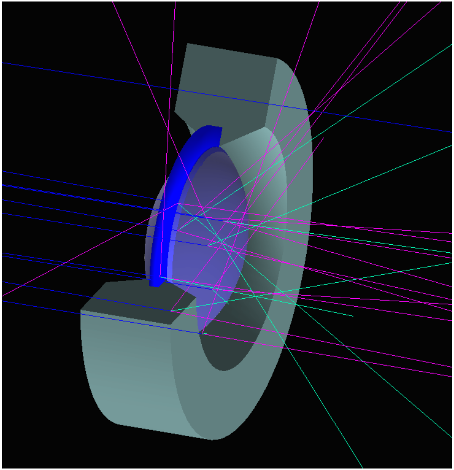
```
CryogenicTarget
  NominalThickness= 10 mm
  Material= LH2
  Density= 8 mg/cm3
  Radius= 10 cm
  Angle= 0 deg
  X= 0
  Y= 0
  Z= 0
  FrontDeformation= 10 mm
  FrontThickness= 10 micrometer
  FrontRadius= 8 cm
  FrontMaterial= Mylar
  BackDeformation = 3 mm
  BackThickness= 10 micrometer
  BackRadius= 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

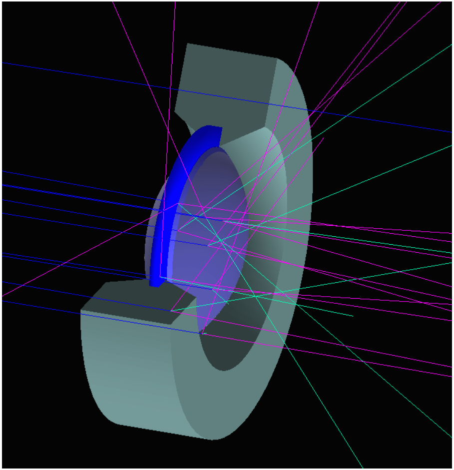
```
CryogenicTarget
  NominalThickness= 10 mm
  Material= LH2
  Density= 8 mg/cm3
  Radius= 10 cm
  Angle= 0 deg
  X= 0
  Y= 0
  Z= 0
  FrontDeformation= 10 mm
  FrontThickness= 10 micrometer
  FrontRadius= 8 cm
  FrontMaterial= Mylar
  BackDeformation = 3 mm
  BackThickness= 10 micrometer
  BackRadius= 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

$$f(x) = (x_0 + b + 1) - cosh(\frac{x}{(R/acosh(b+1))})$$
$$b = \text{window maximum deformation}$$
$$x_0 = \text{offset}$$
$$R = \text{windows radius}$$

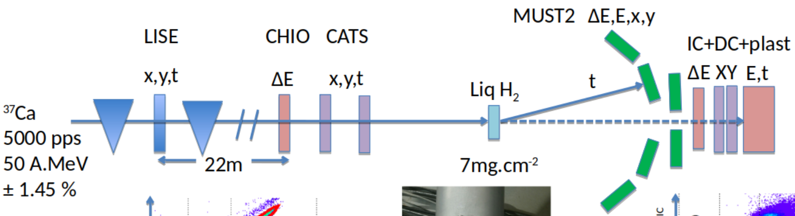
Simulation

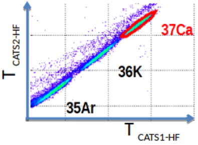
- Generate volumes
- Beam $\otimes$ Target

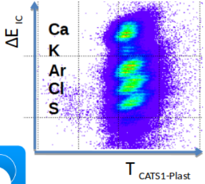
Analysis

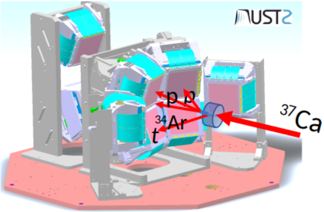
- Beam $\otimes$ Target
- Position dependend E_{Loss}

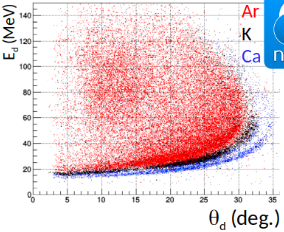
Study case: MUST2 (p,t) campaign (2018)





