

Investigation of Fission in quasi-free-scattering experiments at R³B



Tobias Jenegger
For the R³B Collaboration

DPG Mainz
29.03.2022

Fission via (p,2pf) reaction

R³B Setup at GSI

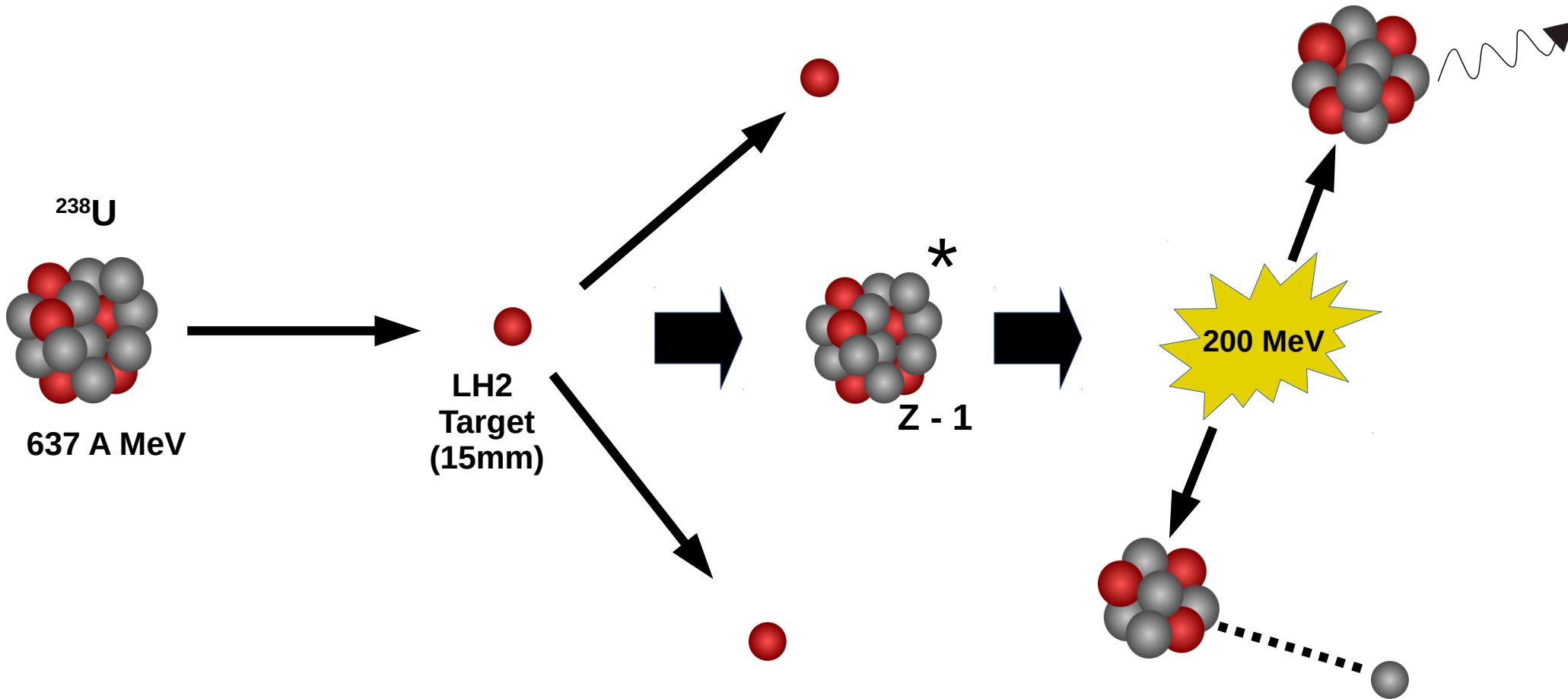
First Analysis Steps

Outlook

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Fission induced by Quasi-Free-Scattering



S455 Experiment (2021) – Nuclear Fission Studies

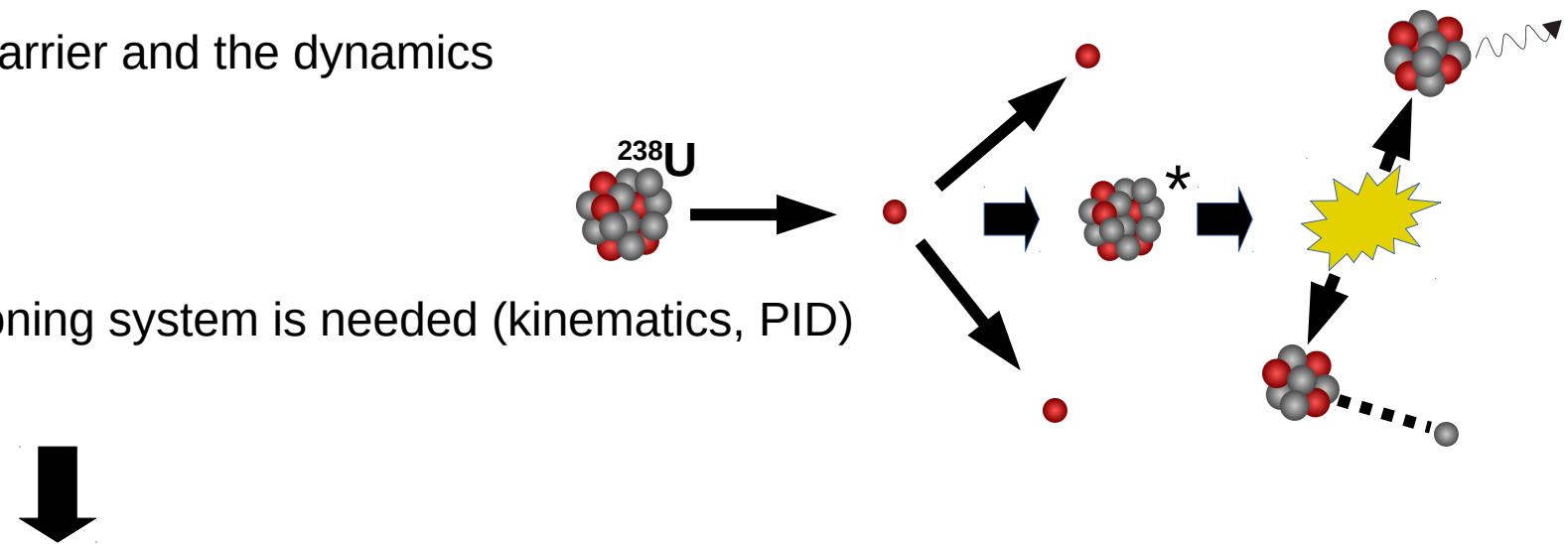
Spokesperson: J. Benlliure, Universidade de Santiago de Compostela, Spain

Why QFS?

- QFS is an excellent method to directly determine the initial excitation energy of the fissile nucleus
- Measurement of the excitation energy on an event-by-event basis
- Unique information about the fission barrier and the dynamics

What we require:

- Complete characterization of the fissioning system is needed (kinematics, PID)



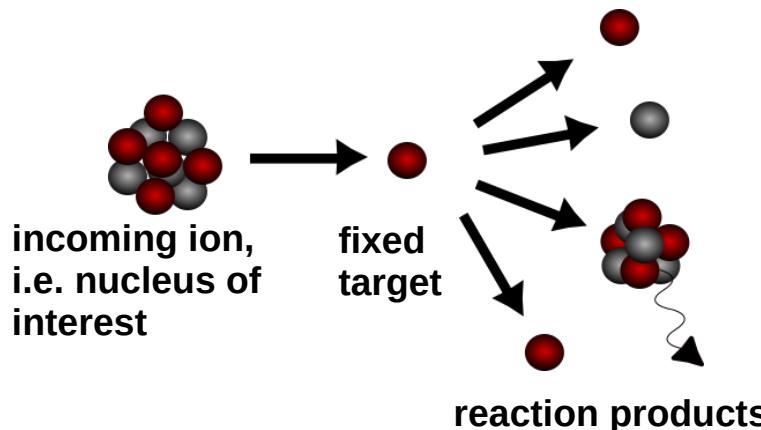
Dedicated experimental setup needed!



