The prespec code and GSI data analysis

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EGAN Data Analysis School, Legnaro, October 1-3, 2014

Contents

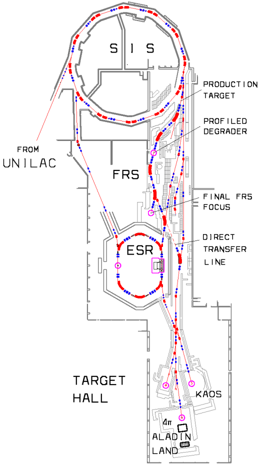
Contents

Contents

Contents

Contents

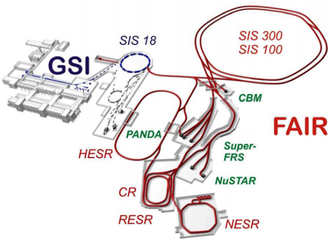
GSI Darmstadt



- Founded in 1969
- 1075 employees + PhD students
- Equipments:
  - UNILAC: Linear accelerator
  - SIS: Heavy ion synchrotron
  - ESR: Experimental Storage Ring
  - FRS: Fragment Separator
  - PHELIX: High energy laser
  - Biophysics
  - Participation in ALICE

www.gsi.de

The future FAIR facility



http://www.fair-center.eu

APPA Physics (Atomic, Plasma Physics and Applications)

- **BIOMAT** (**Bio**logy and **Mat**erial Science)
- **FLAIR** (**F**acility for **L**ow-Energy **A**ntiproton and Heavy **I**on **R**esearch)
- **HEDgeHOB** (**H**igh **E**nergy **D**ensity Matter **ge**nerated by **H**eavy i**O**n **B**eams)
- **SPARC** (**S**tored **P**articles **A**tomic **R**esearch **C**ollaboration)
- **WDM** (**W**arm **D**ense **M**atter) collaboration

Nuclear Matter Physics

- **CBM** (**C**ompressed **B**aryonic **M**atter) experiment

NUSTAR Physics (Nuclear Structure, Astrophysics and Reactions)

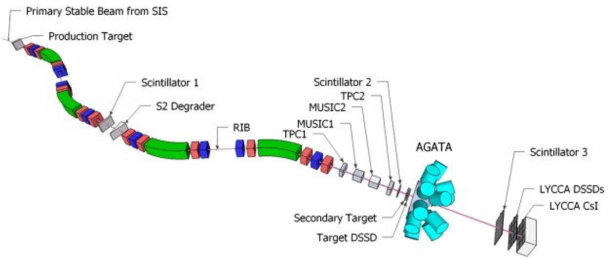
- **DESPEC/HISPEC** (**De**cay **Spec**troscopy/**Hi**gh-Resolution **Spec**troscopy)
- **ELISe** (**El**ectron-**I**on **S**cattering in a Storage Ring)
- **EXL** (**Ex**otic nuclei studied in **l**ight-ion induced reactions at the NESR storage ring) experiment
- **ILIMA** (**I**someric Beams, **Li**fetimes and **Ma**sses)
- **LaSpec** (**La**ser **Spec**troscopy)
- **MATS** (Precision **M**easurements of very short-lived nuclei with **A**dvanced **T**rapping **S**ystem)
- **R3B** (**R**eactions with **R**elativistic **R**adioactive **B**eams)
- **SuperFRS** (**Super F**ragment **S**eparator) project

