High-Precision Tracking Algorithm for Mass Reconstruction of Heavy Fragments in R3B Experiment at FAIR

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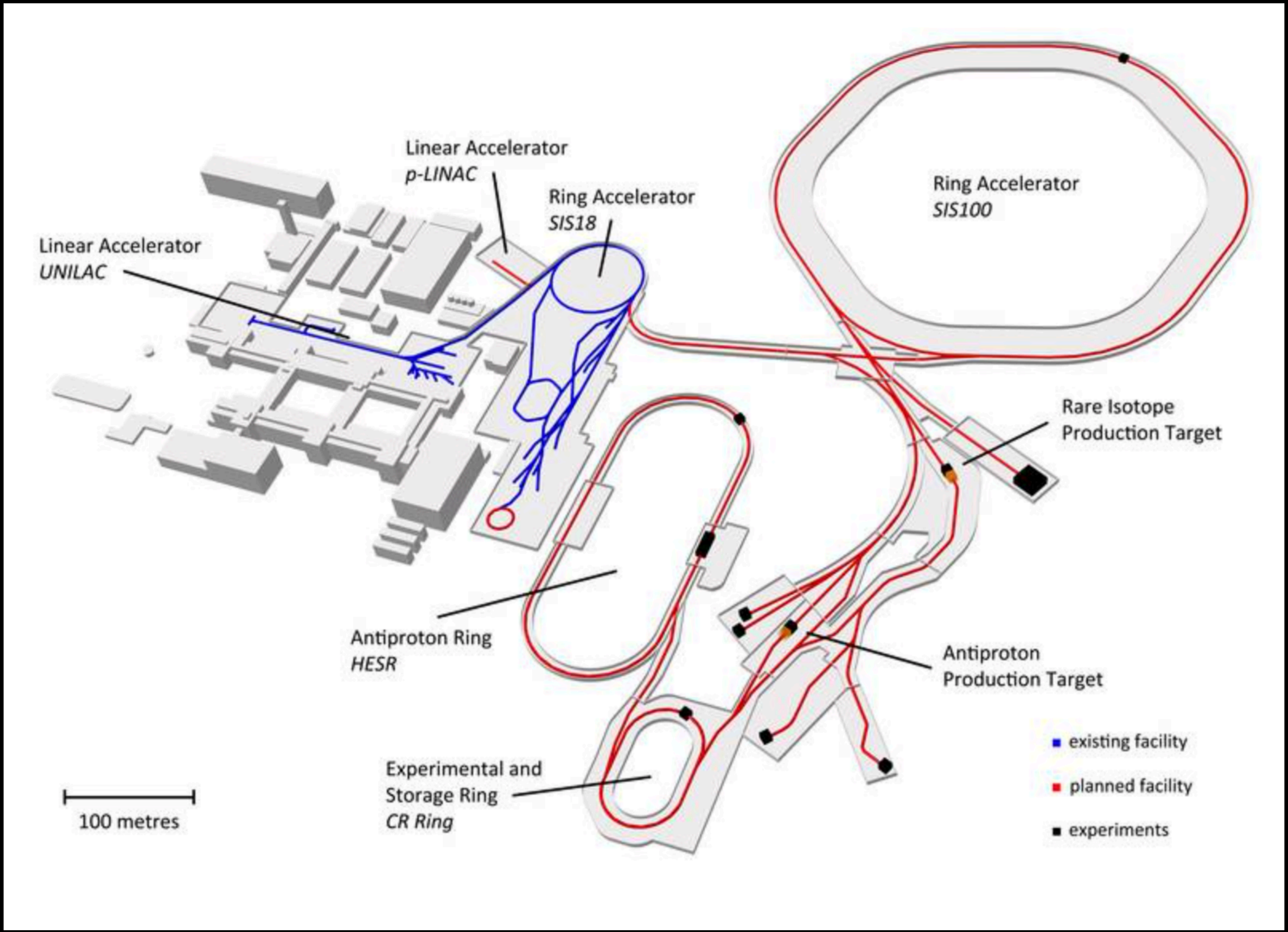
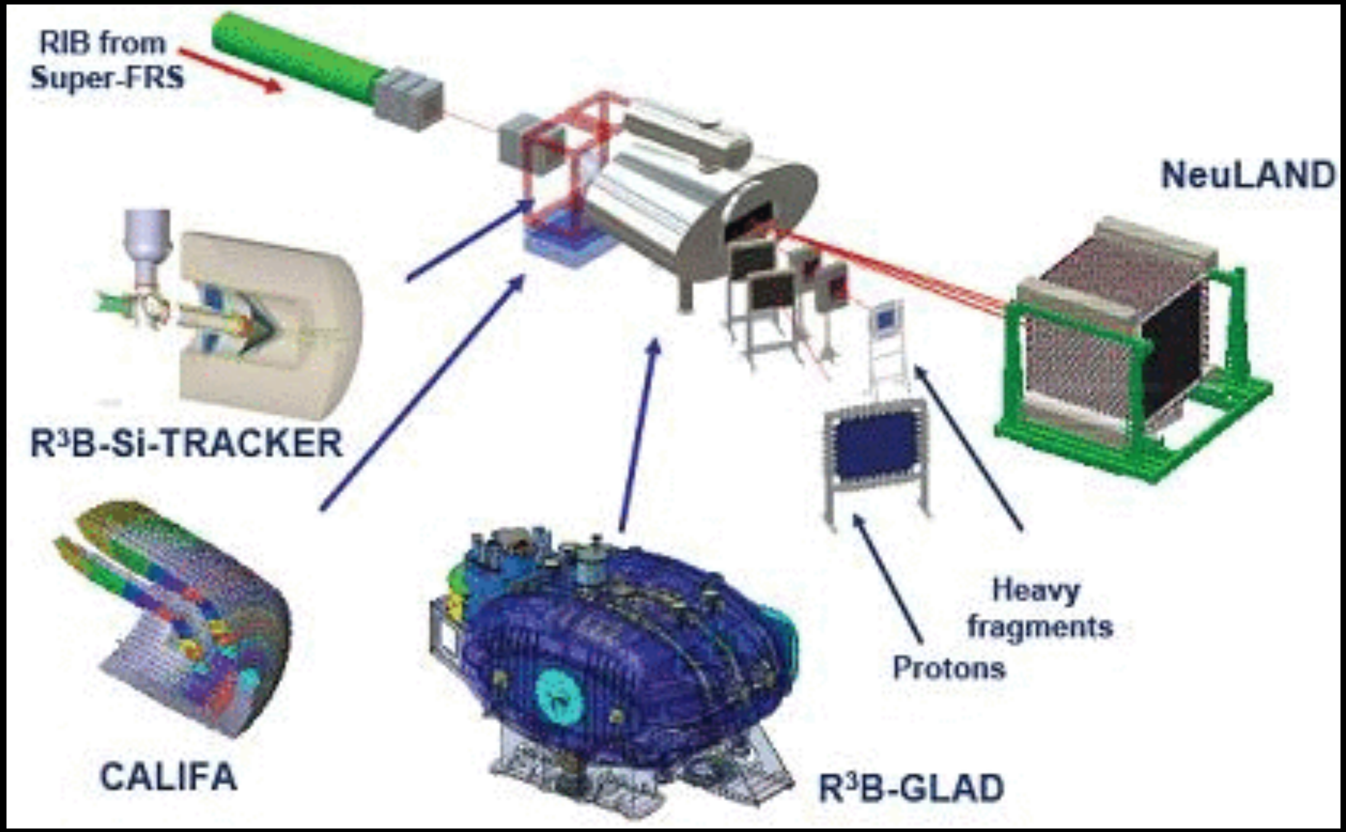


