MUGAST campaign Data analysis tools and status

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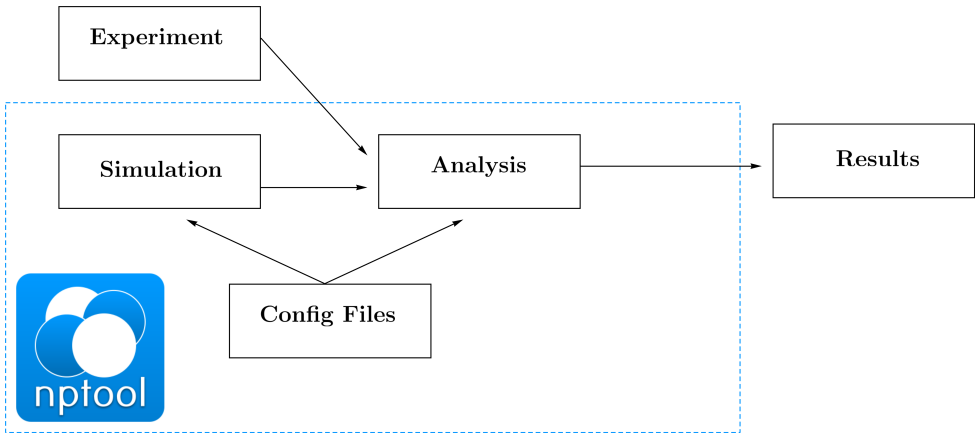
AGATA Week,
3 Mars 2021, the cloud

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 (IJCLab)
- Pierre Morfouace (CEA/DAM)
- Marc Labiche (STFC/Dares. Lab)
- Freddy Flavigny (LPC)
- Valerian Alcindor (TU Darmstadt)
- Greg Christian (Texas A&M)
- Daniel Cox (Lundt)

Other lab users

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

nptool in numbers

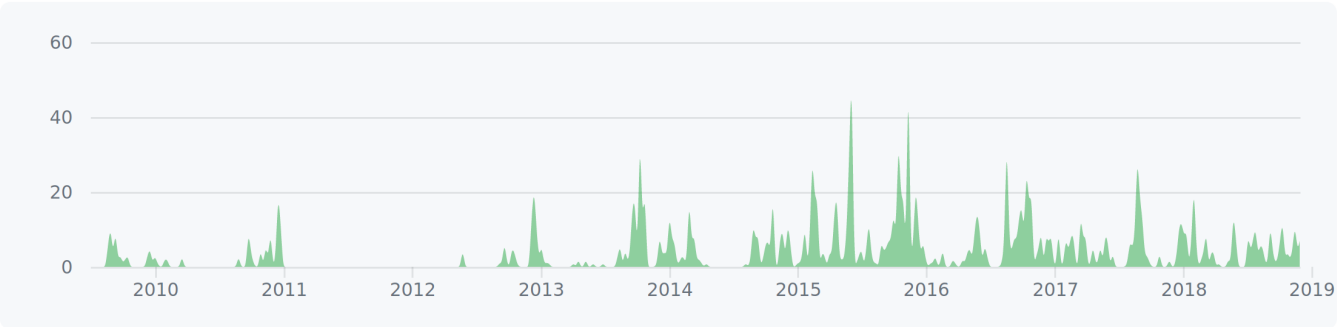
The collaboration

- ~20 contributors, around 30 users
- 15 PhD, 1 dedicated paper, 8 citations
- 15 laboratory involved

Code repository

- 3000+ commits
- 50 000 line of code (mainly C++)
- 50+ detectors
- 6 minutes to build and test each commit with gitlab-CI

#10yearsChallenge

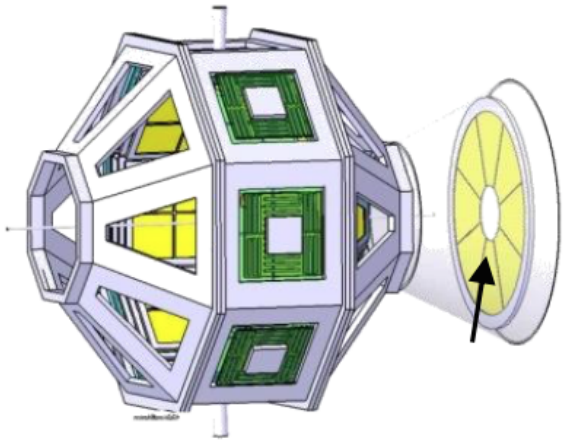


GASPARD (SPIRAL2)+ TRACE (SPES) = GRIT

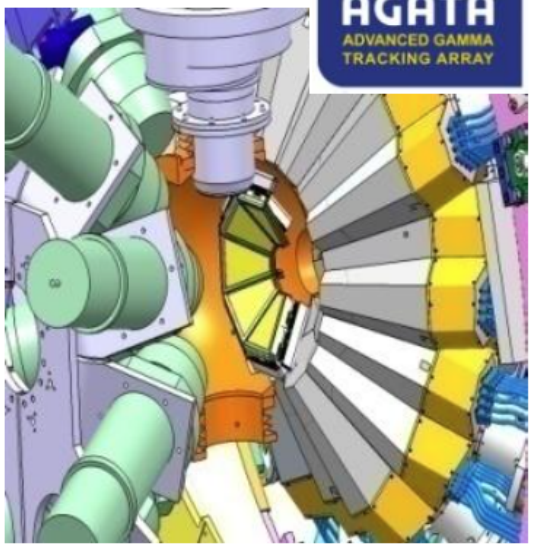
GRIT in a nut shell

GASPARD

GAmma SPectroscopy
and PArticle Detection



AGATA
ADVANCED GAMMA TRACKING ARRAY



- High geometric efficiency
  - → couverture 4π
- enhanced PID capability
  - → PSA, TOF and E-ΔE

- γ-compatible
  - → AGATA
- Cryogenic Target
  - → CHyMENE (LH2/LD2)
  - → HECTOR (^{3,4}He)