R³B Experiment @ GSI

Reactions with Radioactive Relativistic Beams

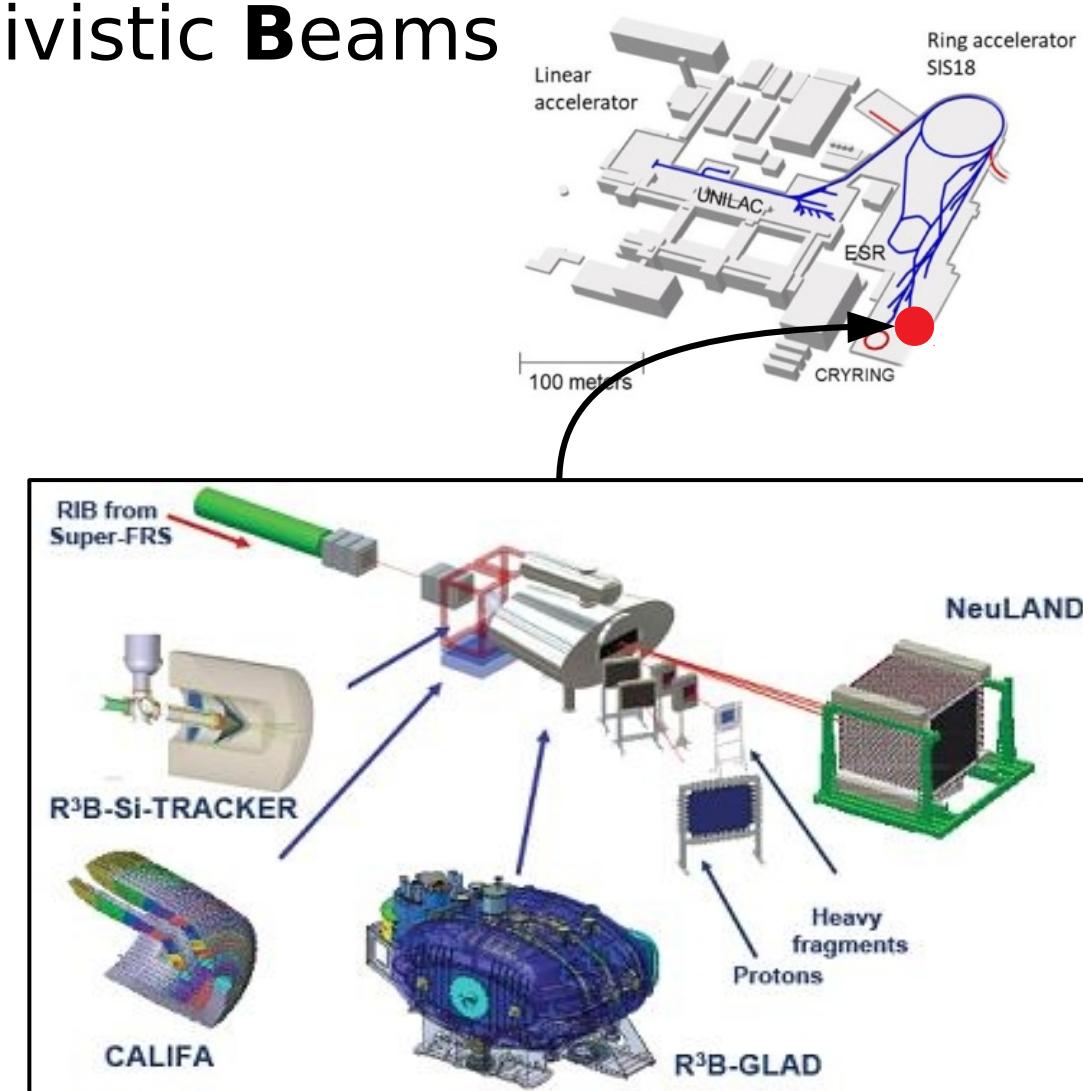
- Physics program on exotic nuclei in inverse kinematics:



- kinematically complete measurements**

Talk from Lukas Ponnath:

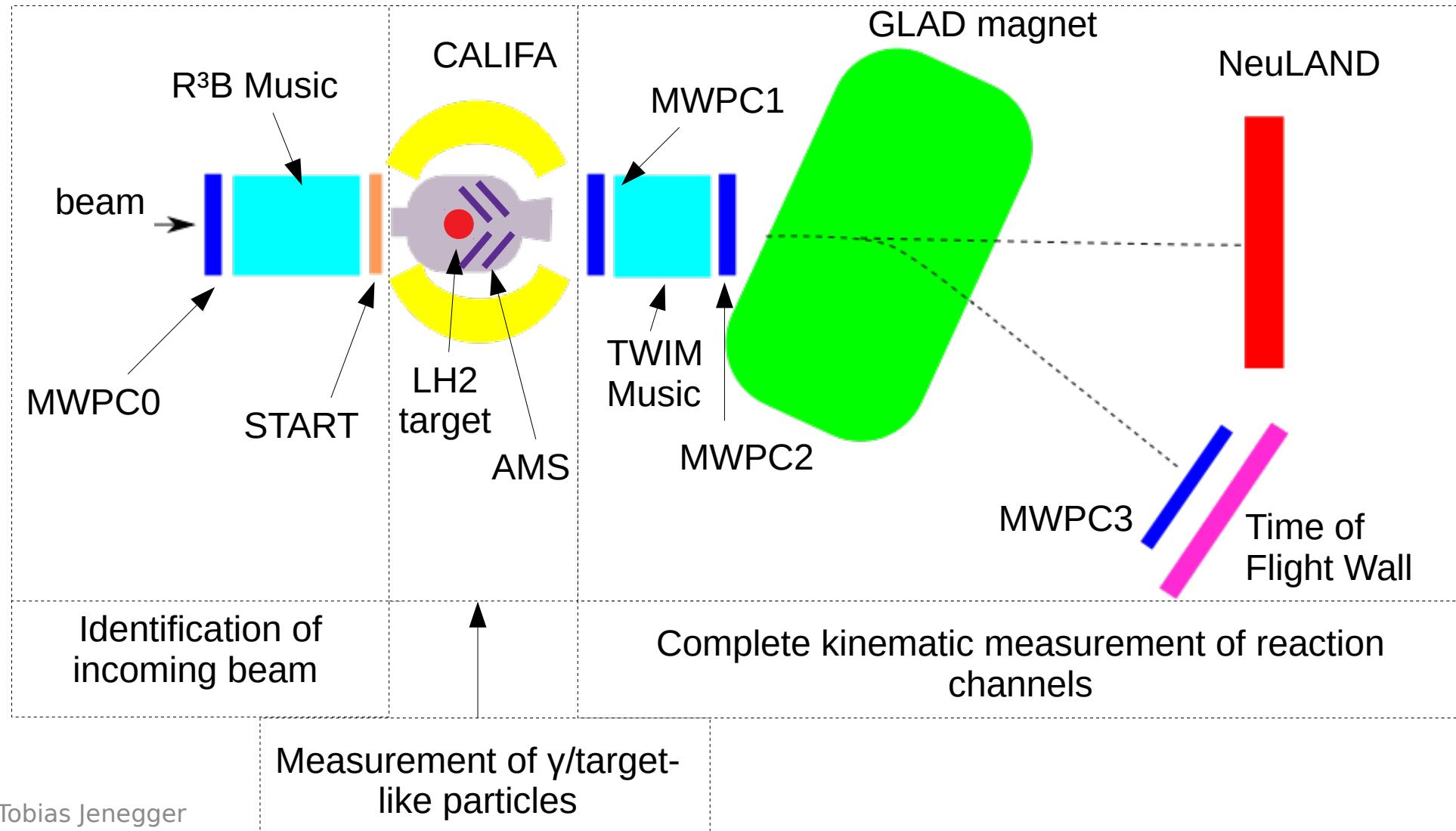
"Total Reaction Cross-Section Measurements in the S444 Commissioning Experiment for R³B" (HK 29.1)



