Simulations of PRESPEC Plunger experiments

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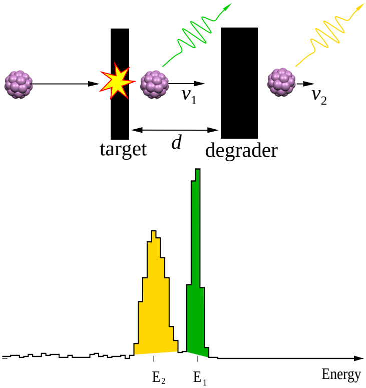
Outline:

- Lifetime measurements with radioactive beams
- Simulation details
- Comparison with data
- Some examples
- Future improvements

Lifetime Measurements with Exotic Beams



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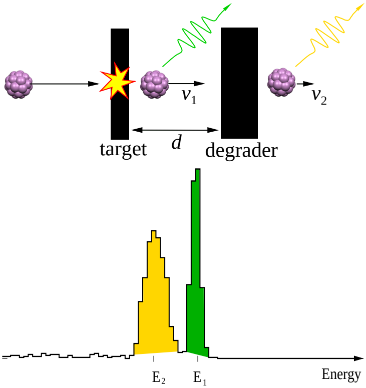

Doppler shift method for lifetime measurements (Plunger Method)

- Important tool for nuclear structure investigation
- Model independent lifetimes
- Many future experiments will use this technique

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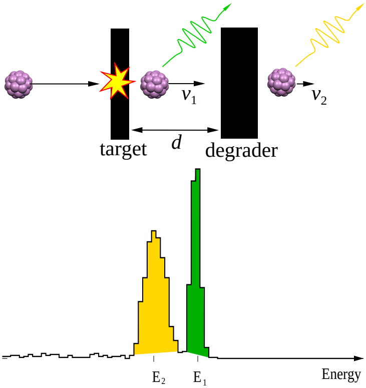

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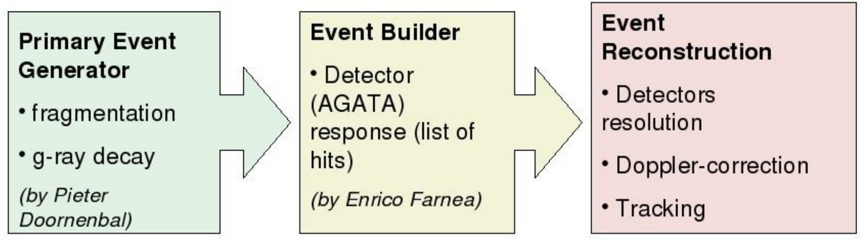
PRESPEC plunger experiments

- Fast beams: v/c several 10%
- Thick target and degrader
- Broad beams: FWHM are several cm in x- and y-direction
- Low event rate (compared to stable beam facilities)

Changes to the existing Simulation System



[C. Domingo Pardo]

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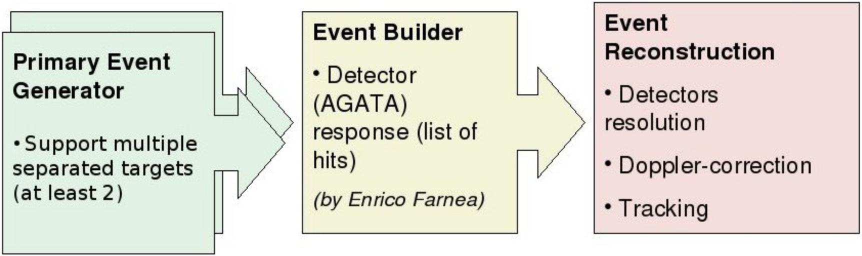

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Simulation of plunger experiments requires a different Primary Event Generator

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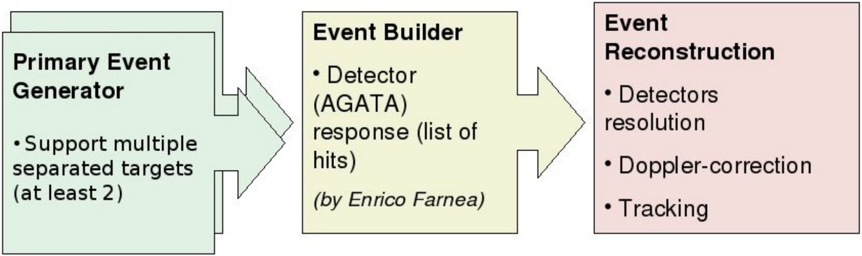