GASPARD (SPIRAL2)+ TRACE (SPES) = GRIT

GRIT in a nut shell

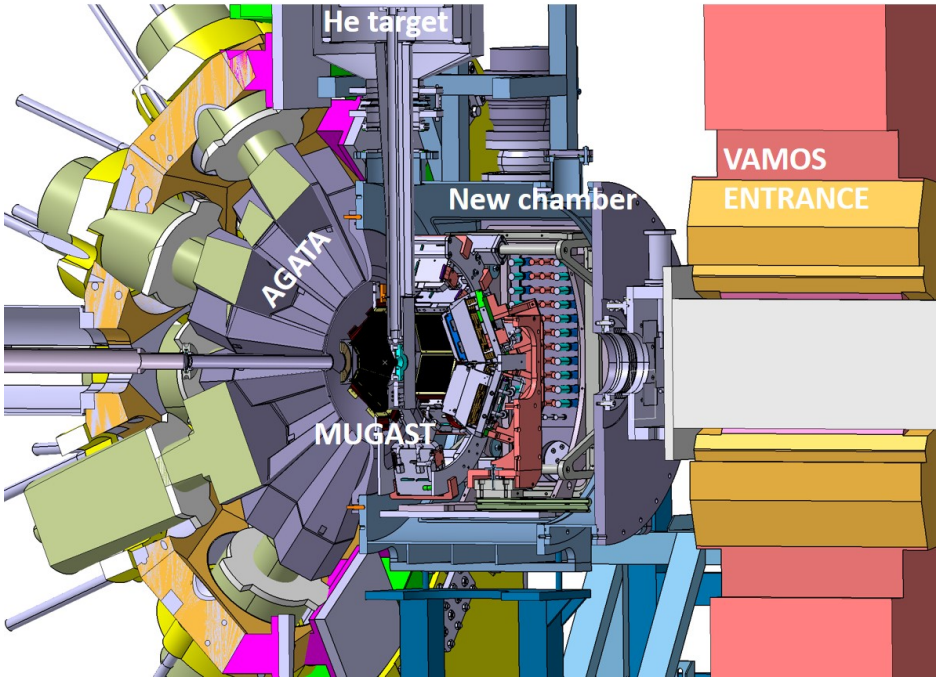
- Mechanical design
  - → to be finalized in 2021 (IJCLab)
- Detector Design
  - → nTD Trapezoid and Square
  - → float zone thick layer
- Front End Electronic ASICs
  - → iPACI (IJCLab)
  - → TOT (MILANO)
  - → PLAS (Valencia/LPC Caen)
- Back End electronique
  - → FASTER v3 (LPC Caen)
  - → SMART/FASTER coupling (GANIL / LPC Caen)

Foundings

5 years MoU ∼600kEUR (IN2P3/INFN)
Normandie ∼500 kEUR (SIREN and ETSI)

MUGAST-AGATA-VAMOS

MUst2 + GASpard + Trace



MUST2 FEE/BEE (2006)

Transfert Reactions

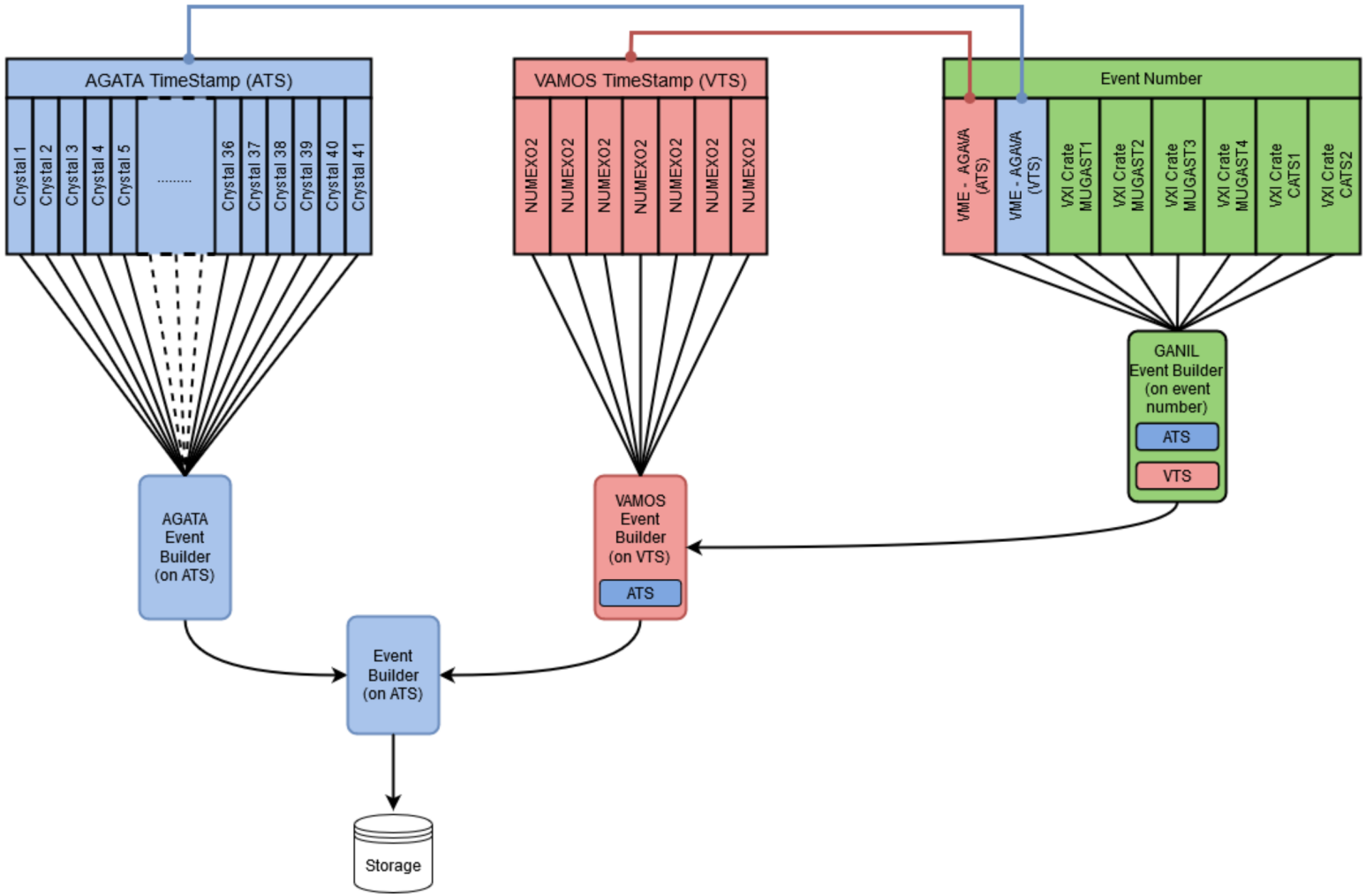
- **Four MUST2 telescope**
  → $(d,{}^3\mathrm{He}/t)$, $(d,{}^4\mathrm{He})$, $(p,{}^3\mathrm{He})$
- **Two TRACE square**
  → (d,d) et (p,p)
- **5 GASPARD trapezoid**
  → (d,p) et $({}^3\mathrm{He},d)$
- **AGATA 1π**
  → 10% efficiency
- **VAMOS Spectrometer**
  → 0° PID

Reactions

- (d,pγ)
- (^{7}Li,dγ)
- (^{3}He,dγ)
- (p,p')