Construction site
April 2018

Reactions with Relativistic Radioactive Beams - R3B

http://www.gsi.de/r3b



- Properties of exotic nuclei far off stability
- Study nuclear structure and dynamics
- Astrophysical aspects
- Technical applications

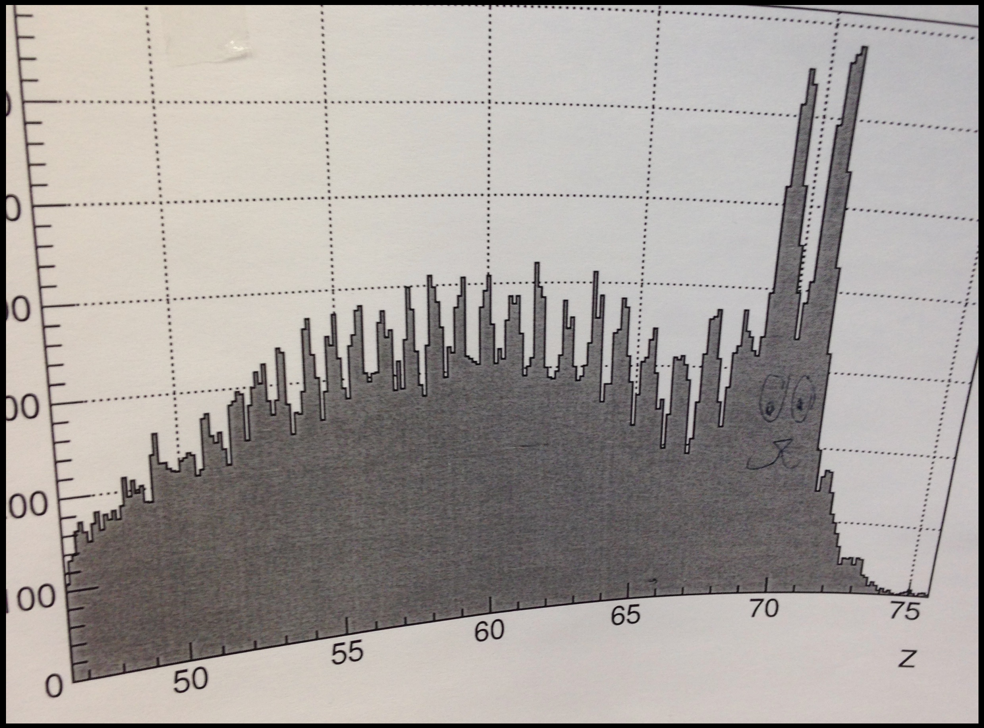
Fragment tracking arm

Measurement of the whole final state is needed to reconstruct the properties of a reaction: neutrons, protons, reaction fragment

Small effects in transversal relative energy on top of Lorentz boost

Momentum resolution in the order of 10^{-3} required

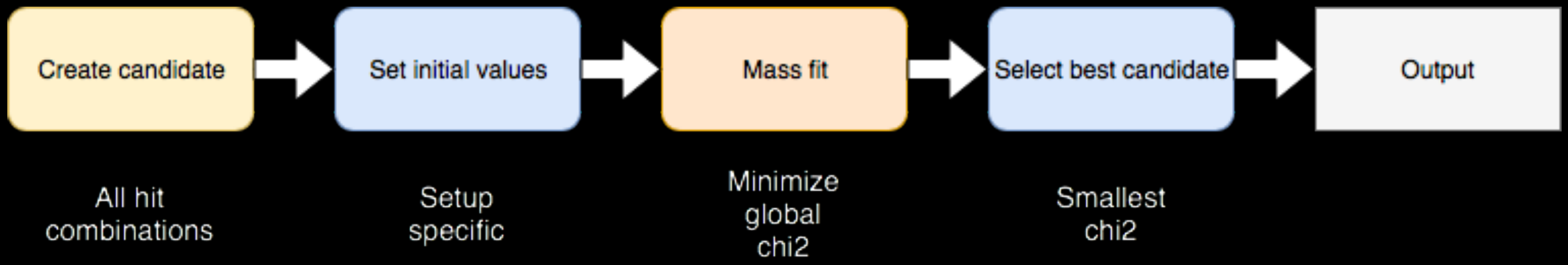
Clean separation of heavy isotopes



Challenges compared to HEP experiments

- Variety of different setups — changes in configuration and detector types
- Due to moderate beam energies and high charge, energy loss in detector layers impacts velocity (and thus trajectory) significantly. Has to be corrected for in the reconstruction
- Highly non-homogeneous magnetic dipole field
- No position measurement inside of field

Tracking algorithm



Depending on the setup:

I. 2 detectors before the magnet, 1 after — forward fit
II. 1 detector before the magnet, 2 after — backward fit
III. 2 before, 2 after — both fits sequentially

No improvement if both fits are applied in cases I. and II.

Components

- Simplified geometry description

No sophisticated stepping navigation
Current approximation model: 1 layer per detector