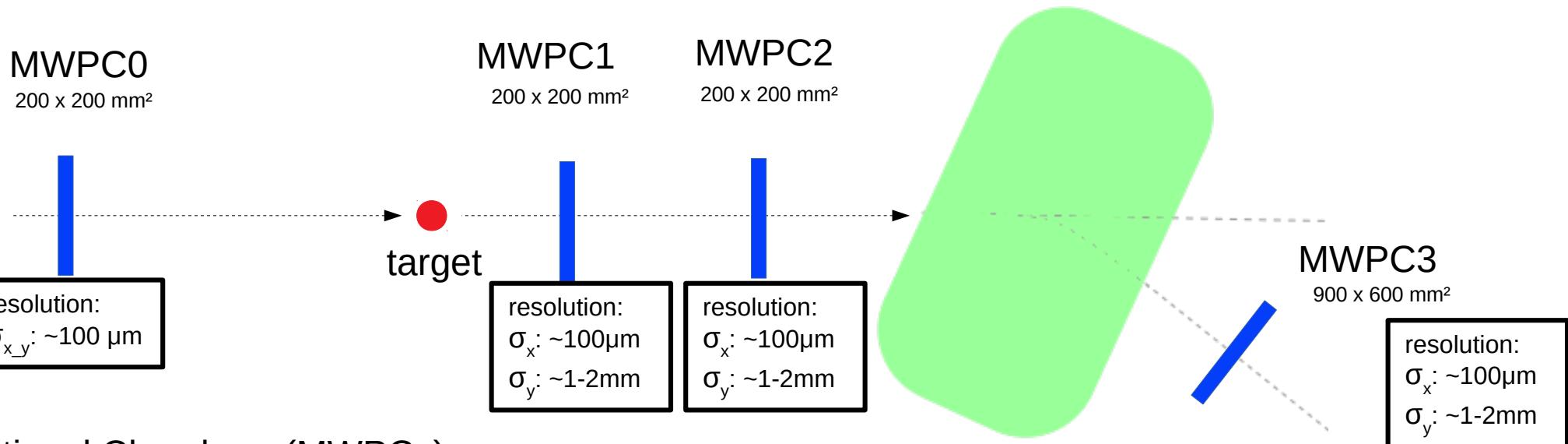
R³B Setup for Pilot Experiments (2021)

Beam: ^{238}U beam, 637 AMeV beam energy

Target: liquid hydrogen

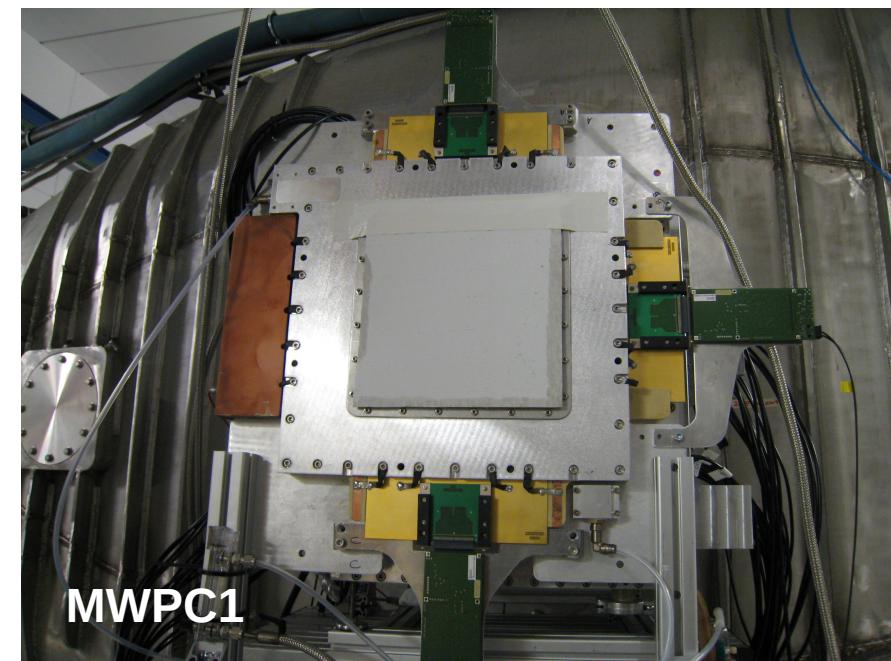
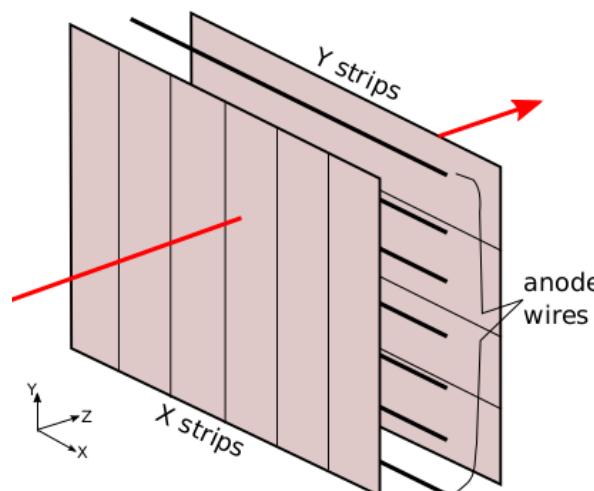


Tracking with the MWPC



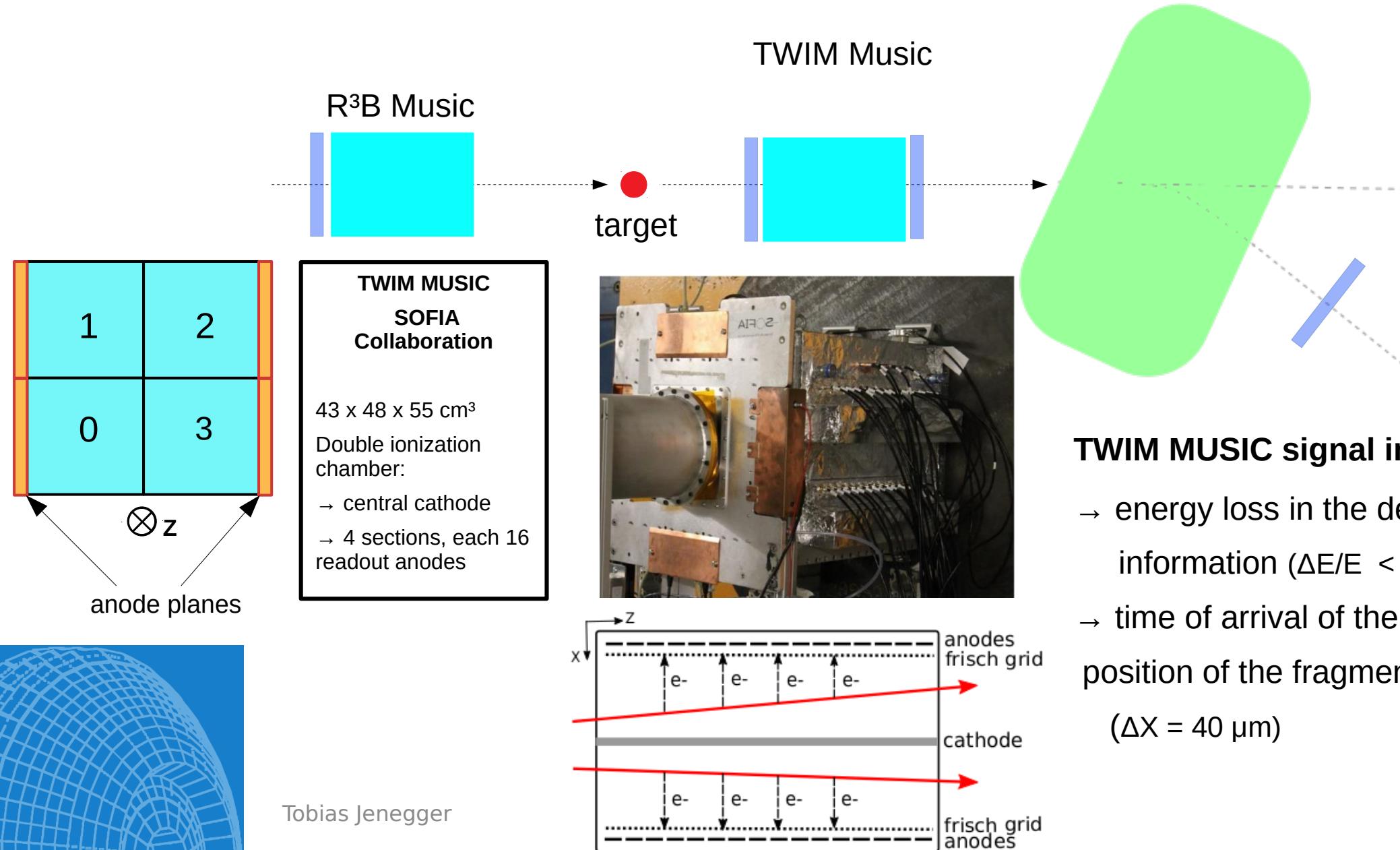
Multi Wire Proportional Chambers (MWPCs):