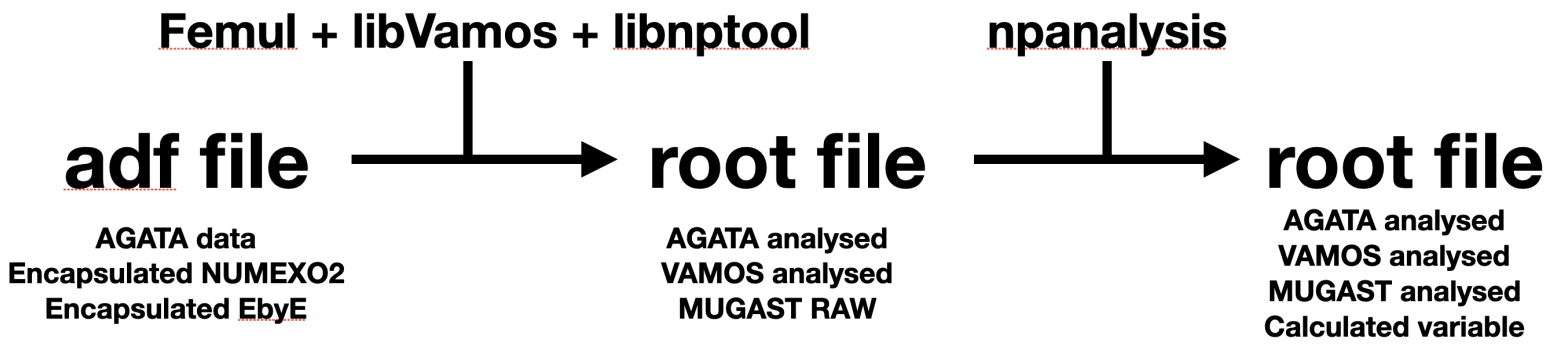
MUGAST-AGATA-VAMOS

DAQ



MUGAST-AGATA-VAMOS

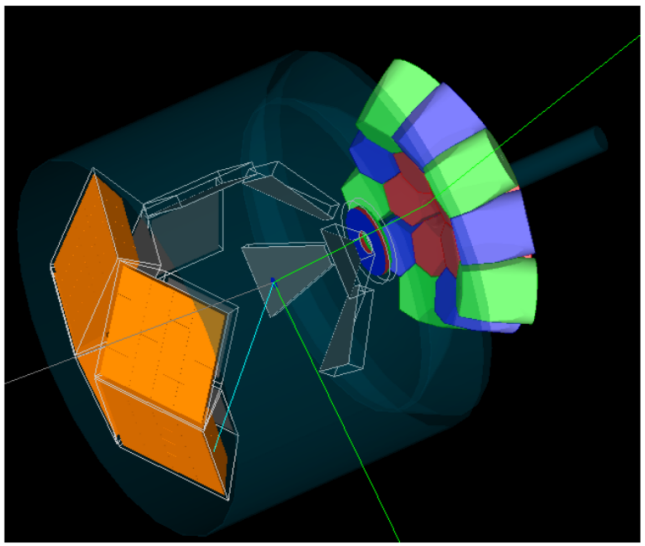
Analysis

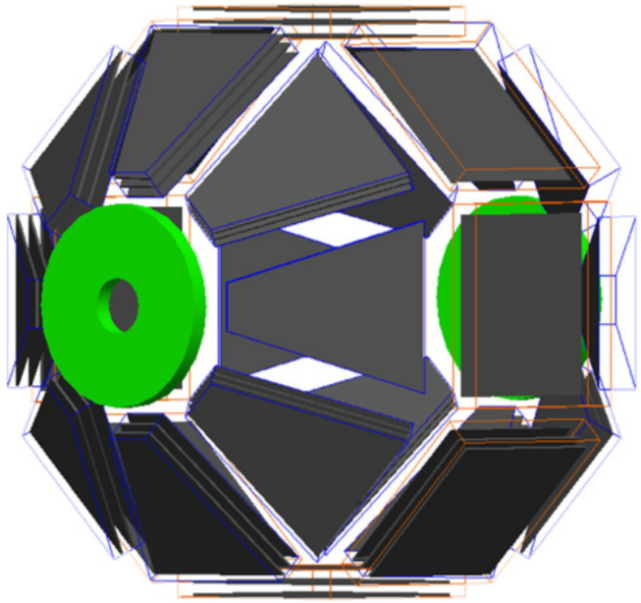


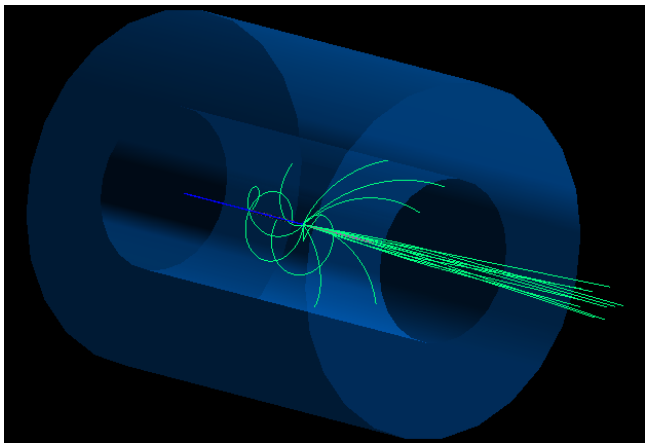
FEMUL integration: J. Duduouet, A. Lemasson, E. Clement

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)