Physics with High Energy Antiprotons

- **PANDA** (Antiproton **An**nihilation at **Da**rmstadt) experiment

Contents

The PreSPEC-AGATA setup

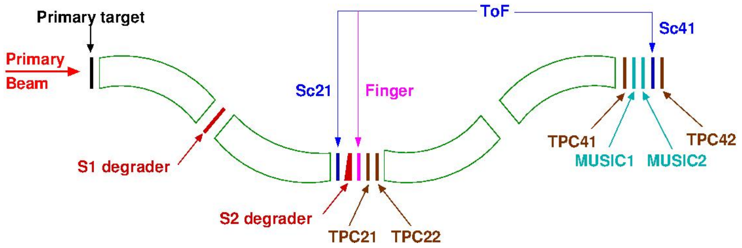


FRS
LYCCA
AGATA
HECTOR

N. Pietralla, et al., EPJ Web of Conferences 66, 02083 (2014)

C. Domingo-Pardo et al., NIM A 694, 297 (2012)

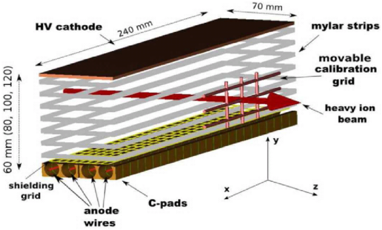
The FRagment Separator

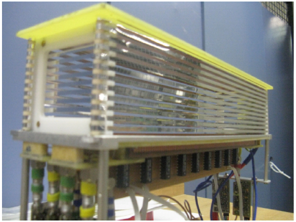


- Primary beam impinges on a primary target
- Use of $B\rho - \Delta E - B\rho$ technique
- Event-by-event measure of velocity, trajectory and energy-loss

http://www-wnt.gsi.de/frs/index.asp

FRS standard detectors

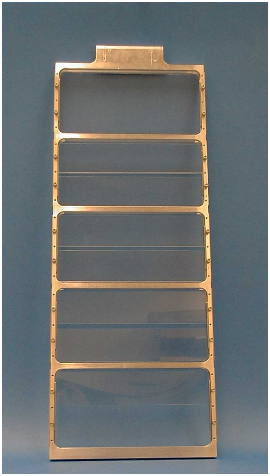




Time Projection Chambers

- Four x-positions and two y-positions
- Condition to get valid events: Checksums
- Calibration using a mask
- Efficiency decreases around 10^6pps

FRS standard detectors



Plastic scintillators

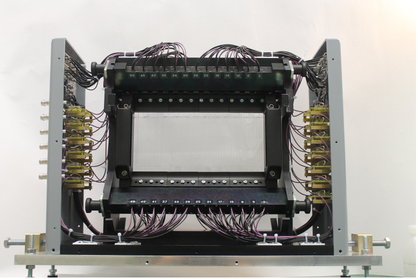
- Fast timing output
- Max. count rate: 10^6 pps
- Can also give position information
- Tof obtained from a TAC and a MhTDC
- Calibration runs needed

The Finger detector in 2012

- Strips of plastic scintillator
- 15 strips, 13 mm wide
- Gives time and position information
- Charge used to select the strip hit

F. Ameil et al., GSI Scientific Report 2011 (2012) 171

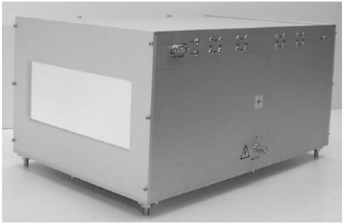
The Finger detector in 2014



- Strips of plastic scintillator
- 51 strips, 4.5 mm wide
- Gives better position resolution
- Time-over-threshold used to select the strip

M.L.Cortés, et al., GSI Scientific Report 2013 (In press)

FRS standard detectors



Multisampling ionization chambers

- Eight anodes per MUSIC
- Filled with gas at atmospheric pressure and room temperature
- Energy loss proportional to charge of the particle
- Pile-up can lead to wrong id

Incoming Particle Identification: Mass over charge ratio

$$\frac{A}{Q} = \frac{B\rho e}{u\gamma c\beta}$$

$$\rho = \rho_0 \frac{1-(x_2)}{D_{Ta-S2}} \qquad \rho = \rho_0 \frac{1-(x_4 - Mx_2)}{D_{S2-S4}}$$

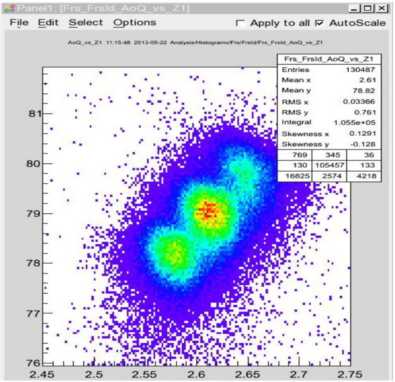
D→ Dispersion   M→ Magnification

- B: Magnetic fields
- β: velocity of the particle
- $\gamma = 1/\sqrt{1-\beta^2}$
- e: electron charge
- u: atomic mass unit
- c: speed of light