[C. Domingo Pardo]

Simulation of plunger experiments requires a different Primary Event Generator

Current version of the Plunger Primary Event Generator

- New code
- Fits into the existing framework
- Supports an arbitrary number of separated target layers

Simulation Details

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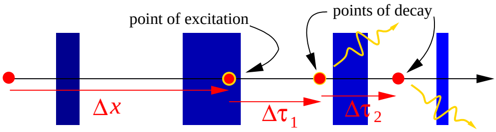

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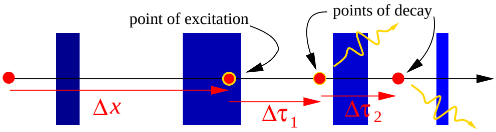

For every primary

- Choose reaction point
- Integrate Bethe-Bloch formula (in space)
- Reaction kinematics and ejectile excitation

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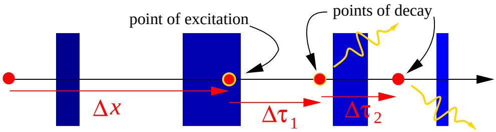

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- Emit gamma (write input file for AGATA code)

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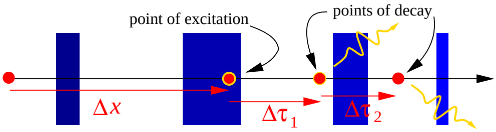

Bethe-Bloch Formula

At high energy: reasonable approximation

$$\frac{\mathrm{d}E}{\mathrm{d}x}(\beta) \sim n\, Z_p^2$$

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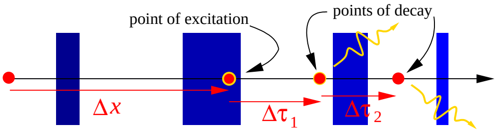

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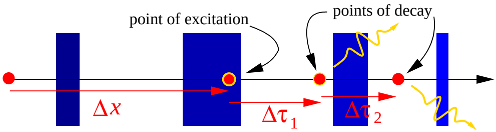

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Propagate in proper time of projectile

$$\frac{\mathrm{d}\beta}{\mathrm{d}\tau} = \frac{\mathrm{d}E}{\mathrm{d}x}\frac{\mathrm{d}\beta}{\mathrm{d}E}\frac{\mathrm{d}x}{\mathrm{d}\tau}$$

$$\frac{\mathrm{d}x}{\mathrm{d}\tau} = \gamma\beta c$$

Example Input

```
# all length in micometers
# Layer: A Z density(in g/cm^3)   thickness(in um)  cross_section
# A = Z = 1 and density = 0 means vacuum

Layer:  93 41  8.57  108.0   80.0 C # target
Layer:   1  1    0   2000.0    0.0 C # vacuum
Layer:  12  6  1.85  803.0    0.0 C # degrader 1
Layer:   1  1    0   3000.0    0.0 C # vacuum
Layer:  12  6  1.85  400.0    0.0 C # degrader 2

Ap: 110     # projectile mass
Zp:  46     # projectile charge number

E0:     80.0 # initial projectile energy (in MeV/A)
deltaE:  1.0 # variance of initial projectile energy (in MeV/A)

Ae: 110     # ejectile mass
Ze:  46     # ejectile charge number
Bn:   8.0   # binding energy in MeV/u

decay_filename: decay

x0: 0.0         # primary beam position
deltax: 30000   # and variance in x-direction (in um)
y0: 0.0         # primary beam position
deltay: 30000   # and variance in y-direction (in um)
```