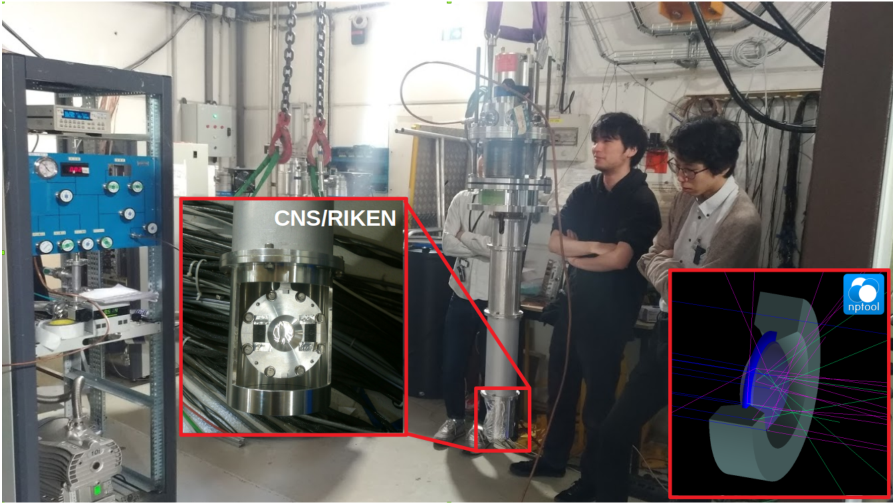






Kinematics in MUST2
gated on outgoing Z

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



CryPTa (CNS/RIKEN)

DSAM target setup

```
Target
 Thickness= 3 micrometer
 Radius= 5 mm
 Material= CD2
 Angle= 0 deg
 X= 0 mm
 Y= 0 mm
 Z= 0 mm
 BackingMaterial= Au
 BackingThickness= 5 micrometer
```

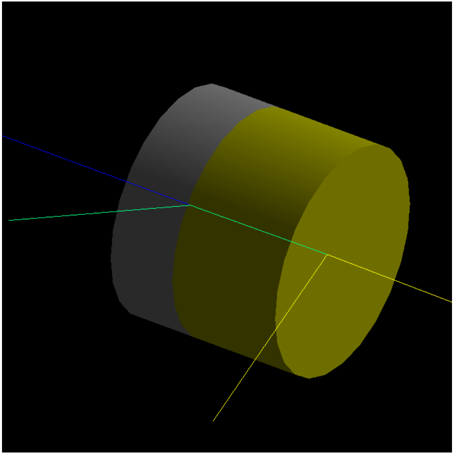
DSAM target setup

```
Target
 Thickness= 3 micrometer
 Radius= 5 mm
 Material= CD2
 Angle= 0 deg
 X= 0 mm
 Y= 0 mm
 Z= 0 mm
 BackingMaterial= Au
 BackingThickness= 5 micrometer
```

DSAM target setup

```
Target
 Thickness= 3 micrometer
 Radius= 5 mm
 Material= CD2
 Angle= 0 deg
 X= 0 mm
 Y= 0 mm
 Z= 0 mm
 BackingMaterial= Au
 BackingThickness= 5 micrometer
```

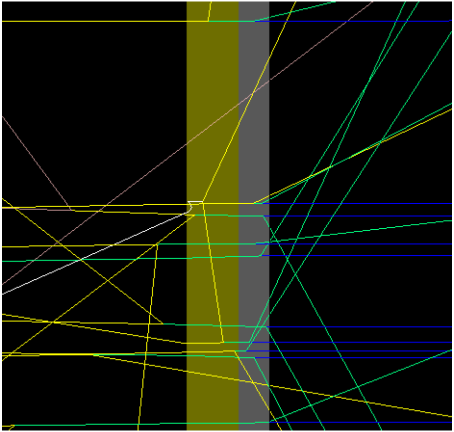
Target



DSAM target setup

```
Target
 Thickness= 3 micrometer
 Radius= 5 mm
 Material= CD2
 Angle= 0 deg
 X= 0 mm
 Y= 0 mm
 Z= 0 mm
 BackingMaterial= Au
 BackingThickness= 5 micrometer
```