- horizontal wires: 50 μm diameter, 2.5 mm spacing
- vertical/horizontal pads:
Al-deposited on a 12 μm Mylar foil,
5/3.125 mm width (vertical/horizontal)
- gas mixture: 84% Ar, 16% CO₂
- pad readout

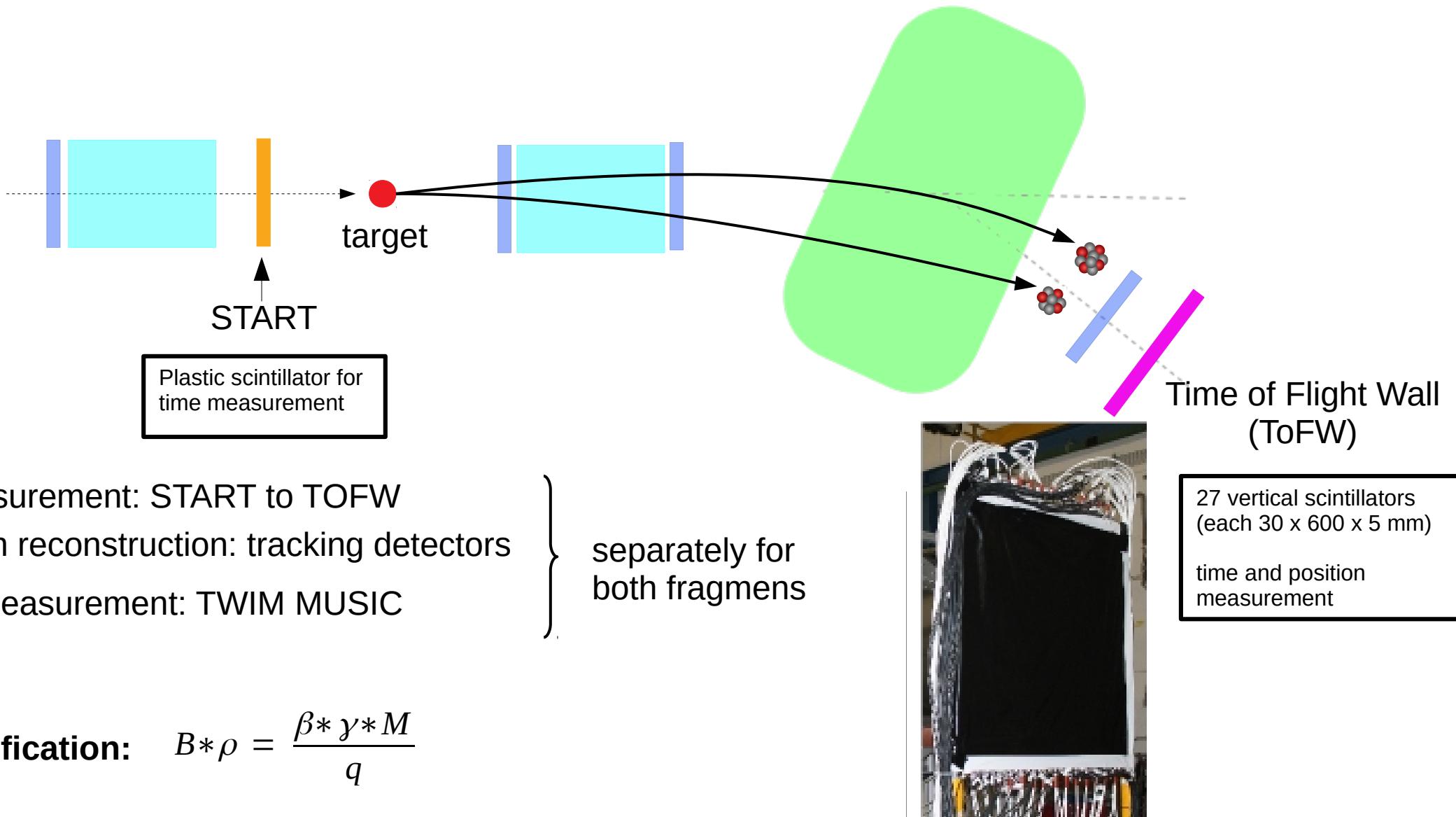


MWPC1

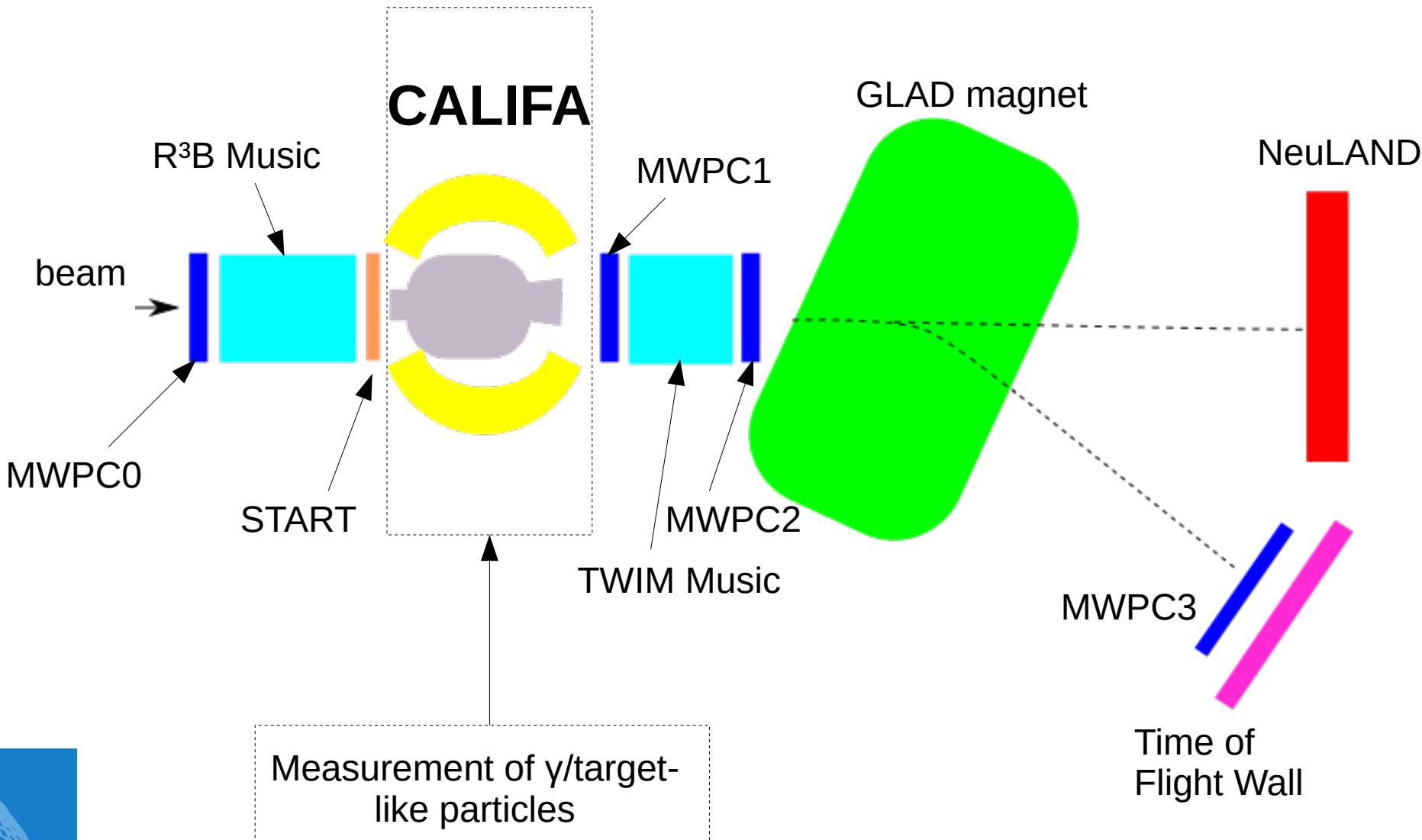
Charge Measurement – Ionization Chambers



Time Measurement – START & TOFW



Mass Identification: $B * \rho = \frac{\beta * \gamma * M}{q}$



CALIFA Detector @ R³B

CALorimeter for the In Flight detection of γ -rays and light charged pArticles

Endcap:

iPhos:

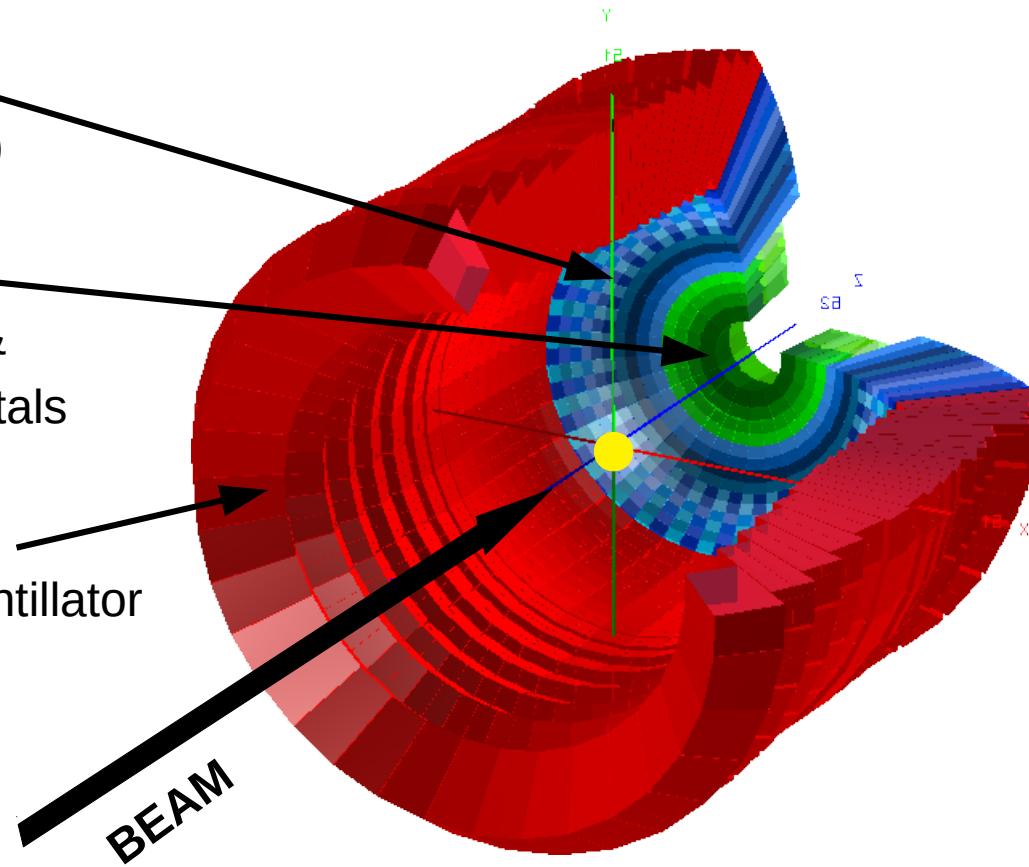
512 CsI(Tl)
crystals

CEPA:

96 LaBr₃ &
LaCl₃ crystals

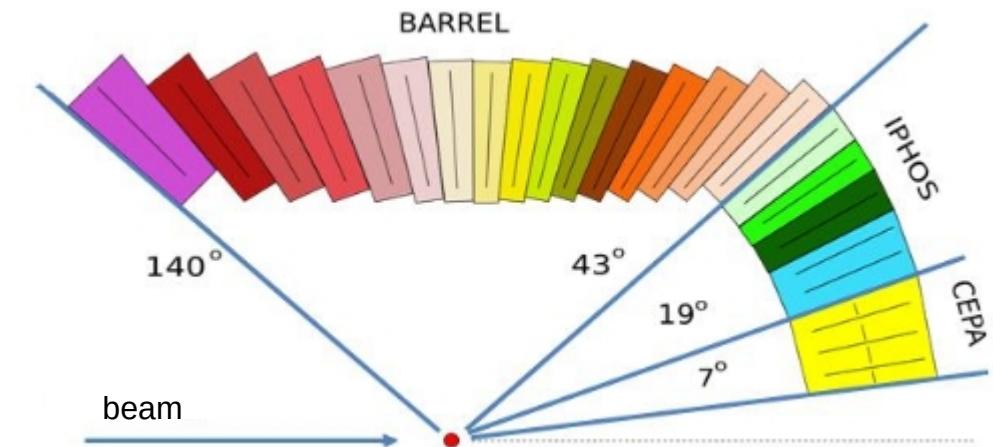
Barrel:

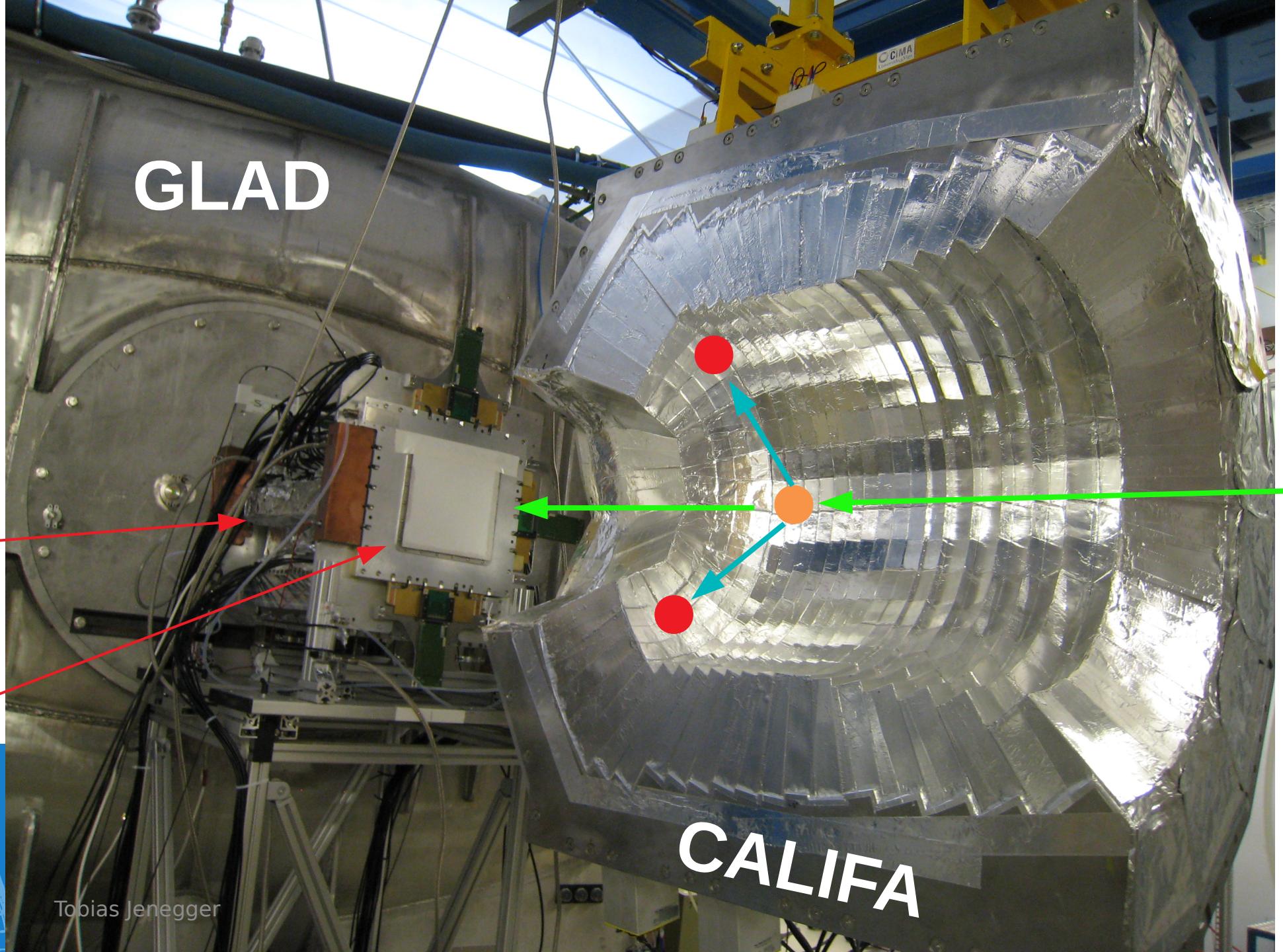
1952 CsI(Tl) scintillator
crystals



Highly segmented detector:

- Angular reconstruction
- Doppler correction





First Analysis Steps



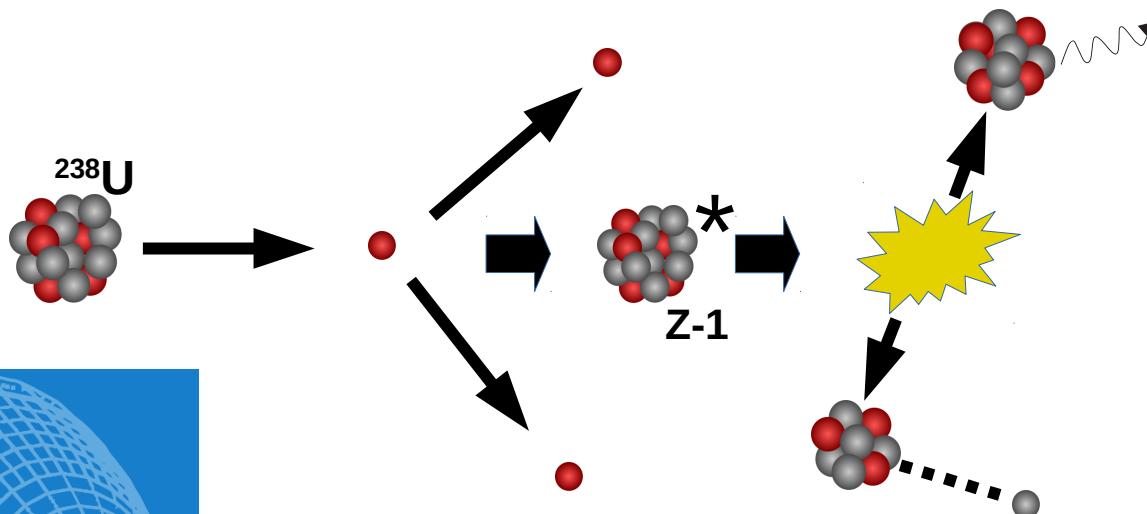
Identification of Fission Process

TWIM MUSIC Charge Identification:

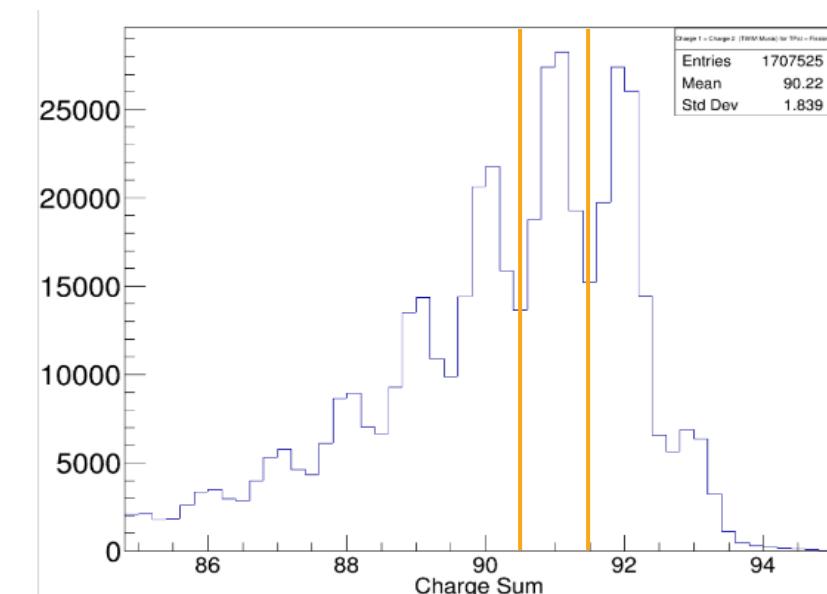
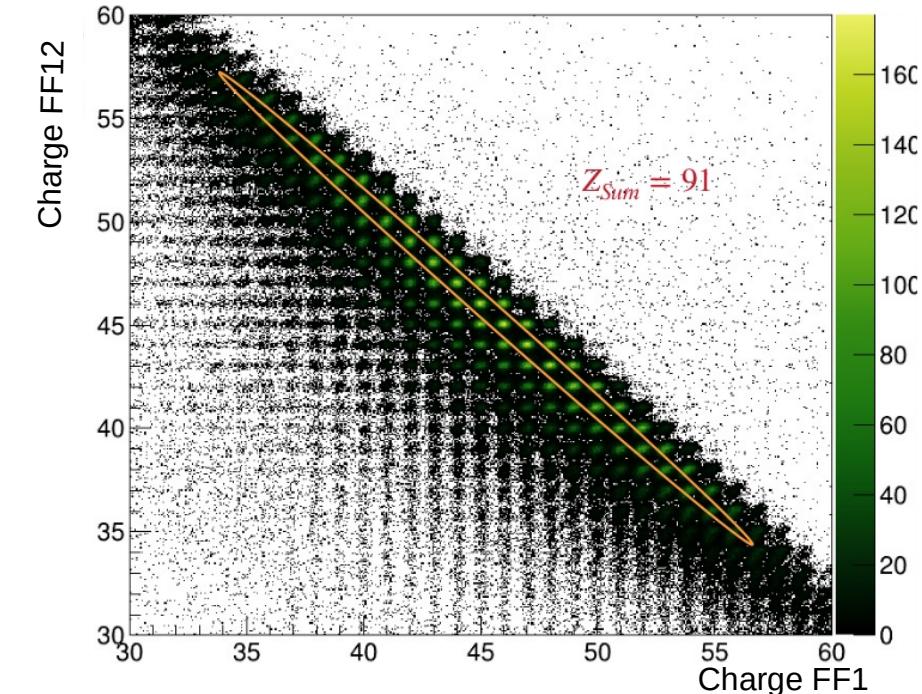
→ two fission fragments (FF)

