AGATA Pulse Shape Analysis Implementation

- Status
- Performance
- Opportunities

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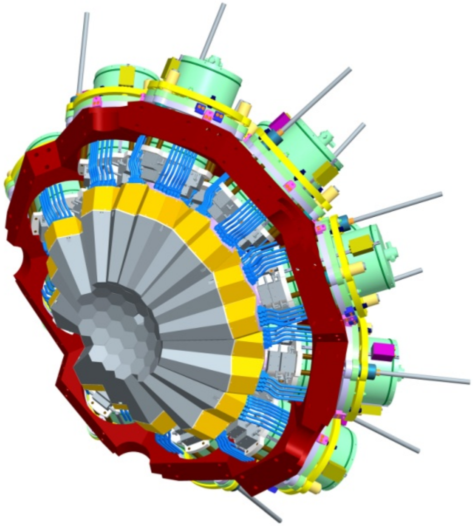
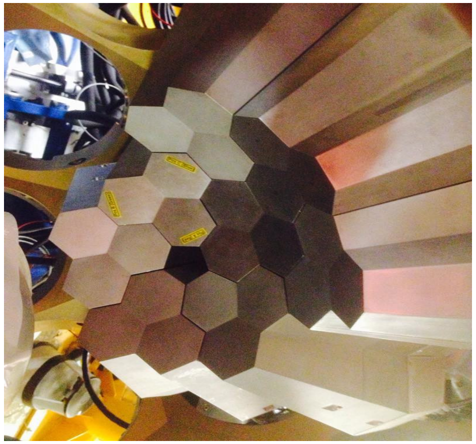
The AGATA PSA team

AGATA
ADVANCED GAMMA TRACKING ARRAY

AGATA PSA Implementation

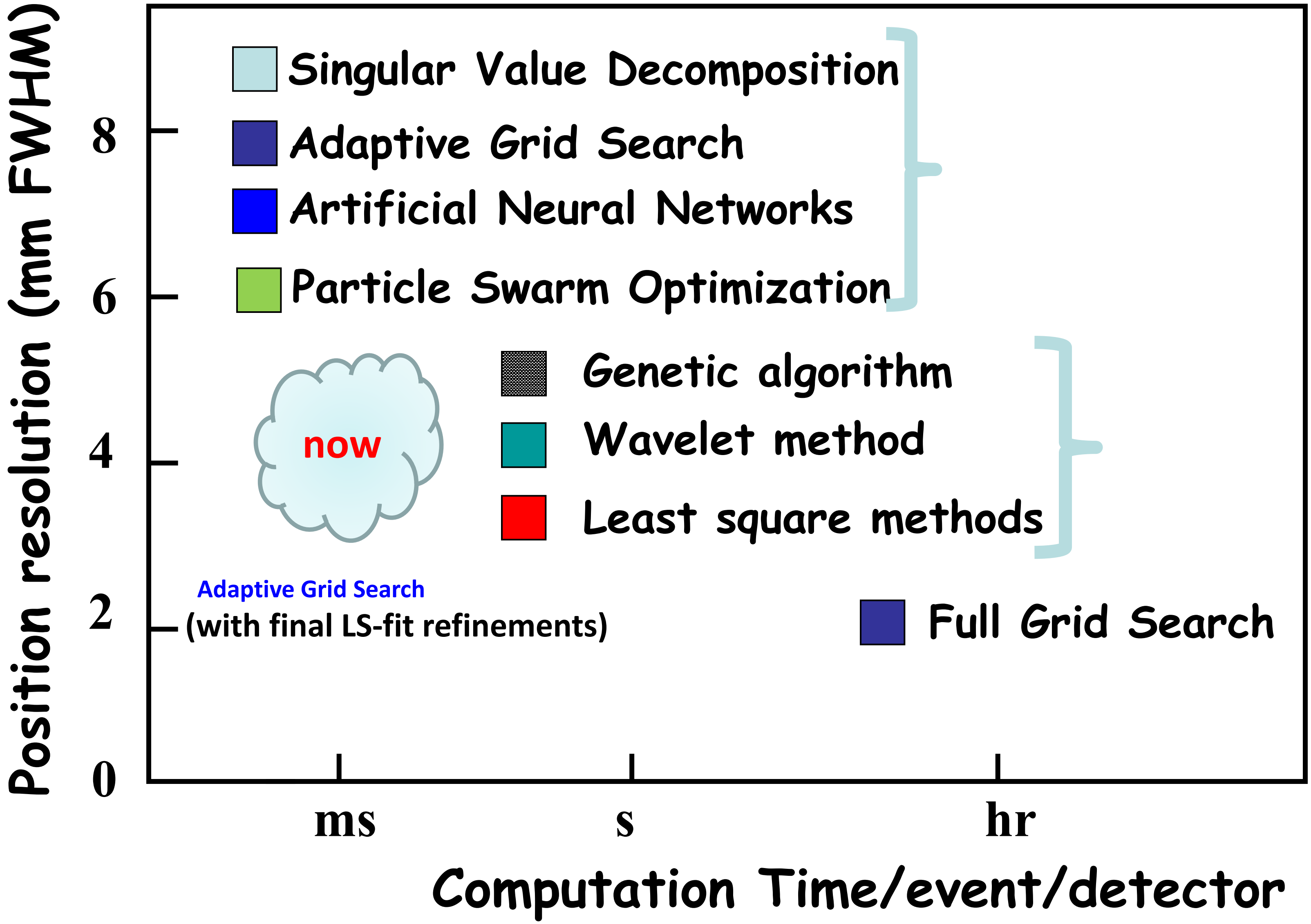
- Algorithms
- Implementation
  - ADL
  - Experimental basis
- Performance