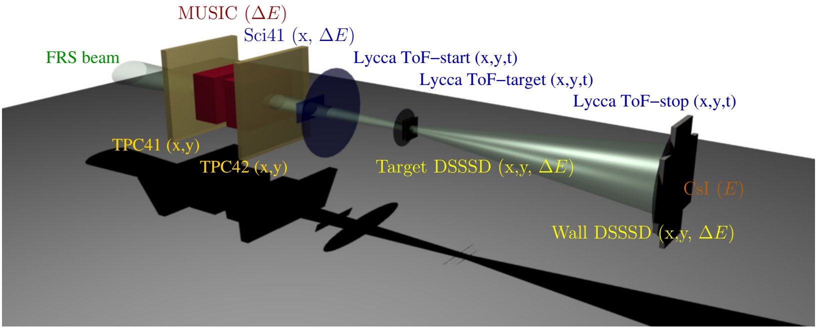
Incoming Particle Identification: Z

$$Z = Z_0\sqrt{\frac{\Delta E}{f(\beta)}}$$

- ΔE: Energy loss in the MUSICS
- $f(\beta)$: Function of the velocity. Usually quadratic
- Z_0: Atomic number of the beam used to calibrate



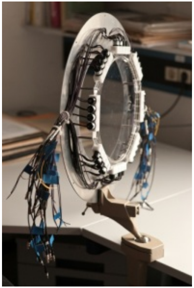
The LYCCA (+FRS) setup

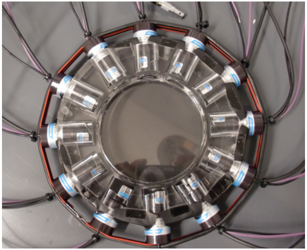


P. Golubev et al., Nucl. Instr. Meth. A 723, 55 (2013)

Time of Flight Detectors

- Two circular scintillators 27 cm Ø, 1 mm thick, 32 PMTs
- One circular scintillator 7.7 cm Ø, 0.5 mm thick, 12 PMTs
- Give timing and position information

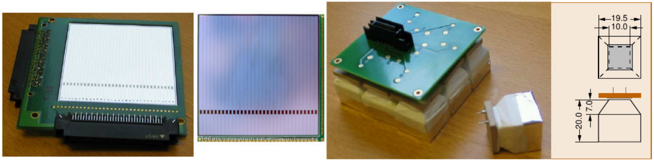




R.Hoischen, et al., NIM A 654 (2009) 354

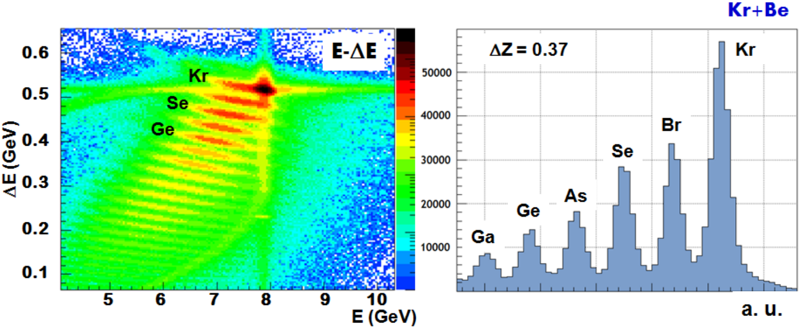
LYCCA Wall Modules

- DSSSD, 300 μm thick, with 32 strips on p- and n-side
- stripwise readout for the target DSSSD
- pairwise readout in the LYCCA wall modules
- 9 CsI scintillators read out with SiPM
- Module dimension 6 $\times$ 6 cm



D. Rudolph, et al., Technical Report, V1,2, June 2008

Outgoing Particle Identification: Z



P. P. Singh, et al., GSI Scientific Report 2012 (2013) 184

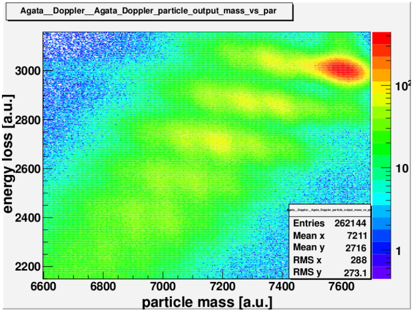
Outgoing Particle Identification: Mass

$$m\,c^2 = \frac{E_{\mathrm{kin}}}{\gamma - 1}$$

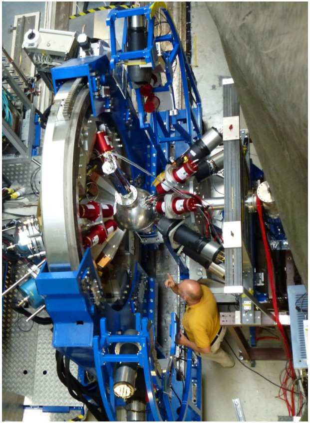
with $E_{\mathrm{kin}} = E_{\mathrm{CsI}} + \Delta E_{\mathrm{DSSSD}}$