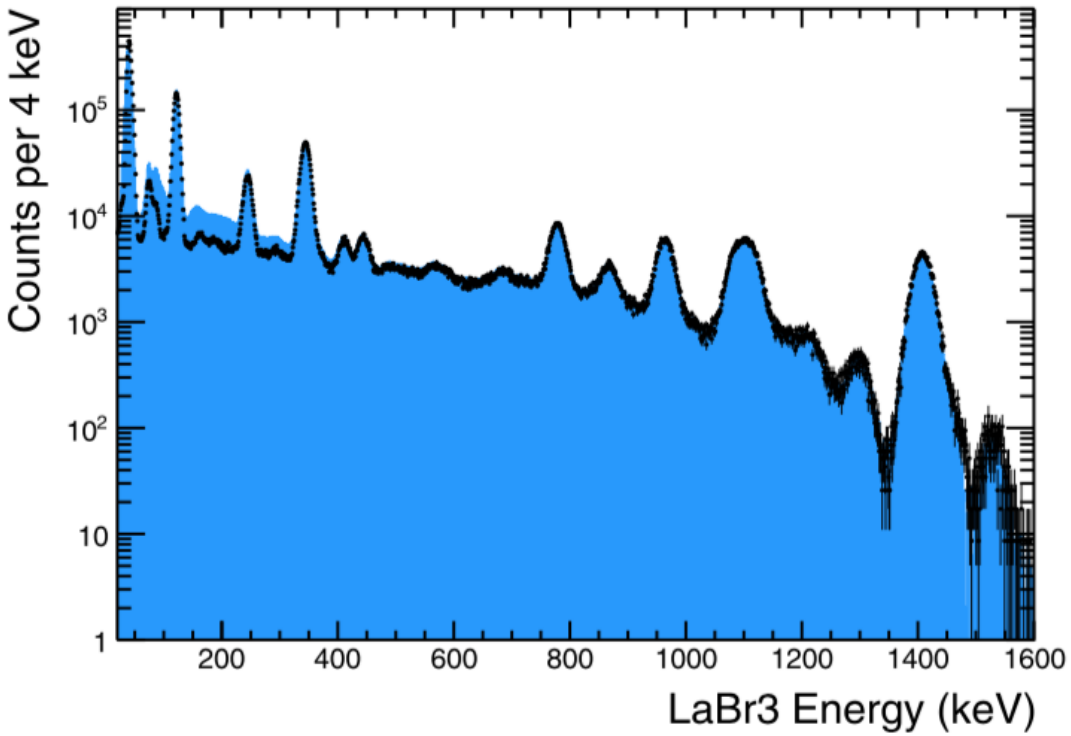


Modular Physics List

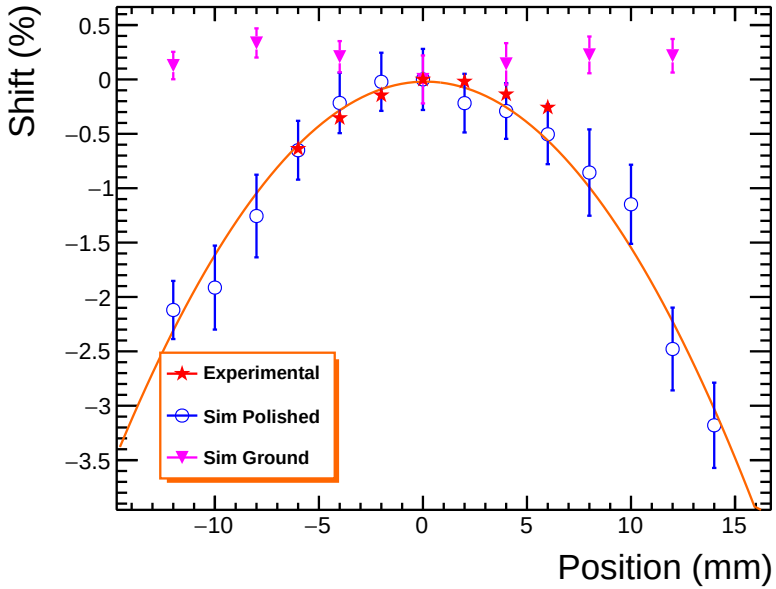
- Interactive change of the physics list
- Support for inflight decay
- Support for neutron
- Support for optical photon
- Support for **drift electrons**

```
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



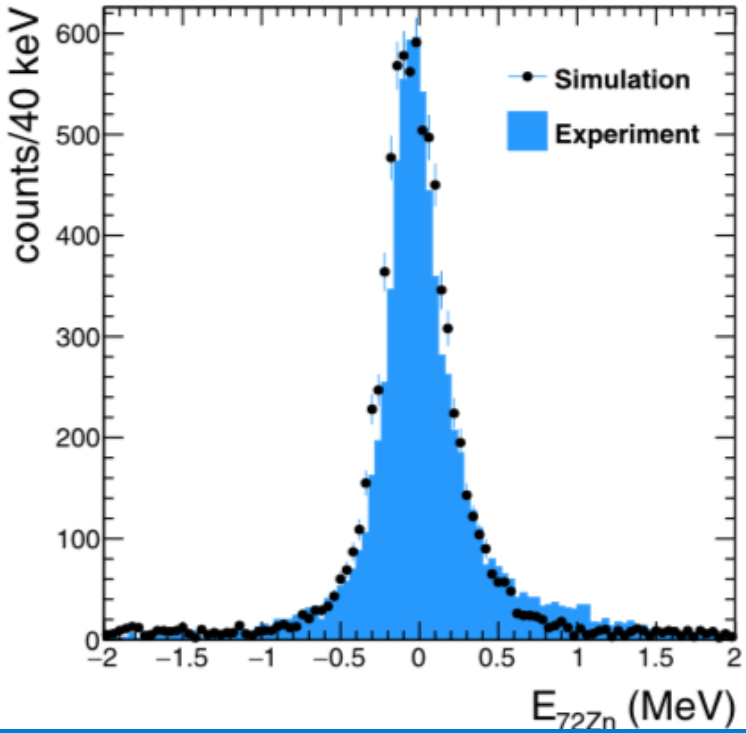
LaBr3 (R. Shearman)

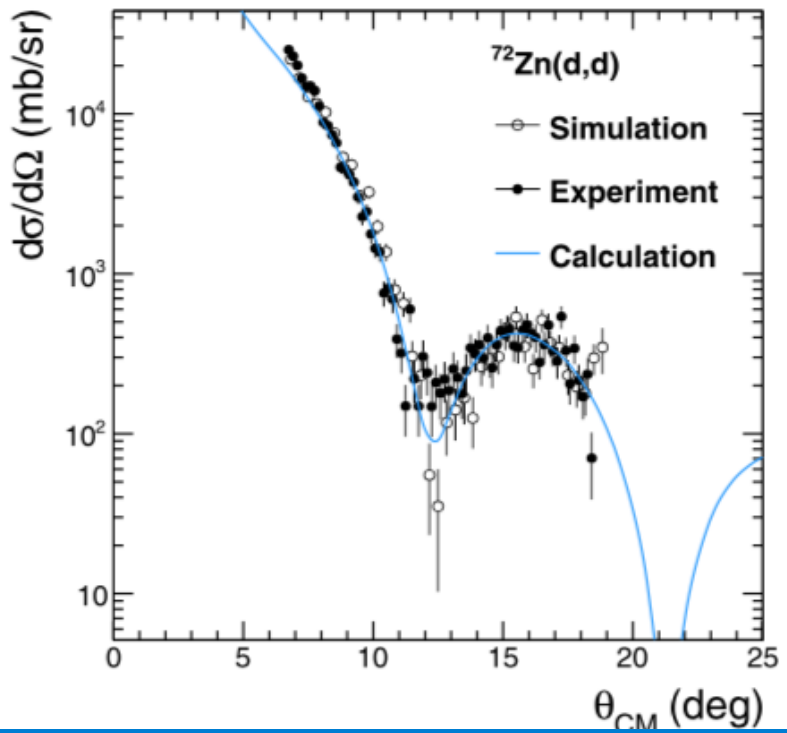


CsI (P. Morfouace)

Event Generator

- Beam and source → Emmitance, energy distribution,...
- Two body reaction → angular distribution, beam energy dependence, ...
- Decay → Particle and γ, angular distribution, life-time
- Cosmic ray
- Quasi-Free Scattering (p,2p)



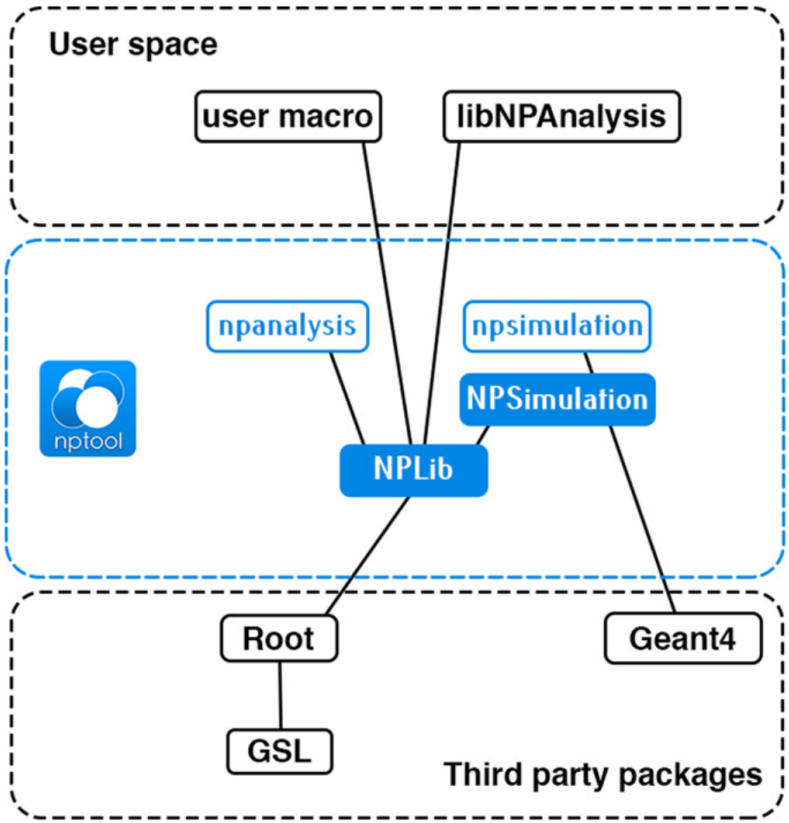


User space

Philosophy

- Experiment specific
  - → Project based directory
  - → Sim., Analys., Calib. in one place
- Detector generic
  - → NPLib, NPSimulation
- Separate Framework from plugins
  - → Focus on what matters
- Best of ROOT and Geant4
  - → More on physics

Layout



Toolbox

Energy loss, Calibrations, Kinematics, Online ...

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
```