Target



Event generator setup

```
Beam
  Particle= 190
  ExcitationEnergy= 0 MeV
  Energy= 125.4 MeV
  SigmaEnergy= 0.1 MeV
  SigmaThetaX= 0.01 deg
  SigmaPhiY= 0.01 deg
  SigmaX= 0.0 mm
  SigmaY= 0.0 mm
  MeanThetaX= 0 deg
  MeanPhiY= 0 deg
  MeanX= 0 mm
  MeanY= 0 mm
  %EnergyProfilePath=
  %XThetaXProfilePath=
  %YPhiYProfilePath=

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
TwoBodyReaction
  Beam= 190
  Target= 2H
  Light= 1H
  Heavy= 200
  ExcitationEnergyLight= 0.0 MeV
  ExcitationEnergyHeavy= 4.072 MeV
  CrossSectionPath= CS.txt CSR1
  ShootLight= 1
  ShootHeavy= 1
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
LevelData 200
  Path= ./200.level
```

Event generator setup

```
Beam
  Particle= 190
  ExcitationEnergy= 0 MeV
  Energy= 125.4 MeV
  SigmaEnergy= 0.1 MeV
  SigmaThetaX= 0.01 deg
  SigmaPhiY= 0.01 deg
  SigmaX= 0.0 mm
  SigmaY= 0.0 mm
  MeanThetaX= 0 deg
  MeanPhiY= 0 deg
  MeanX= 0 mm
  MeanY= 0 mm
  %EnergyProfilePath=
  %XThetaXProfilePath=
  %YPhiYProfilePath=

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
TwoBodyReaction
  Beam= 190
  Target= 2H
  Light= 1H
  Heavy= 200
  ExcitationEnergyLight= 0.0 MeV
  ExcitationEnergyHeavy= 4.072 MeV
  CrossSectionPath= CS.txt CSR1
  ShootLight= 1
  ShootHeavy= 1
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
LevelData 200
  Path= ./200.level
```

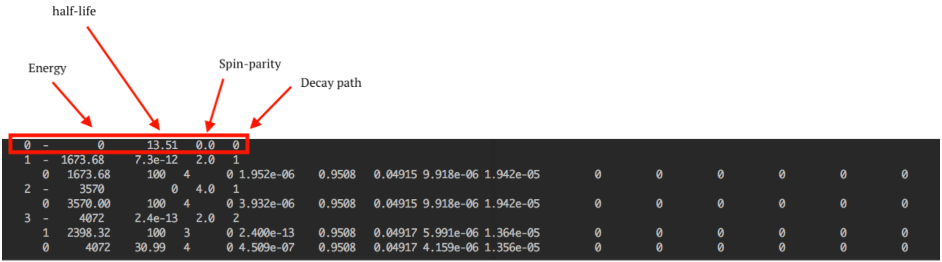
Event generator setup

Geant4 Photon Evaporation file format

```
  0  -       0      13.51   0.0   0
  1  -  1673.68    7.3e-12   2.0   1
     0  1673.68      100   4      0 1.952e-06    0.9508    0.04915 9.918e-06 1.942e-05         0         0         0         0         0         0
  2  -     3570          0   4.0   0
     0  3570.00      100   4      0 3.932e-06    0.9508    0.04915 9.918e-06 1.942e-05         0         0         0         0         0         0
  3  -     4072    2.4e-13   2.0   2
     1  2398.32      100   3      0 2.400e-13    0.9508    0.04917 5.991e-06 1.364e-05         0         0         0         0         0         0
     0     4072    30.99   4      0 4.509e-07    0.9508    0.04917 4.159e-06 1.356e-05         0         0         0         0         0         0
```