PSA ALGORITHMS

Pulse Shape Analysis algorithms



AGATA PSA Codes

- **Typical PSA scheme consists of 3 components**
- **Figure of Merit (FOM) e.g.** $\Sigma\ |event1_i - event2_i|^n$
- **Search Routine: optimization of FOM over library**
  - Adaptive Grid Search (A. Venturelli, INFN Padova)
  - Particle Swarm Optimization (M. Schlarb, TU Munich)
- **Decomposition strategy for multiple interactions**
  - assuming maximum 1 hit per segment
  - segments influenced by multiple hits excluded

AGATA PSA Codes

Other PSA schemes

- Matrix method (A. Olariu, P. Desesquelles, CSNSM Orsay)

Partial PSA

- Recursive Substraction algorithm (Fabio Crespi, INFN Milan)
  - Gets radial coordinates & # interactions (~ steepest slope)

Practical PSA Challenges

- A basis calculated on a 1 mm grid contains ~ 400000 points, each one composed by 37 signals each one with > 50 samples (for a 10 ns time step)
- Direct comparison of the experimental event to such a basis takes too much time for real time operation at kHz rate
- Events with more than one hit in a segment are common, often difficult to identify and difficult to analyse

PSA IMPLEMENTATION

PSA Implementation

- **The signal decomposition algorithm (AGS)**
- **The quality of the signal basis**
  - Physics of the detector
  - Impurity profile
  - Application of the detector response function to the calculated signals
- **The preparation of the data**
  - Energy calibration
  - Cross-talk correction (applied to the signals or to the basis!)
  - Time aligment of traces
- **A well working decomposition has additional benefits, e.g.**
  - Correction of energy losses due to neutron damage

The Grid Search algorithm

- Signal decomposition assumes one interaction per segment
- The decomposition uses the transients and a differentiated version of the net charge pulse
- Proportional and differential cross-talk are included using the xTalk coefficients of the preprocessing.
- The minimum energy of the “hit” segments is a parameter in the PreprocessingFilter → 10 keV
- No limit to the number of fired segments (i.e. up to 36)

The Grid Search algorithm

- The algorithm cycles through the segments in order of decreasing energy;
  the result of the decomposition is removed from the remaining signal
  -> subtraction method at detector level

- Presently using ADL with the neutron-damage correction model

- Using 2 mm grids -> ~48000 grid points in a crystal; 700-2000 points/segments
- Speed is ~ 150 events/s/core for the Full Grid Search
  ~ 1000 events/s/core for the Adaptive Grid