Components

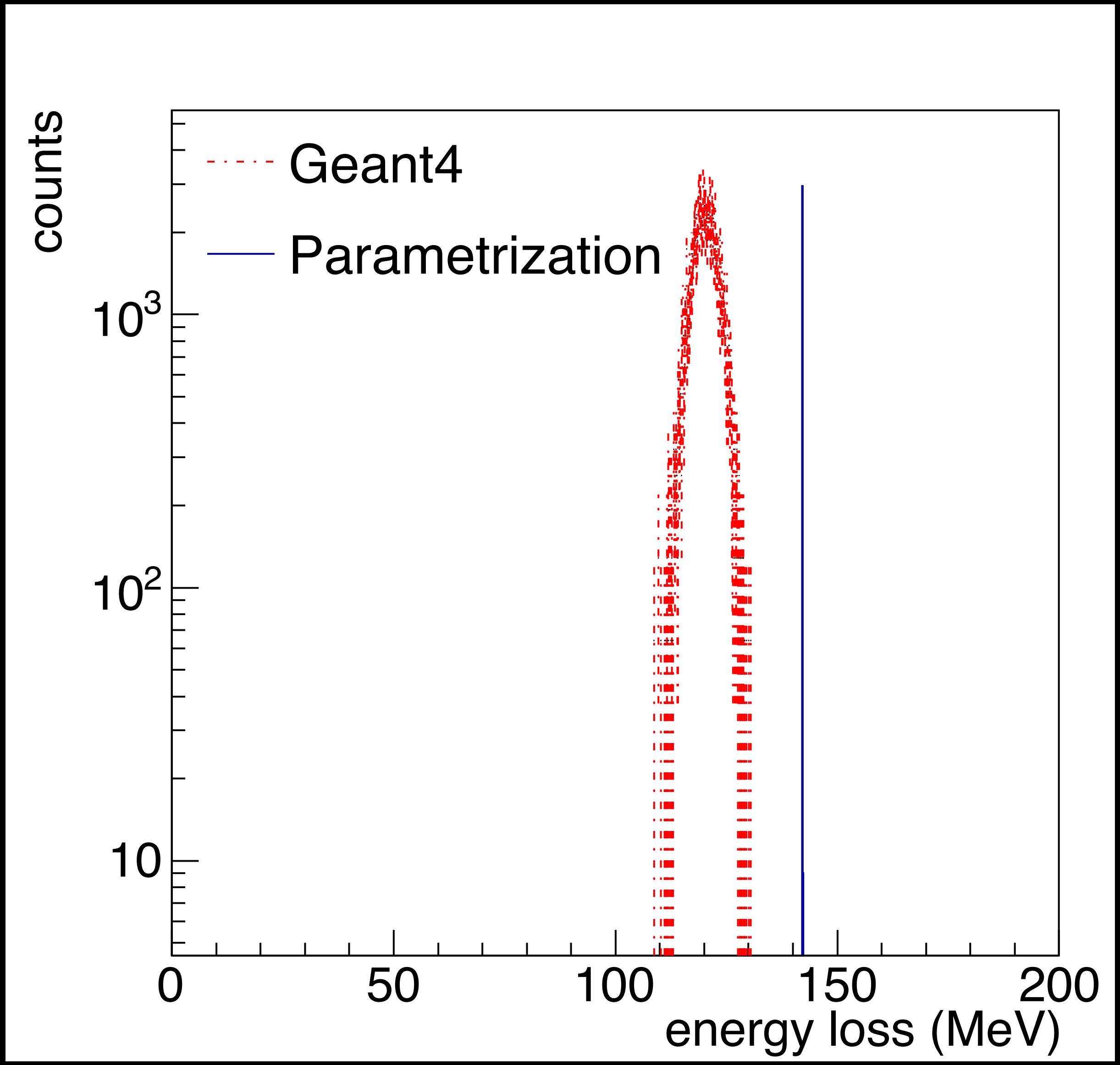
- Simplified geometry description
- Propagation in magnetic field

Highly non-homogeneous dipole field
Step-like propagation based on
Runge Kutta 4-th order method
(implemented in the FairRoot framework https://fairroot.gsi.de)

Components

- Simplified geometry description
- Propagation in magnetic field
- Energy loss calculation