and $\gamma = \frac{1}{\sqrt{1-\beta^2}}$

with β from LYCCA-ToF



The HECTOR array

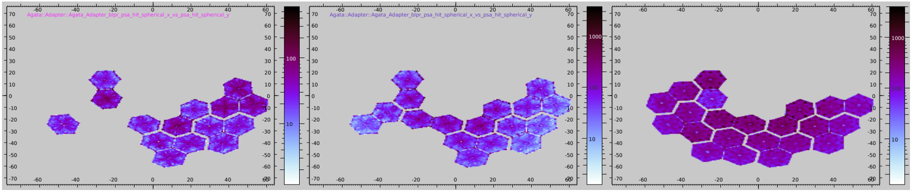


- HECTOR:
  - 8 Large volume BaF_2 detectors
    H= 17 cm, Ø= 14.5 cm
- HECTOR +
  - 2-8 Large volume $LaBr_3$:Ce detectors
    H= 20 cm, Ø= 9.5 cm
  - $\geq$ 1 medium volume $LaBr_3$:Ce detectors
    H= 7.5 cm, Ø= 7.5 cm

F. Camera, et al., EPJ Web of Conferences 66, 11008 (2014)

Geometry of AGATA@GSI

Increasing number of crystals



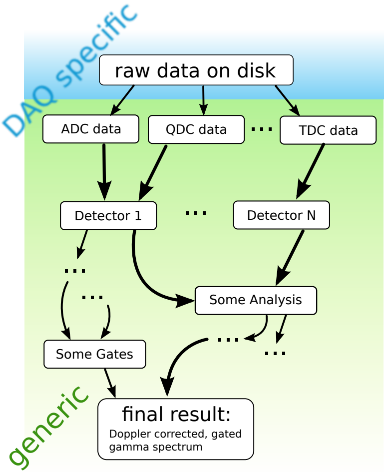
Perf. Commissioning November 2012 April 2014

Contents

Event-By-Event Data Analysis

Graph structure

- specific part:
  - data file → graph nodes
  - depends on the file format written by DAQ
- generic part:
  - directed, acyclic graph
  - data flow along edges
  - data processing inside nodes



Software for PreSPEC Data analysis

prespec package contains three parts:

- Tools that open/handle raw data files (.lmd, .adf)
  - Go4 plugin "Go4prespec" for PreSPEC data.
  - command-line tool "preplay"
- Framework that supports the creation of data analysis graphs
  - C++ base class for graph nodes ("Processor")
  - Script language to define graphs
- Libraries of processors for PreSPEC analysis
  - particle: FRS,LYCCA,FINGER
  - gamma: AGATA, HECTOR
  - utilities: UTILS

Get the package (password needed):

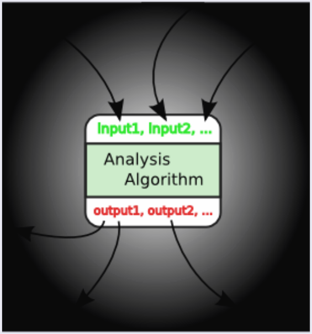
```
git clone agatagsi@lx-pool.gsi.de:git/prespec
```

Defining Algorithms

Algorithms are defined as C++ classes

Paradigm

- The implementation of an algorithms independent of its use: *"Black-Box Environment"*
- The algorithm designer specifies:
  - what kind of input is needed
  - what output is provided

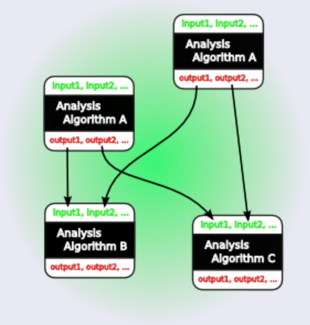


Using Algorithms

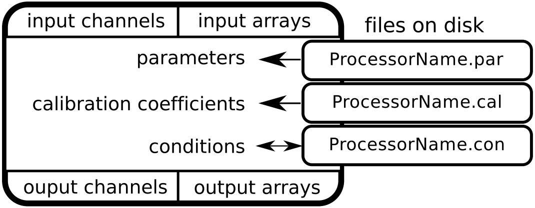
Data flow is defined using configuration (.config) scripts