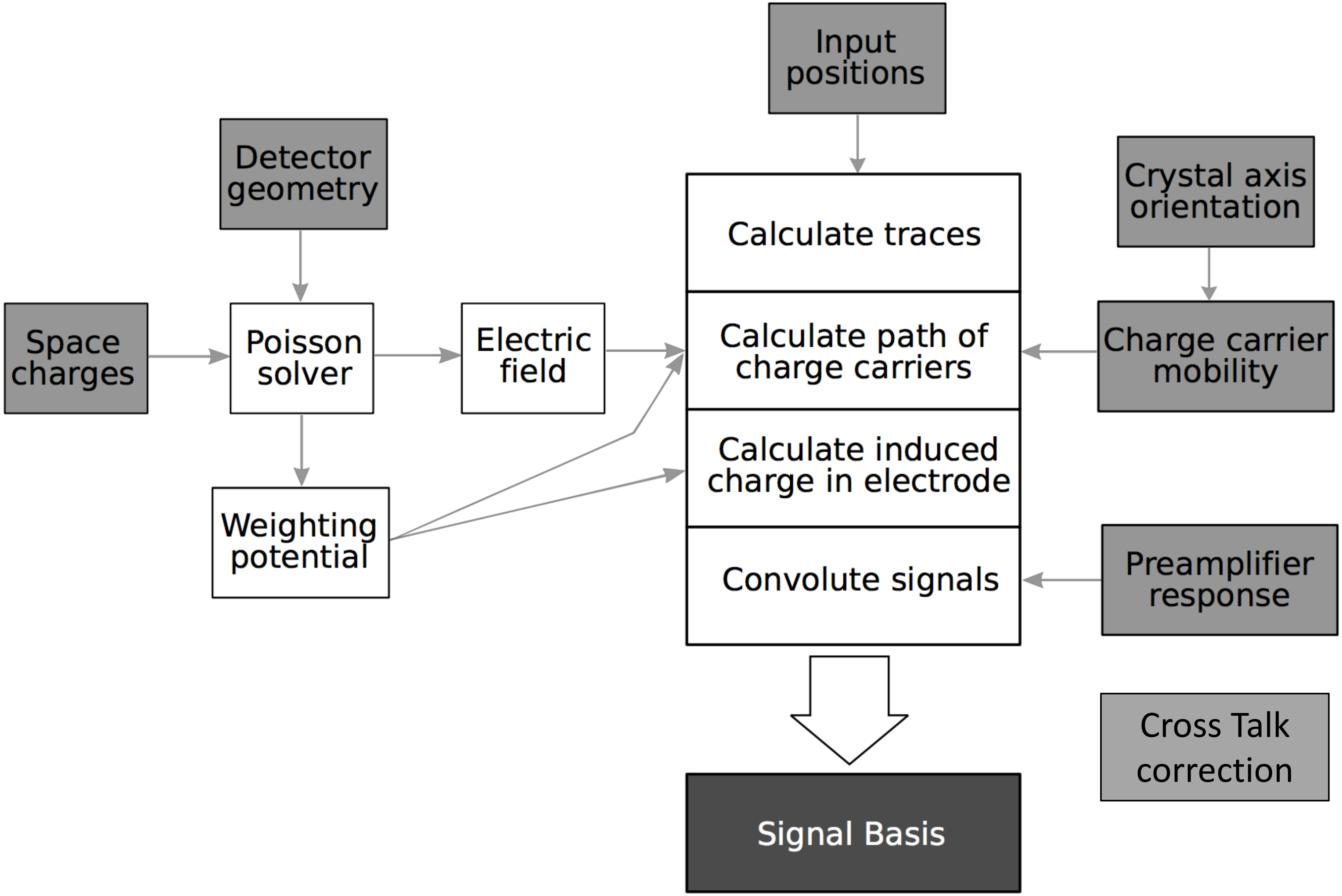
Signal basis generation

- Simulation: MGS, JASS, **ADL**
- Experimental: Coincidence, PSCS

- AGATA Data Library
  - Geometries for a wide variety of detectors
  - E-field solver, SIMION potential arrays
  - Creates the calculated basis for each detector