Event generator setup

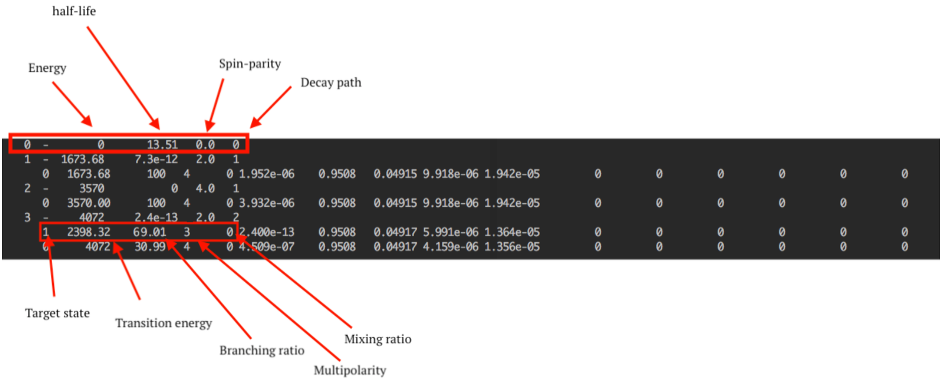
Geant4 Photon Evaporation file format → Defining State




```
 0  -      0       13.51   0.0   0
 1  -   1673.68    7.3e-12 2.0   1
    0   1673.68      100   4     0 1.952e-06   0.9508   0.04915 9.918e-06 1.942e-05    0    0    0    0    0    0
 2  -     3570           0 4.0   1
    0   3570.00      100   4     0 3.932e-06   0.9508   0.04915 9.918e-06 1.942e-05    0    0    0    0    0    0
 3  -     4072     2.4e-13 2.0   2
    1   2398.32      100   3     0 2.400e-13   0.9508   0.04917 5.991e-06 1.364e-05    0    0    0    0    0    0
    0      4072    30.99   4     0 4.509e-07   0.9508   0.04917 4.159e-06 1.356e-05    0    0    0    0    0    0
```

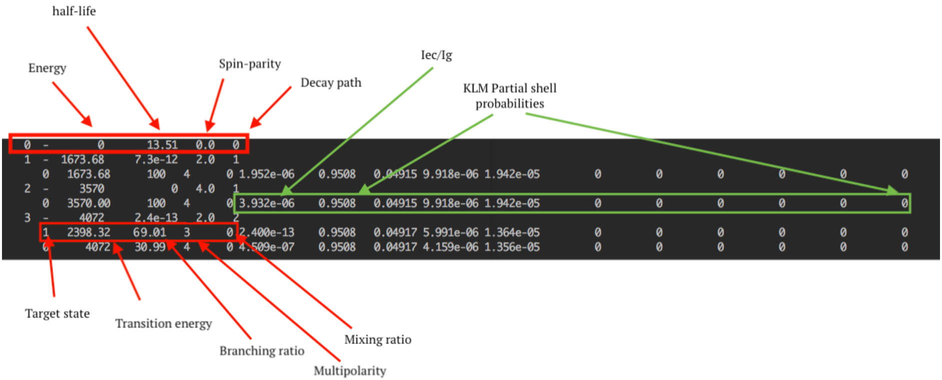
Event generator setup

Geant4 Photon Evaporation file format → Defining transition



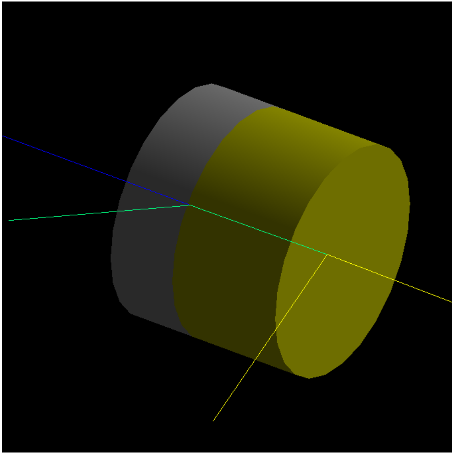
Event generator setup

Geant4 Photon Evaporation file format → Defining EC properties



Simulation of upcoming ^{19}O(d,p)

- Work just started
- Non trivial effect
  - → Kinematic of ^{20}O
  - → Cross section distribution
- Fine tuning
  - → Beam energy
  - → Degrader thickness