Paradigm

- The data flow is independent of details in algorithms: *"Black-Box Graph-Nodes"*
- The user only needs to know:
  - what kind of input is needed
  - what output is provided
- Analysis is defined by composing nodes of **any number and type**



Graph Nodes for Data Processing



Processors (graph nodes) are C++ classes

- Header File serves as documentation of the interface
- Two methods need to be implemented
  - constructor
  - `process` method
- Processor can be organized in (shared) libraries

There is More:

Data visualization

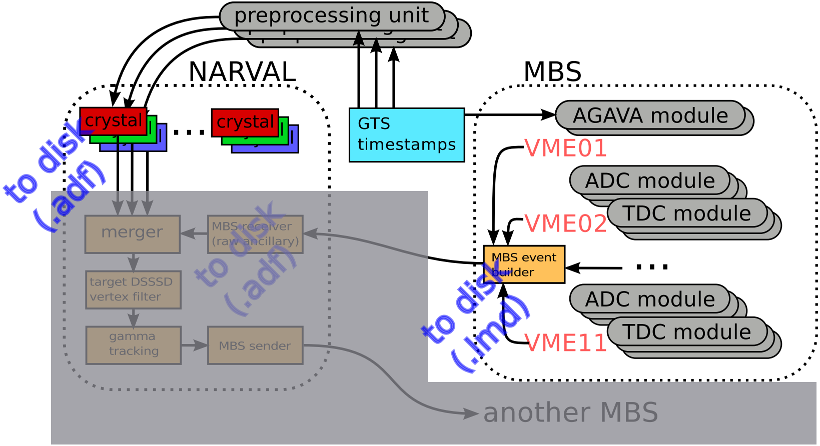
- Fast creation of histograms
- Correlation plots of two different values
- Correlation plots of two arrays in various ways
- Visualization of rates over time or rate ratios

Conditional data flow

- Processors for 1D/2D window/polygon conditions
- Enable/Disable processing by presence of signals
- Data passing only if condition is fulfilled

Contents

AGATA at GSI: Simplified Schematic Picture



Note: Boxes do not represent NARVAL actors but logical functional blocks

Agata Adapter

Inputs

- PSA frames $\{\mathrm{GTS}, E0, T0, E1, T1, \{x, y, z, e, t\}_{\mathrm{hit}}\}_{\mathrm{ID}}$
- Ingredients for particle-γ time difference:
  - GTS timestamp from AGAVA module
  - ΔT between AGAVA timestamp and Sci41
- additional particle-γ time and γ energy measurements

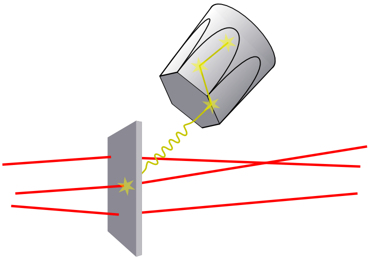
Most important outputs

- PSA hits: Energy and **position in FRS coordinate system**.
- Particle-γ time (low-gain/high-gain/additional)

Tracking

γ Tracking needs particle data

- γ-tracking requires source position, i.e. the particle position at the target
- Only possible after particle tracking analysis



Processors that use existing tracking libraries:

- Core/MGT/(OFT) Tracking processors are available
- MGT/OFT processor similar to MGT/OFT NARVAL actor
- Adding new/improved γ tracking codes is relatively simple

Doppler Correction

$$E_{\text{rest}} = E_{\text{lab}} \frac{1 - \beta \cos \vartheta_{\text{lab}}}{\sqrt{1 - \beta^2}}$$

- E_{lab} $\Rightarrow$ AGATA energy resolution.
- ϑ_{lab} $\Rightarrow$ particle tracking and PSA position resolution.
- $\beta = v/c$ $\Rightarrow$ LYCCA ToF resolution.

Processors for Doppler Correction

- correction based on all measured values
- beta scan (fixed, lycca factor, lycca offset)
- position scan (fixed, lycca factor, lycca offset)

S

A

C

A

R

G

GRACIAS