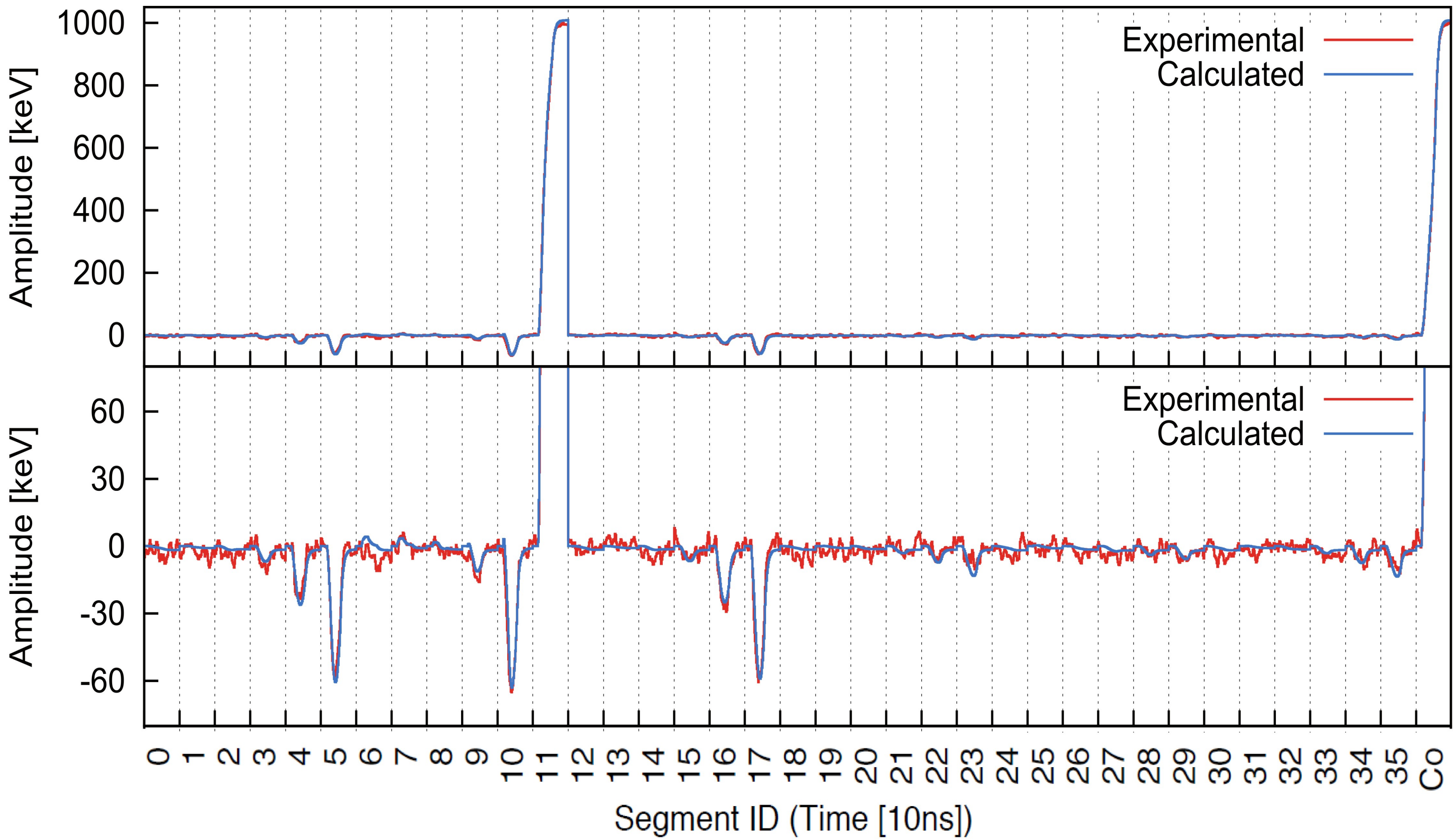
Bart Bruyneel and Benedikt Birkenbach IKP (Eur. Phys. J. A (2016) 52: 70)