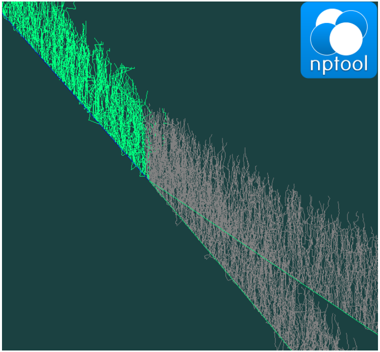


nptool for Gas based detection

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
- Amplification/Absorption
- Realistic Transport
- 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
- Amplification/Absorption
- Realistic Transport
- 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 & C.Lenain)

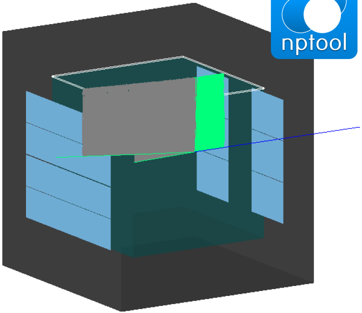
Part of NPLib:

- Track reconstruction
- Vertex detection
- RANSAC
- Hough transformation

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

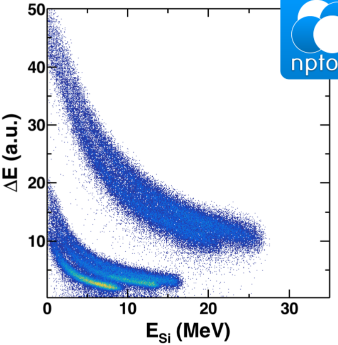


Morfouace, Mauss, Matta

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

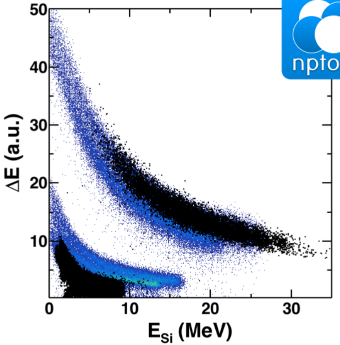


Morfouace, Mauss, Matta

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

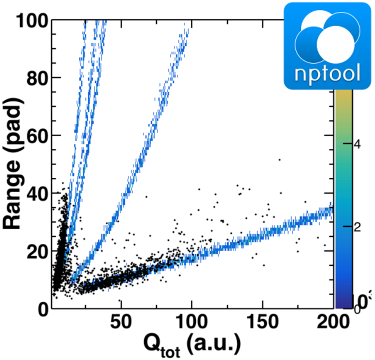


Morfouace, Mauss, Matta

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, Mauss, Matta

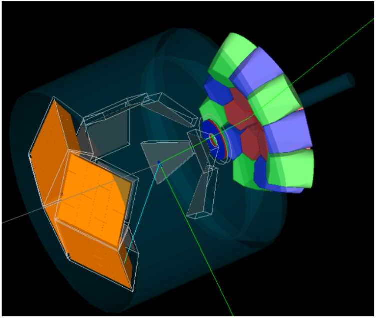
Conclusion

Recent features

- Simulation of DSAM/Plunger with direct reaction (Example5 coming soon)
- Cryogenic target simulation/analysis facilities
- Gaseous detector simulation/analysis facilities

Comming up for you

- New website
  → Better/More documentation
- **Docker image (CI/CD)**
  → Running w/o installation
- Mugast simulation
  → Dedicated class
- GRIT detector
  → re-work of GASPARD
- Quasi-Free Scattering (F. Flavigny)
- Int.Conv./EXOGAM (Goigoux/Vandebrouck)



Thank You

UNIVERSITY OF SURREY

cea

RIKEN NISHINA CENTER

UNIVERSITY OF LIVERPOOL

Grand Accélérateur National d'Ions Lourds

GANIL

Laboratoire commun CEA / DSM - CNRS / IN2P3

NPL National Physical Laboratory

IPN INSTITUT DE PHYSIQUE NUCLÉAIRE ORSAY

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