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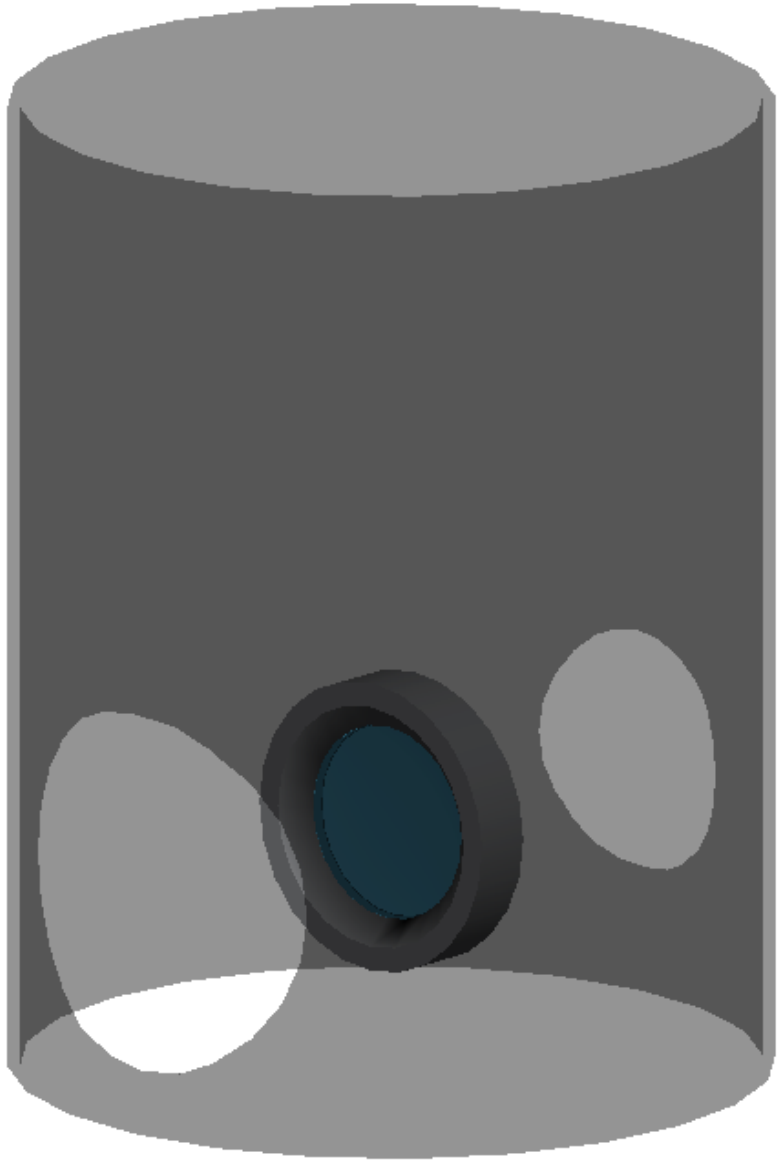
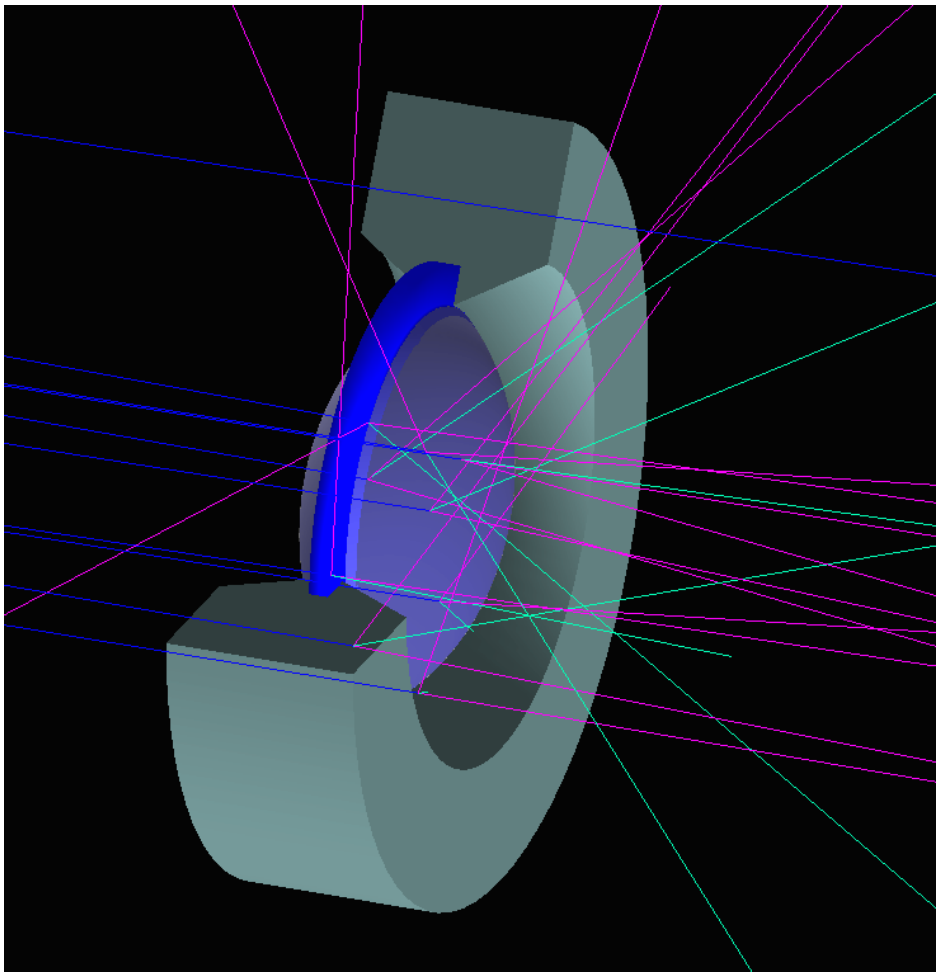
```

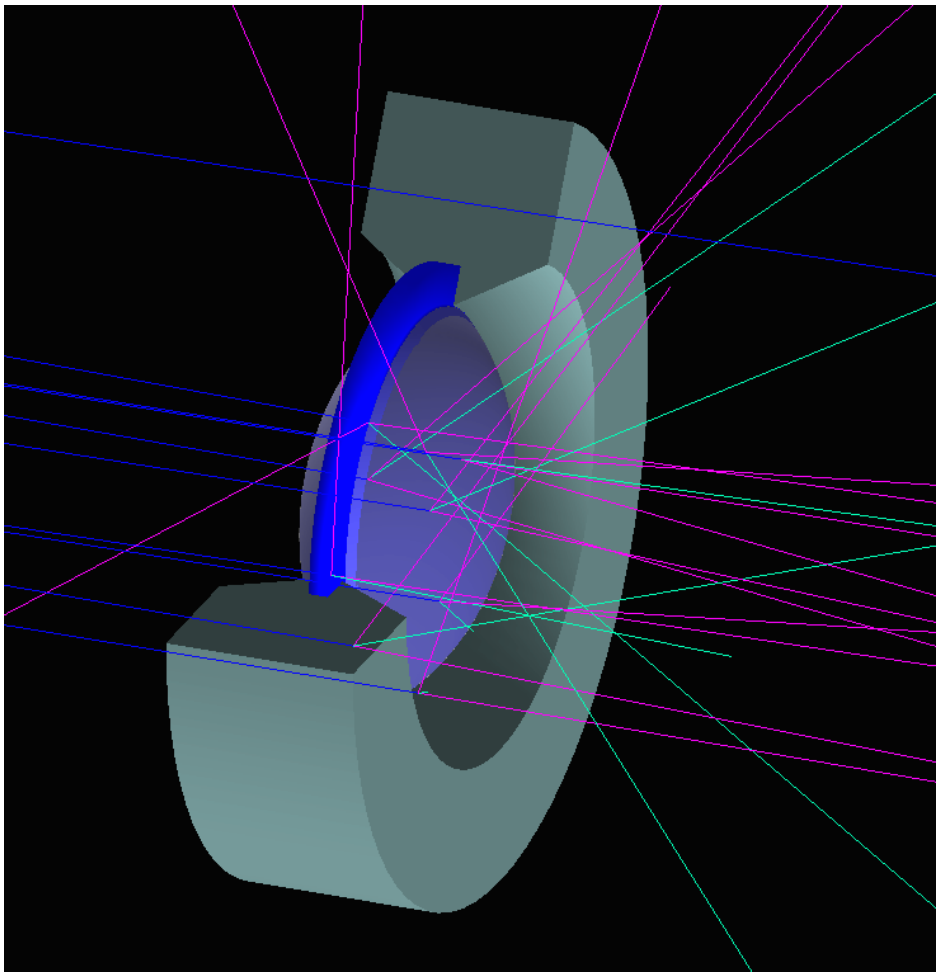
Simulation



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 $\otimes$ Target

Analysis

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

DSAM simulations

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
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DSAM target setup

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Target