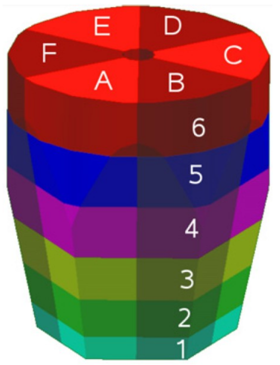
AGATA Data Library



PSA PERFORMANCE

Grid search algorithm result





AGATA-GRETINA Workshop on Data Analysis -> PSA perspective

- Meeting held in ANL December 2016
- Organised by A. Korichi and T. Lauritsen
- Broad range of talks focusing on PSA, Tracking and Data Analysis

- Performance of GRETINA PSA code and AGATA PSA code remarkably similar

- What is the reason for the observed performance?

https://indico.in2p3.fr/event/13409/other-view?view=standard

GRETINA Decomposition Basis

Courtesy David Radford

- Signal decomposition algorithm appears to work very well
  - Validated using simulated signals
- Most issues with the decomposition results appear to come from the fidelity of the signal basis
- Poor fidelity results in
  - Too many fitted interactions
  - Incorrect positions and energies
- Already included
  - Integral cross-talk
  - Differential cross-talk
  - Preamplifier rise-time
  - Differential cross-talk signals look like image charges, so they strongly affect position determination

Factors influencing performance

- Field and Weighting Potential:
  - Overall impurity concentration
  - Longitudinal impurity gradient (Linear? Nonlinear?)
  - Radial impurity gradient?
  - Hole diameter; hole depth; etching cycles; lithium thicknes
  - Neutron damage (p-type)
- Charge carrier mobilities as a function of electric field

Factors influencing performance

- Crystal axis orientation (~ 5 degrees from maker)
- Crystal temperature
- Cross-talk (differential and integral)
- Neutron damage (trapping)
- Impulse response of 37 preamps
- Charge cloud size
- Digitizer nonlinearity

What can be done?

- Extra timing information to constrain t_0
  - External fast detectors or RF signal
  - Ge-Ge coincidences - Requires event building prior to decomposition; hard
- Further improvements in basis fidelity
  - Preamplifier impulse response function
  - Include charge cloud size and charge-sharing in signal generation
    - Especially important at small radius, near segment boundaries
    - But energy-dependent?
- Better field determination
  - Segment capacitance measurements as a function of bias

PSA tasks going forward

- Pristine basis generation with irregular basis using SIG-GEN
- Optimised basis with experimental corrections (from ^{60}Co flood data)
- Development of an integrated data set of two interactions/segment using collimated scanning data
- Development of an integrated data set of two interactions/segment using collimated scanning data from AGATA digitisers

PSA tasks going forward

- Implementation of multiple interaction algorithm for testing in beam
- Inclusion of positon uncertainties in PSA output
- Including regular/irregular basis and ADL/SIG-GEN
- Multiple interaction algorithm implementation
- Tracking: use of uncertainties propagated from PSA

Summary… Lots of opportunities

- In beam use AGS algorithm (Narval implemented)
- Offline have AGS and Particle Swarm (Narval emulator implemented)
- Continuous improvement of signal basis
- Push towards experimental basis generation
- Implementation of multiple segment interaction algorithm

- **Challenges:**
  - Availability of AGATA capsules for characterisation
  - Clustering of points distributed inside detectors
  - Continuity of available personnel to implement PSA algorithms
  - Documentation + Howto guide
- **This work is a big effort from a large number of people.. Thanks to all.**

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AGATA PSA and Data Analysis Schools and WS

- **The Schools and Workshops:**
  - Liverpool 2011 (EGAN)
  - GSI 2012 (EGAN)
  - LNL 2013 (EGAN)
  - GANIL 2016
  - GANIL 2018
- **The teams within the WG aim to have (at least) quarterly team meetings.**