Comparison with NSCL Plunger Simulation
^{110}Pd Coulomb excitation

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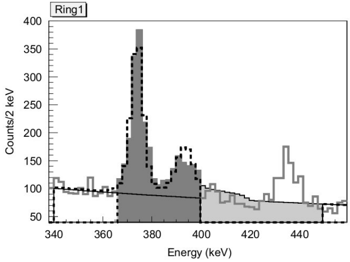
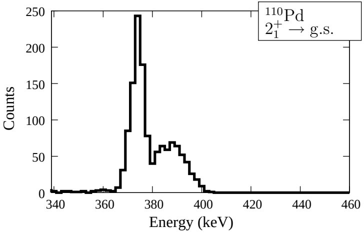
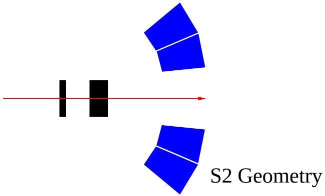




from [P. Adrich et al., Nucl. Instr. and Meth. A **598** (2009) 454]

- 65.8 MeV/u ^{110}Pd beam
- 108μm thick ^{93}Nb target
- 503μm thick ^{12}C degrader
- $\tau_{2_1^+} = 67.1$ps
- $E_{2_1^+} = 373.8$keV
- Coulomb excitation in target and degrader



Different Distances and Doppler Correction
^{110}Pd Coulomb excitation

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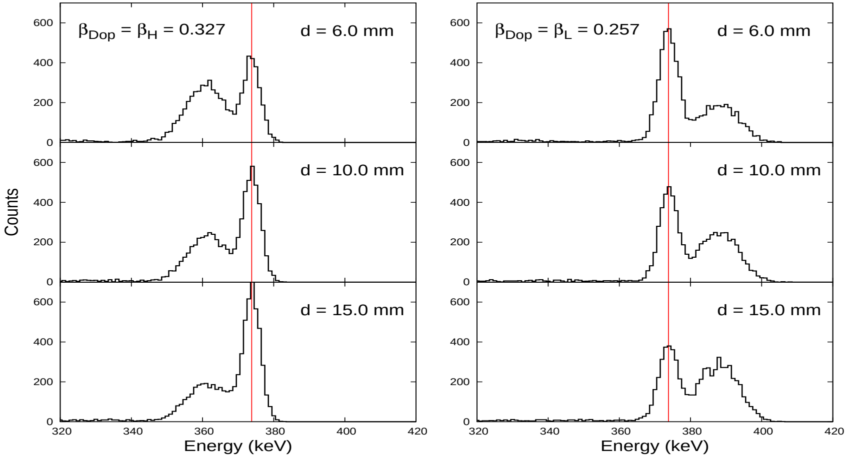

Plunger Data Analysis
Example with 2 Degrader Foils

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Different kinds of plunger data analysis

- Differential Decay Curve (DDC) Method
- τ dependant line shape or simulation $\longrightarrow$ fit τ
- Target with 2 degrader foils (Differential Plunger)
  [Dewald et al, Z. Phys. A **334** 163 (1989)]

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Example setup

- 65.8 MeV ^{110}Pd beam, Coulomb excitation
- 108μm thick ^{93}Nb target
- 800μm thick ^{12}C degrader
- 400μm thick ^{12}C second degrader
- $d_1 = 2.0$mm , $d_2 = 3.0$mm
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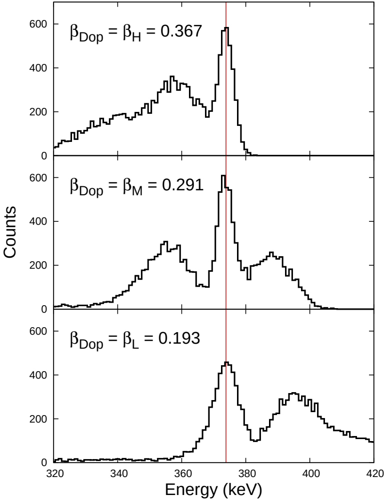

Outlook and Remarks on Geant4

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- Implement particle straggling
- Add more types of reactions
- Consider using Geant4

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Geant4 is a framework for Monte-Carlo particle tracking

- Handles properly any geometry, tracking and production of secondarys
- Interesting for nuclear physics simulations: Geant4 version 9.3 has ICRU'73 based stopping model for ions with $0.025\mathrm{MeV/u} < T < 1\mathrm{GeV/u}$

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- No model for nuclear excitation processes (Coulomb excitation, fusion, transfer)
- Geant4 gets interesting with increasing number simulation details

Summary

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- Implementation and test of new event generator for PRESPEC plunger simulations
- Possibilities of the software
- Further development (Geant4)

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Thank you for your attention!