Energy loss calculation



Bethe Bloch formula with density effect

Weak point: mean excitation energy

Test if can be fitted during alignment with known beam

Components

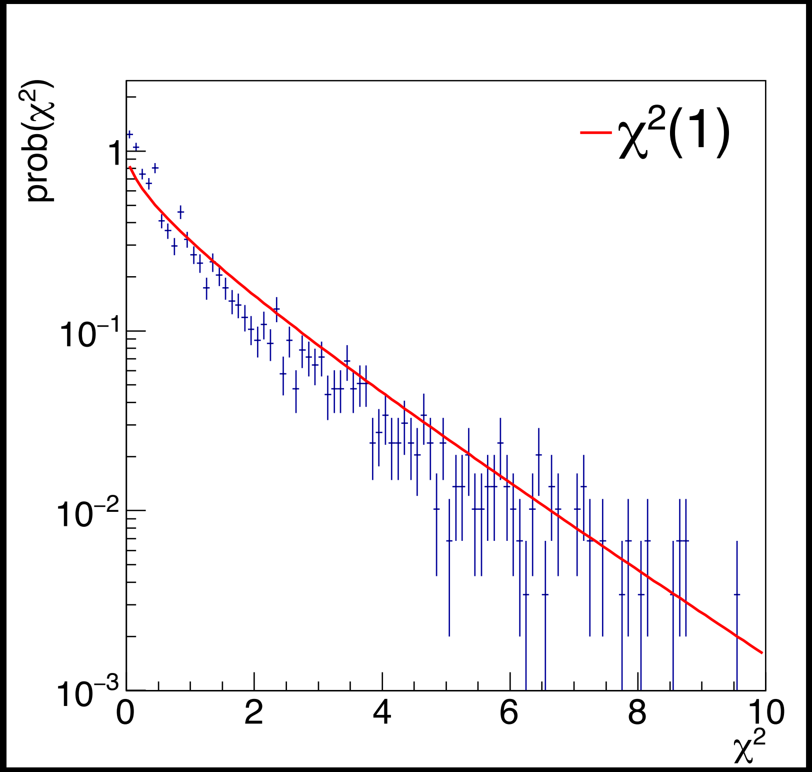
- Simplified geometry description
- Propagation in magnetic field
- Energy loss calculation
- Forward and backward propagation

Components

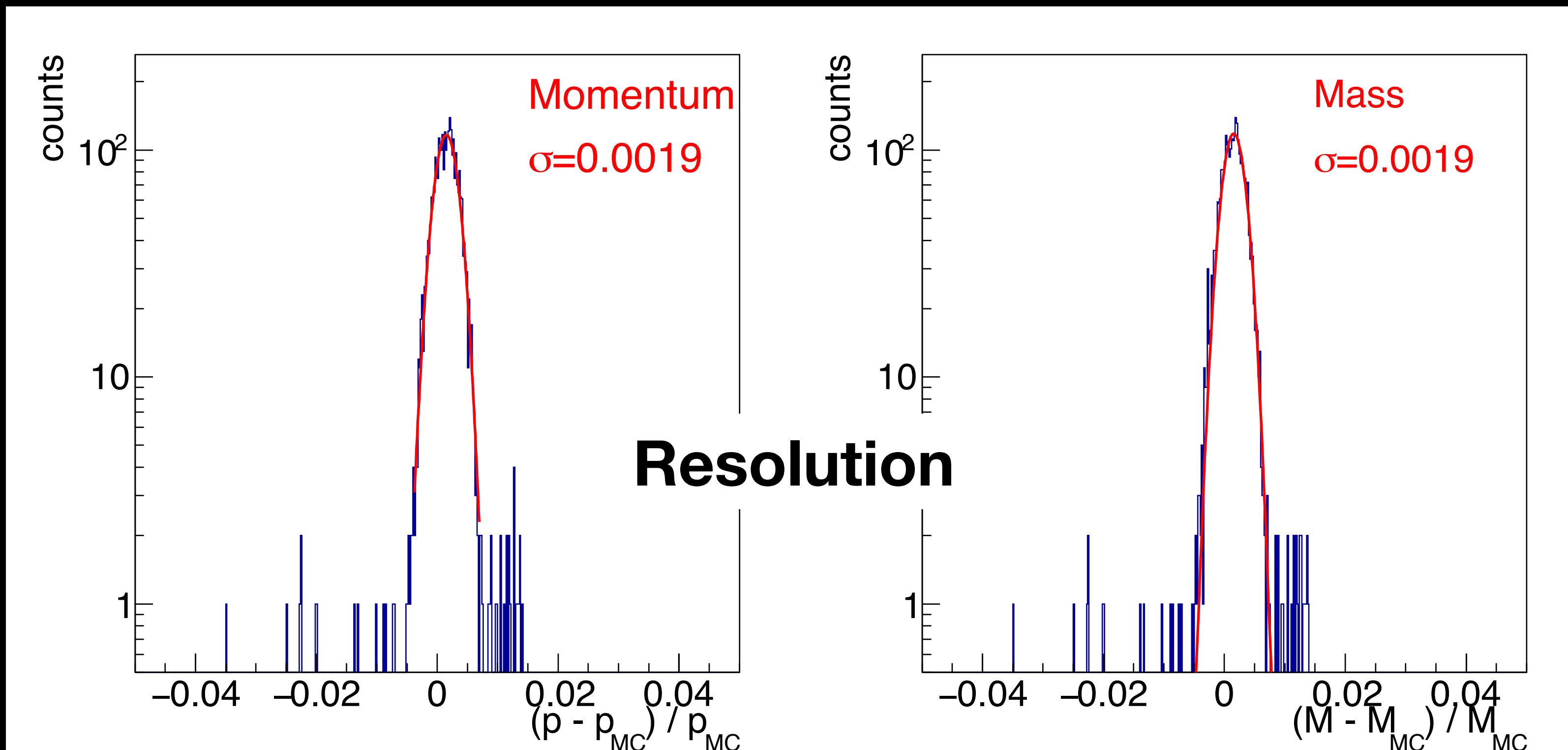
- Simplified geometry description
- Propagation in magnetic field
- Energy loss calculation
- Forward and backward propagation
- Mass fit with Minuit2 from ROOT