$$\rightarrow Z_{FF1} + Z_{FF2} = Z_{SUM} = 92 - 1$$

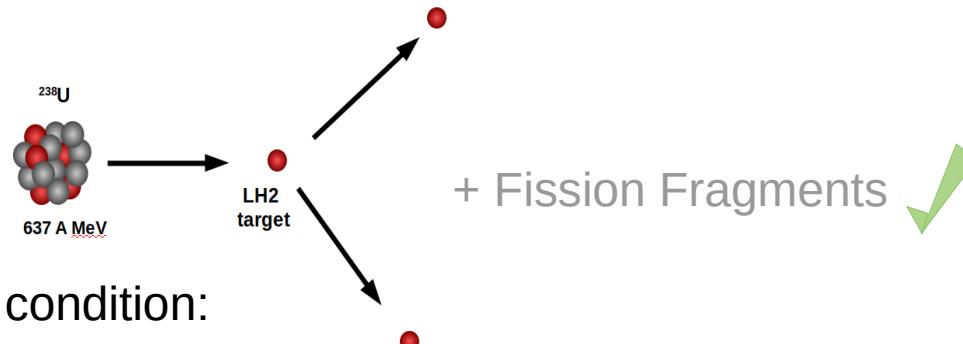
quasi-free scattered proton



Tobias Jenegger

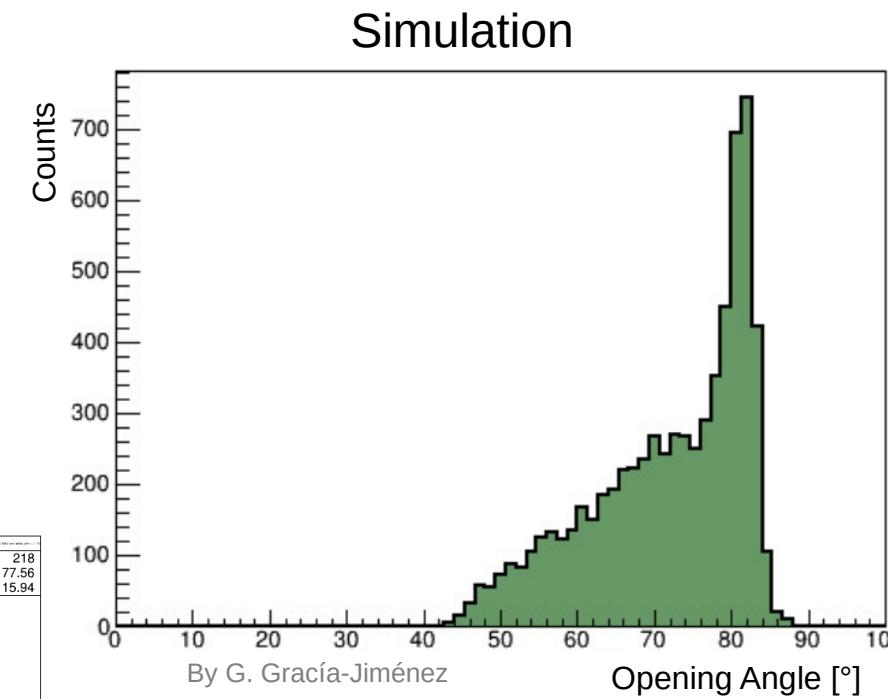
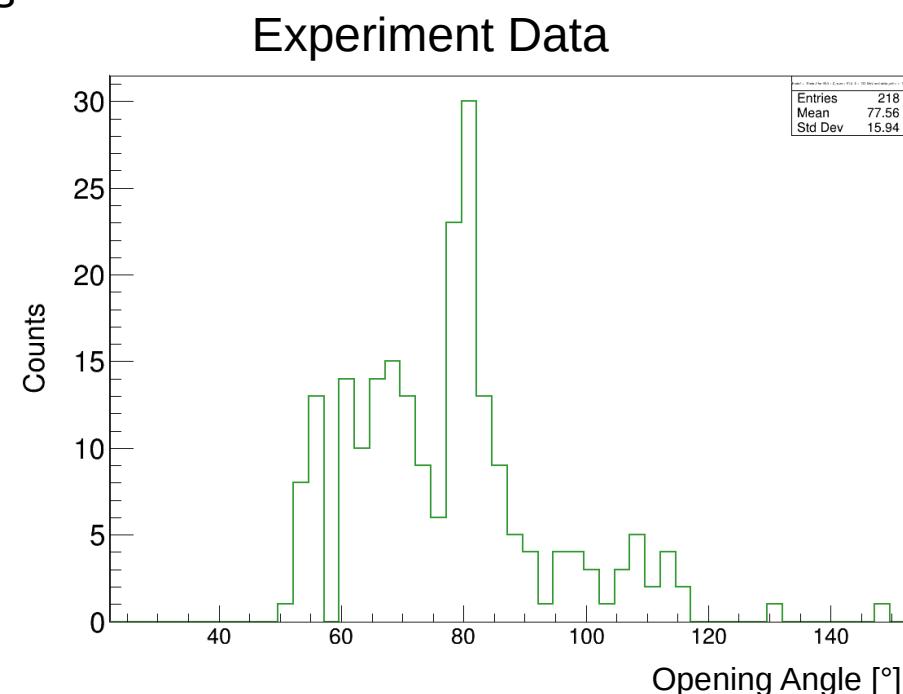


Identification of QFS Process



Select events with ($p, 2p$) condition:

- two hits with $E_{p1}, E_{p2} > 100 \text{ MeV}$
- Coplanarity: $\Delta\phi = 180^\circ \pm 15^\circ$
- reasonable number of crystal hits



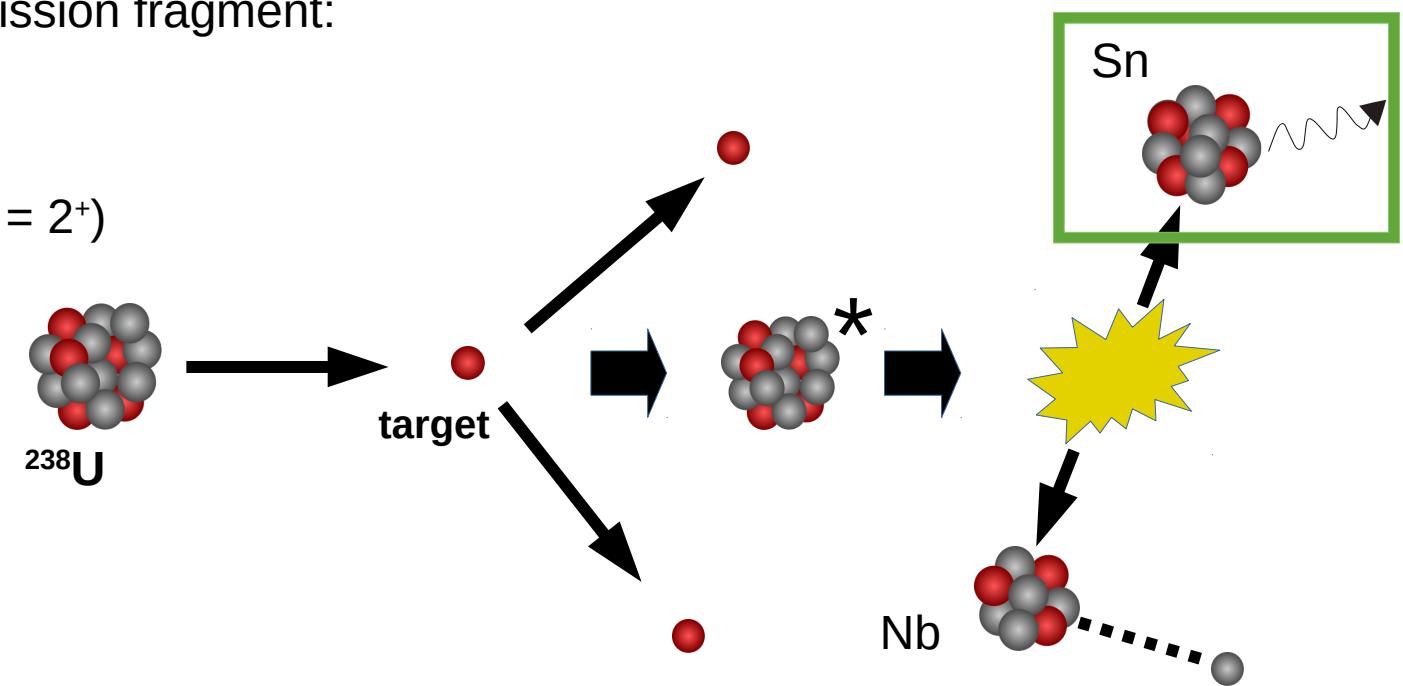
Gamma spectrum in CALIFA

Motivation:

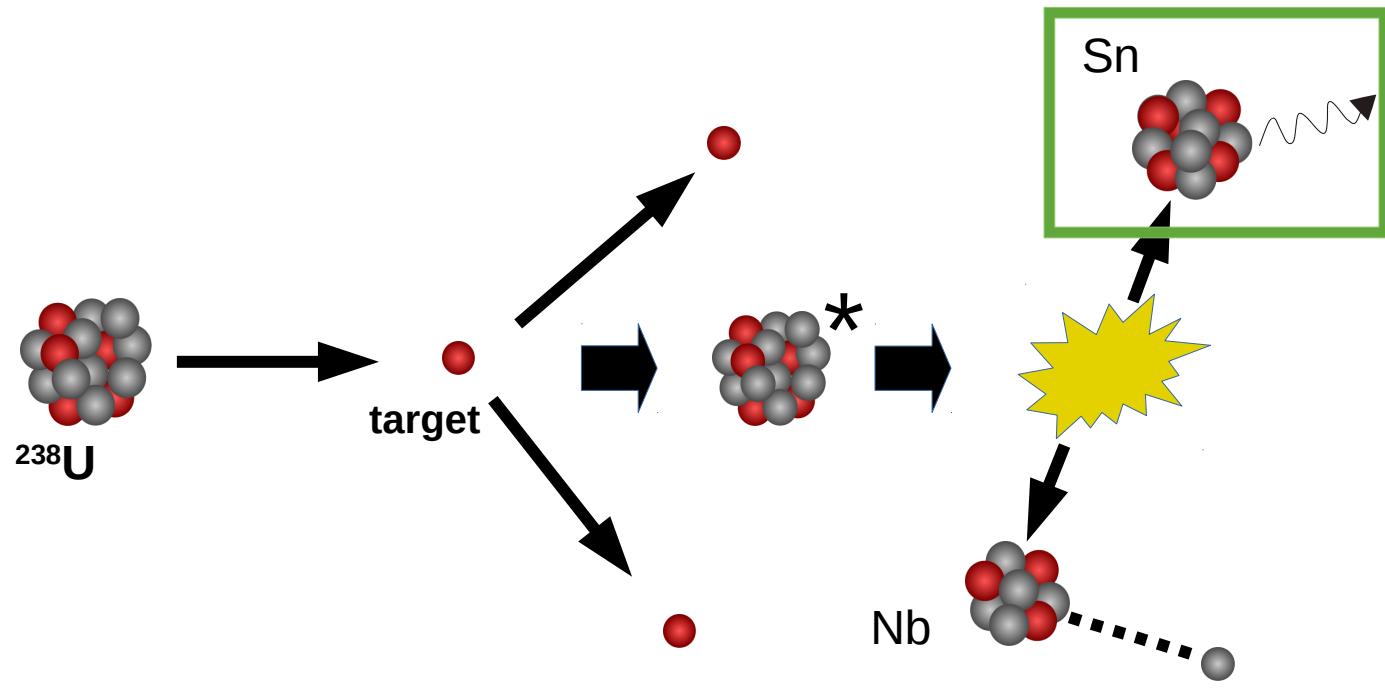
- energetic states of the fission fragments
- information on how the energy dissipated from fission is shared between the two nascent fragments (energy sorting mechanism, shell effects, etc.)