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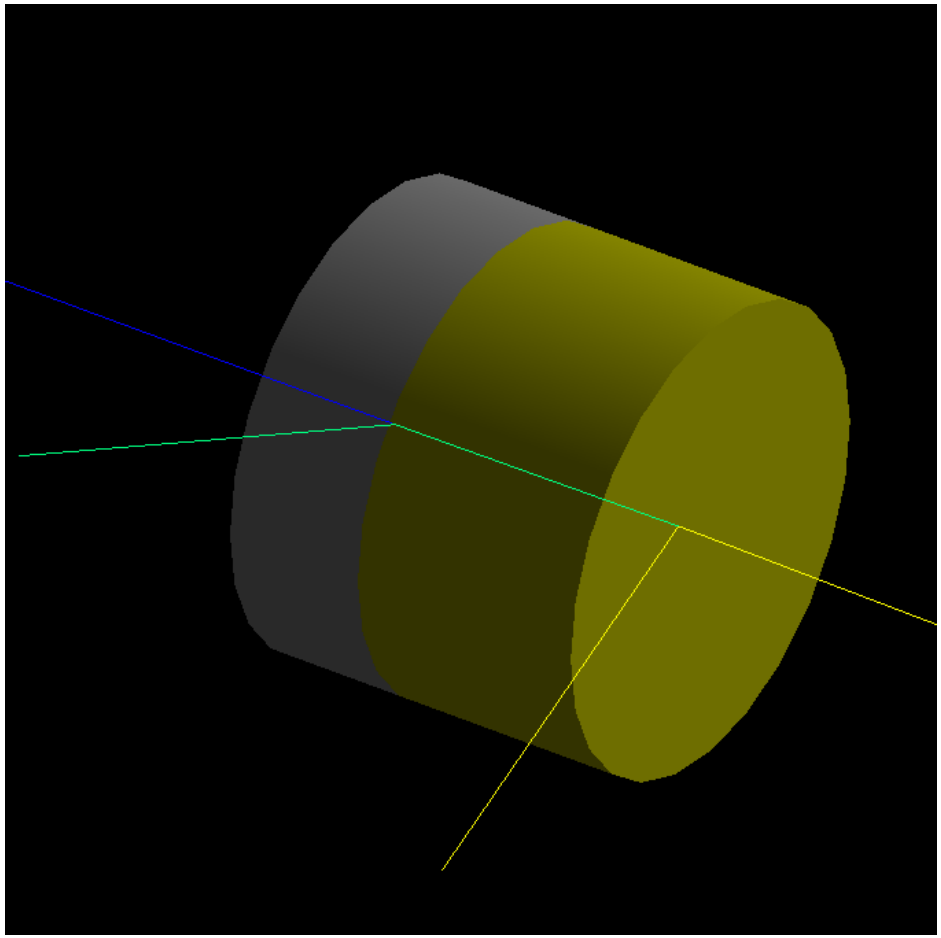
Target



DSAM target setup

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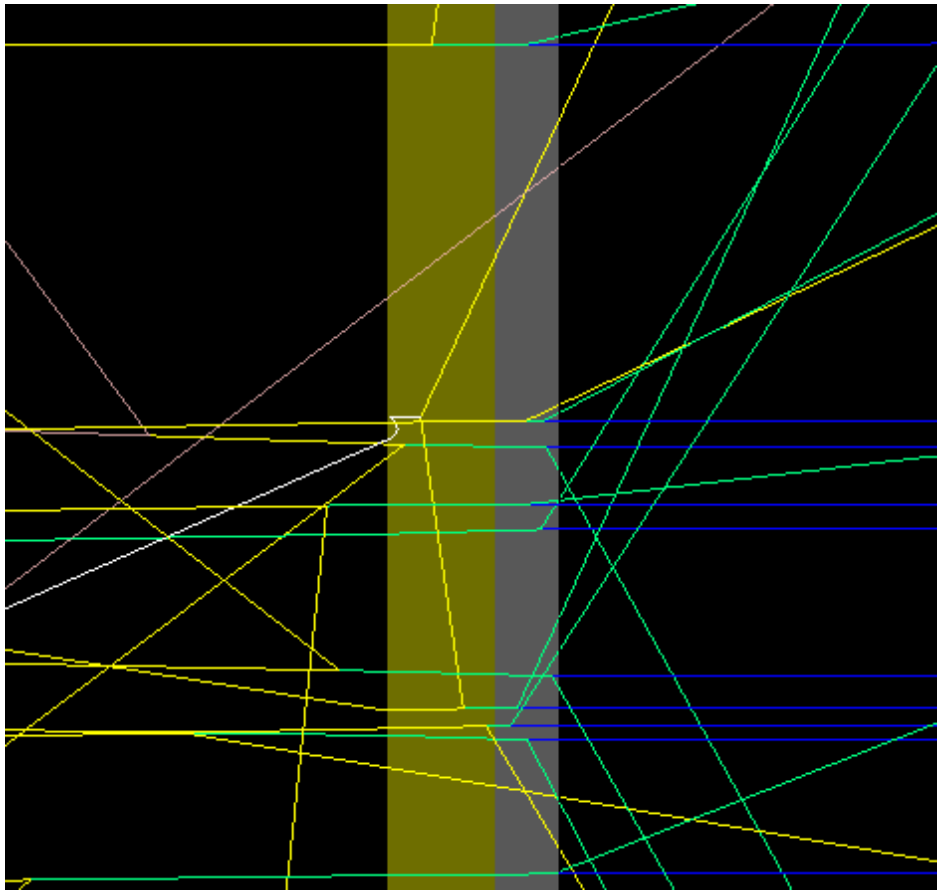
Target



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= 19O
  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= 19O
  Target= 2H
  Light= 1H
  Heavy= 20O
  ExcitationEnergyLight= 0.0 MeV
  ExcitationEnergyHeavy= 4.072 MeV
  CrossSectionPath= CS.txt CSR1
  ShootLight= 1
  ShootHeavy= 1
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
LevelData 20O
  Path= ./20O.level
```