Simulation results

3 Sn isotopes, 1 ion per event
3.000 events
Geant4
p_{LAB} = 1,4 AGeV
backward tracking



Simulation results



Resolution

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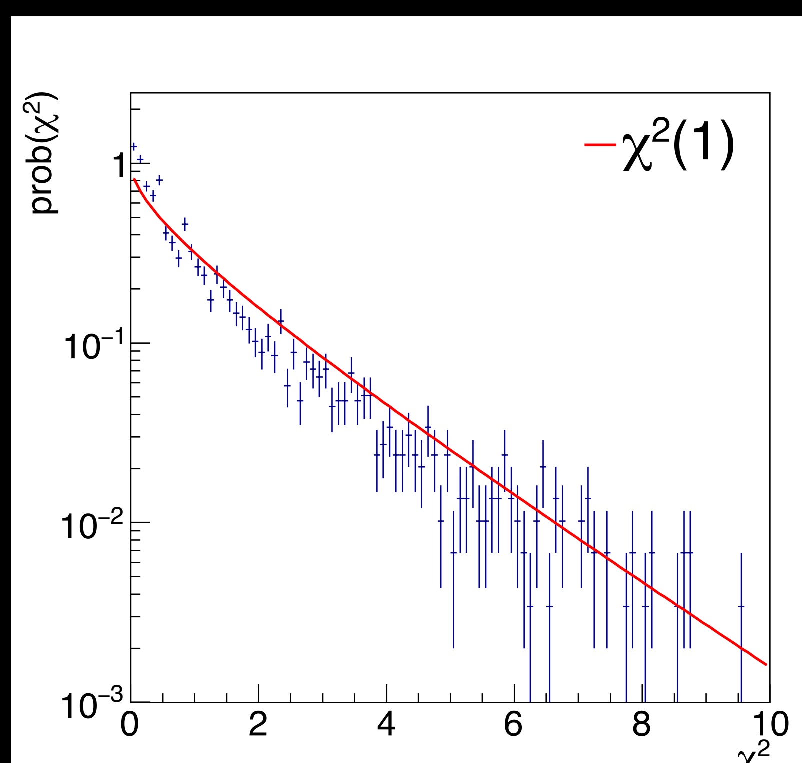