Gamma spectrum of tin ($Z=50$) as one fission fragment:

- gg nuclei with $J = 0^+$ ground state
- energy gap $\sim 1\text{-}2 \text{ MeV}$ (excited state $J = 2^+$)



Gamma spectrum in CALIFA

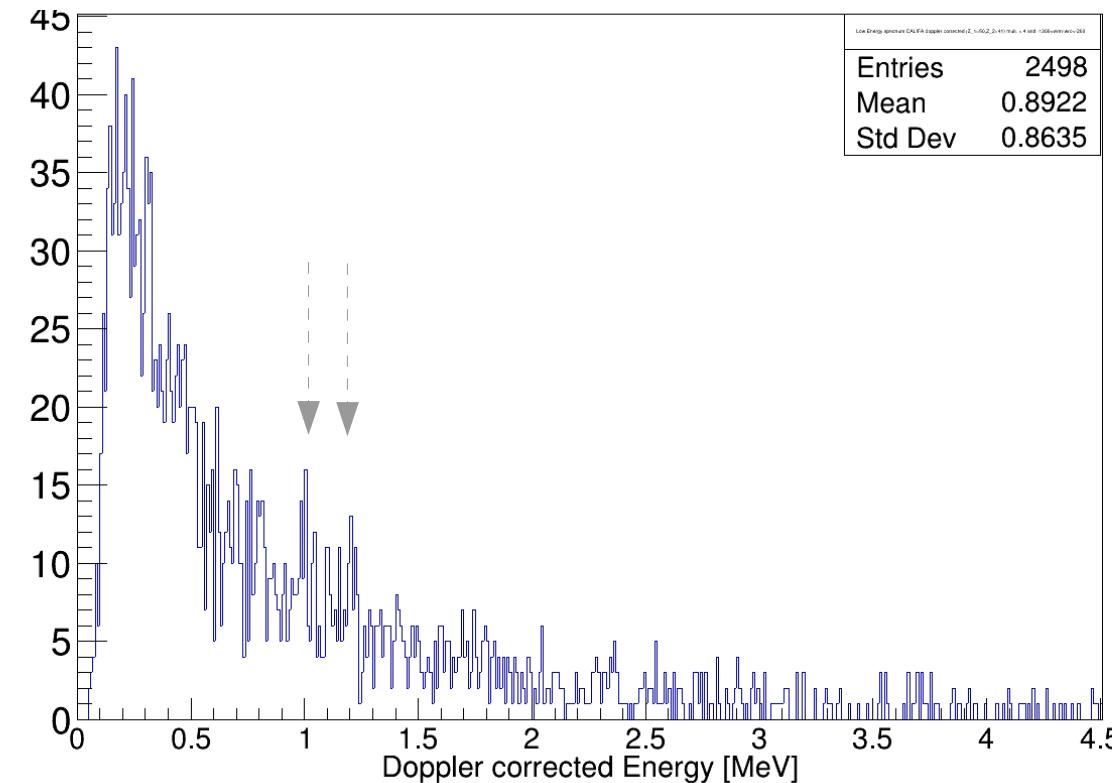


1st excited Sn states of interest:

- ^{126}Sn , 1140 keV
- ^{128}Sn , 1169 keV
- ^{130}Sn , 1121 keV
- ^{132}Sn , 4041 keV

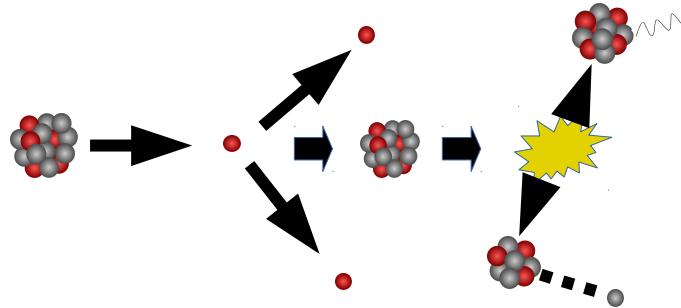


Tobias Jenegger



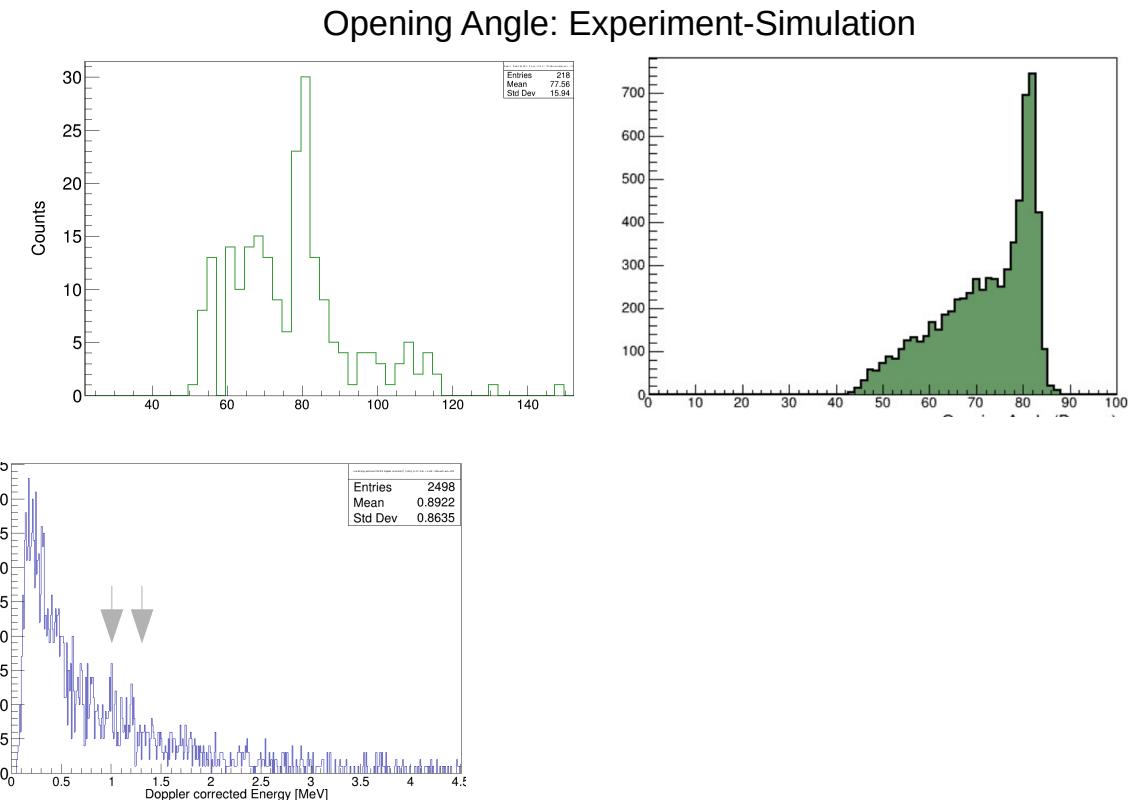
Summary & Outlook

→ $^{238}\text{U}(\text{p},2\text{pf})$ reaction has been identified:



→ gamma spectrum looks promising:

- Fine calibration of TWIM MUSIC
- Time of flight & track reconstruction for exact particle identification
- full energy reconstruction of the fissioning system and the fission fragments
 - fission barriers / spectra of excited fission fragments





Thank you!

CALIFA @ Technical University of Munich (TUM)

Roman Gernhäuser, Lukas Ponnath, Philipp Klenze, Tobias Jenegger



Tobias Jenegger

GEFÖRDERT VOM



Bundesministerium
für Bildung
und Forschung