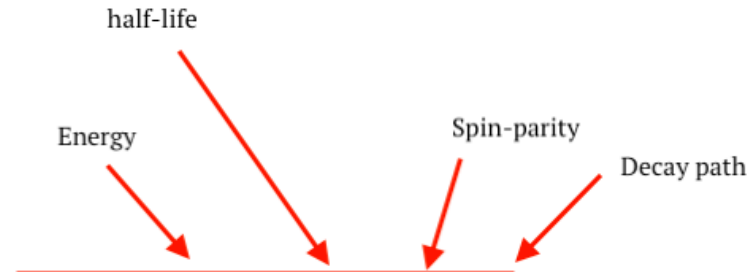
Event generator setup

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

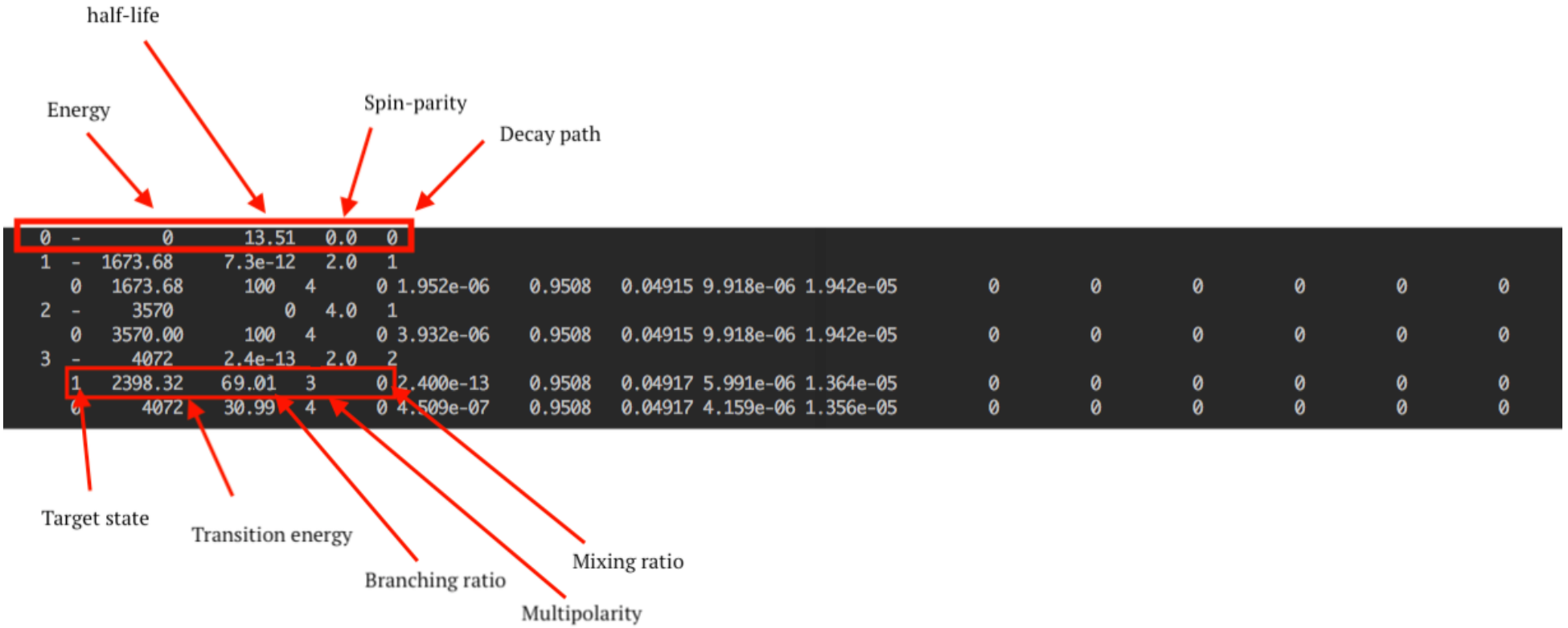
Geant4 Photon Evaporation file format → Defining State




```
 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
```