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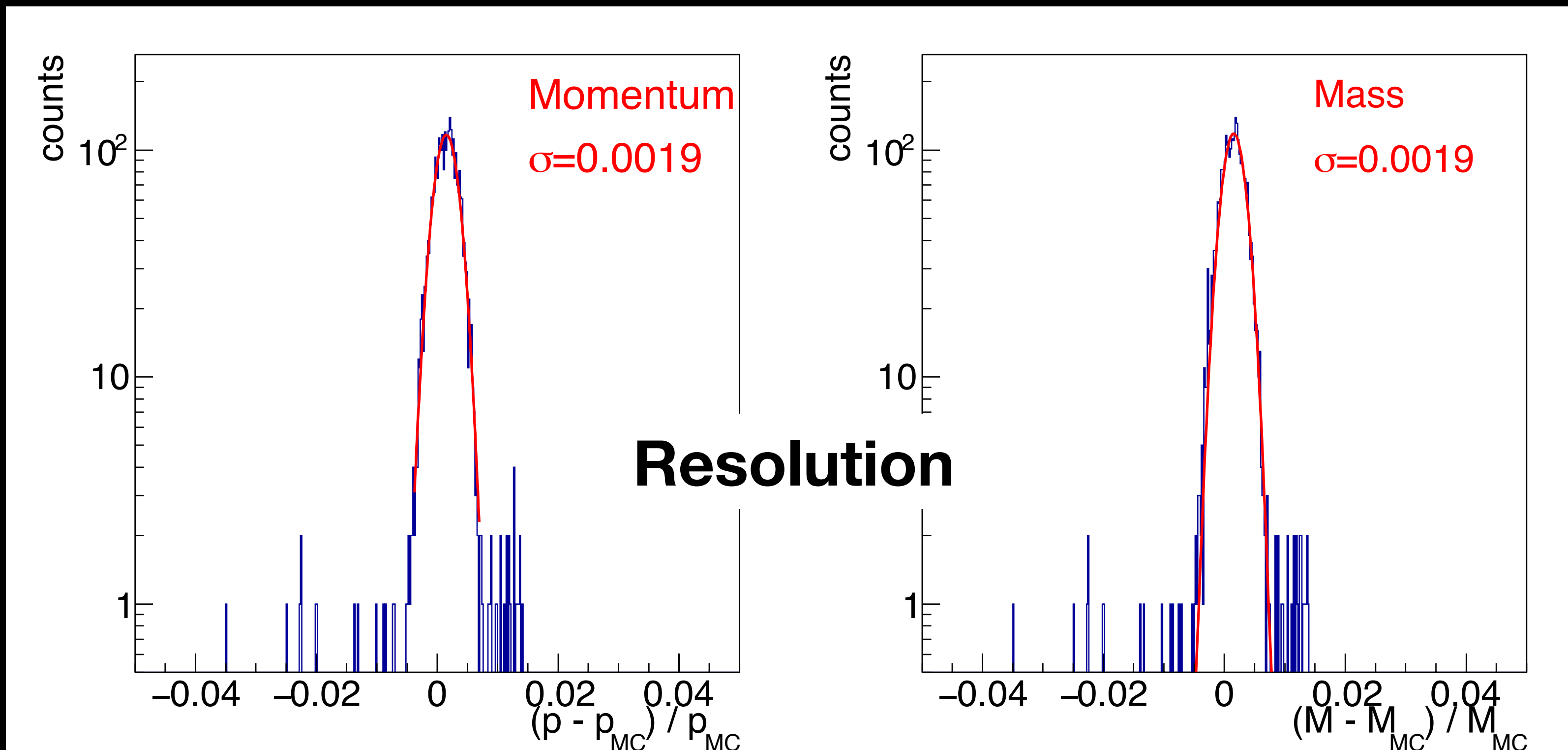

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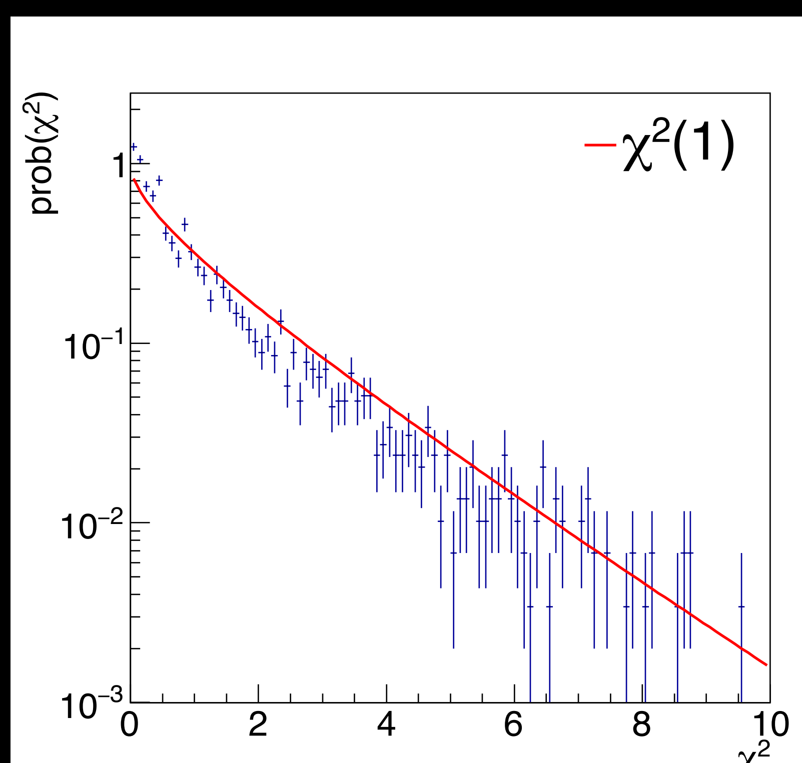

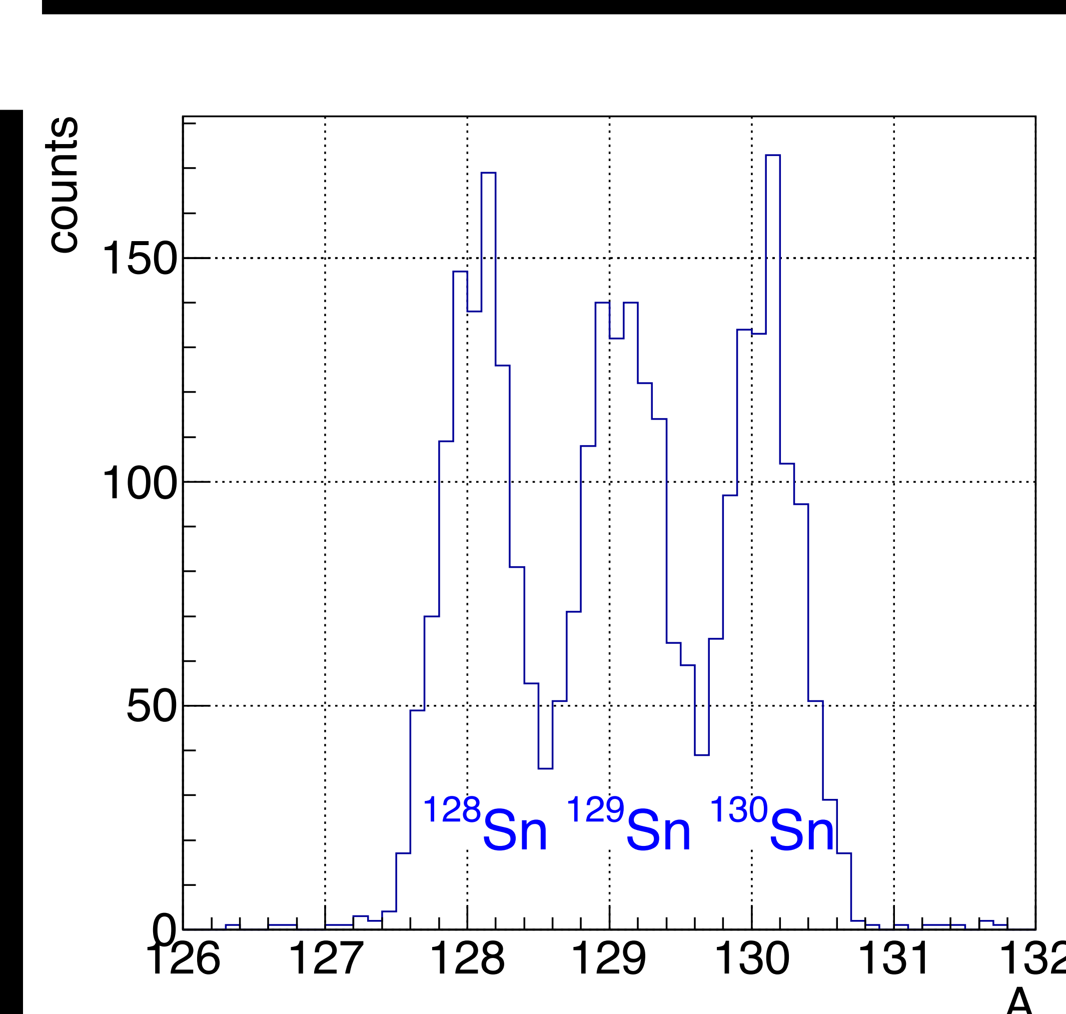

Performance

- Total reconstruction time of 150 ms / event
- Combinatorics penalty: 12.8 candidates / event
- Single fit performance: 11.6 ms / track
- 2000 lines of code

Status

- Tracker code is integrated into R3BRoot framework
  https://www.r3broot.gsi.de

- Single implementation is used to analyze experimental and simulated data

- Ready for data taking this autumn

Summary

- The R3B experiment at FAIR is equipped with the software algorithm for the mass reconstruction using heavy-ion tracking arm
- Required accuracy of 2×10^{-3} in mass reconstruction achieved
- The implementation is modular, compact, straightforward to validate and can be exported
- Further effort needed in timing optimization and in development of automated alignment procedure

Backup

Geometry example - 1 detector plane

```
[fi4GeoPar]
PositionX: Double_t -141.165491
PositionY: Double_t 0.
PositionZ: Double_t 614.
RotationX: Double_t 0.
RotationY: Double_t -16.7
RotationZ: Double_t 0.
DimensionX: Double_t 20.
DimensionY: Double_t 20.
DimensionZ: Double_t 0.02
Z: Double_t 5.57354
A: Double_t 11.0723
Density: Double_t 1.032
IonisationEnergy: Double_t 57.4e-6
```

No recompilation needed when changing geometry