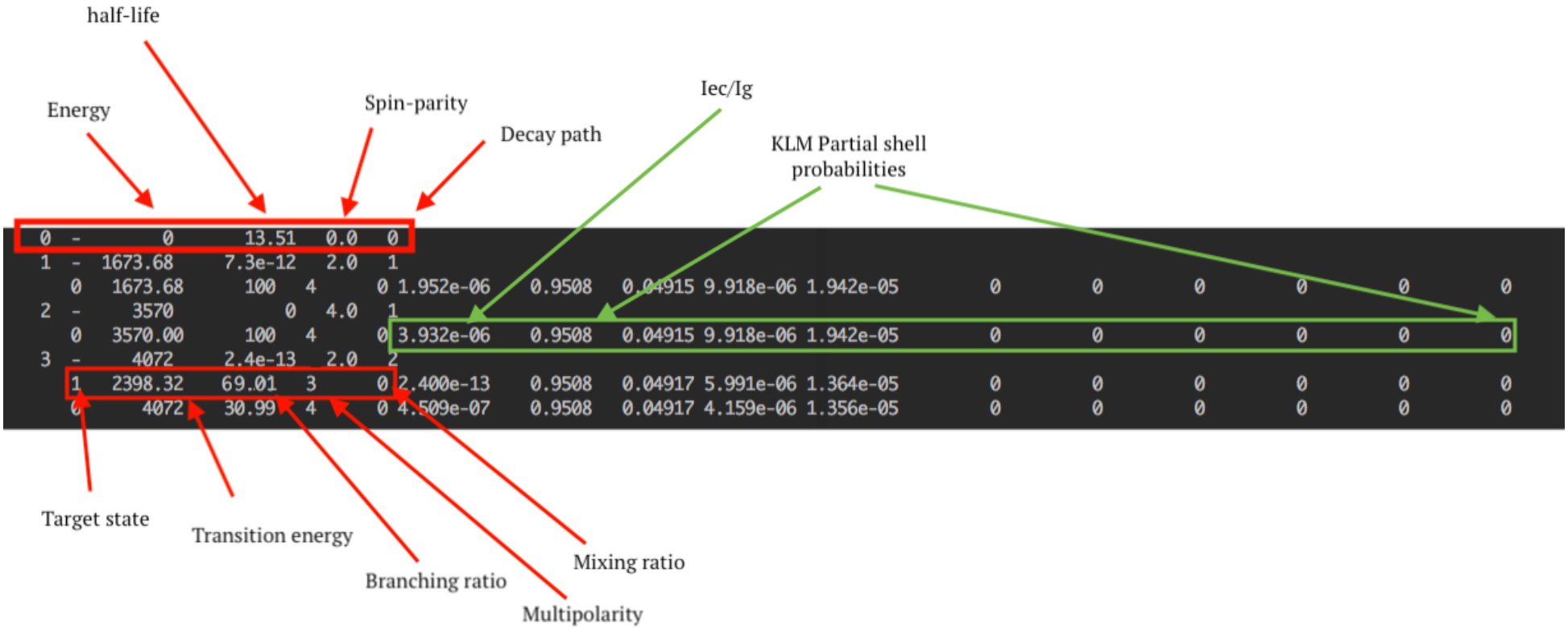
Event generator setup

Geant4 Photon Evaporation file format → Defining transition



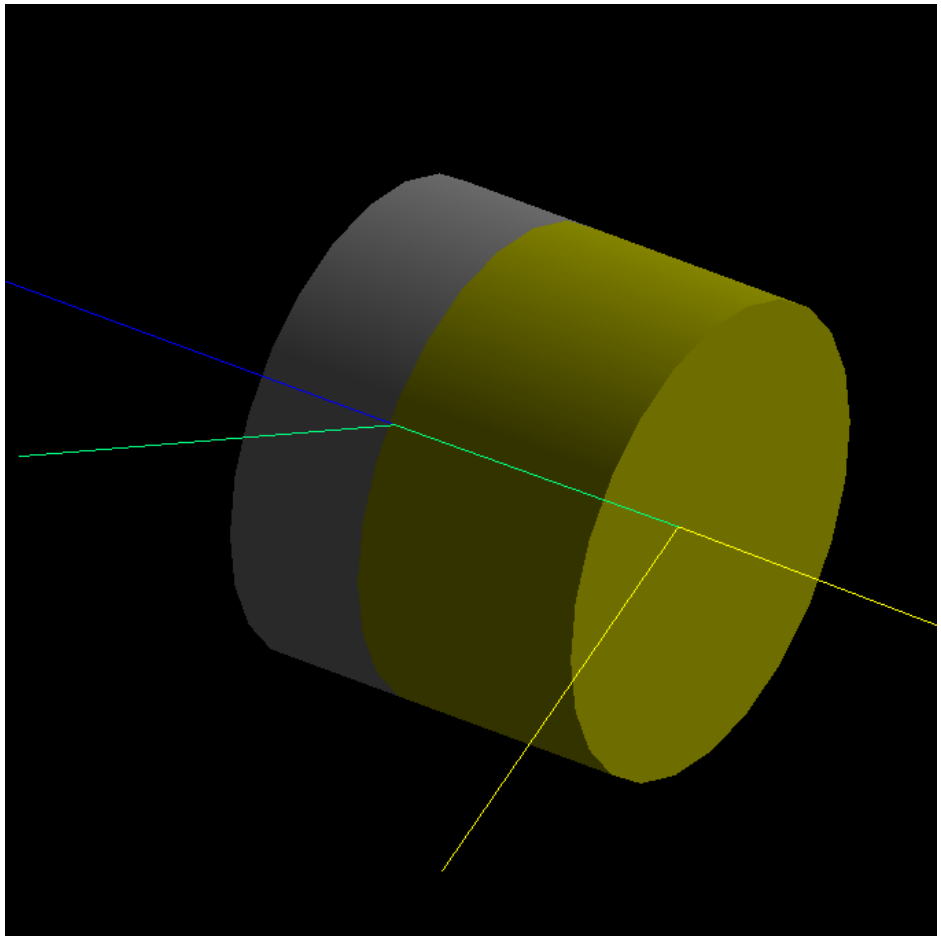
Event generator setup

Geant4 Photon Evaporation file format → Defining EC properties



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

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



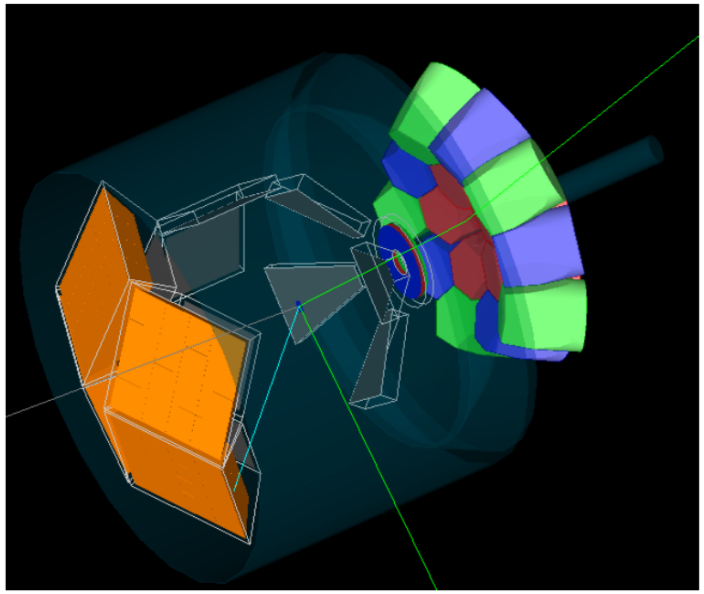
Conclusion

Recent features

- Simulation of DSAM/Plunger with direct reaction
- Cryogenic target simulation/analysis facilities
- Gaseous detector simulation/analysis facilities
- Quasi-Free Scattering (F. Flavigny)
- Int.Conv./EXOGAM (Goigoux/Vandebrouck)

Comming up for you

- **New website**
  - → Wordpress powered
  - → Better/More documentation
- **Docker image (CI/CD)**
  - → Running w/o installation
- GRIT detector
  - → re-work of GASPARD



UNIVERSITY OF SURREY

UNIVERSITY OF LIVERPOOL

Grand Accélérateur National d'Ions Lourds

GANIL

Laboratoire commun CEA / DSM - CNRS / IN²P³

NPL
National Physical Laboratory

Thank You

LUND UNIVERSITY

Science & Technology Facilities Council

Daresbury Laboratory