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

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Fission via (p,2pf) reaction

R³B Setup at GSI

First Analysis Steps

Outlook

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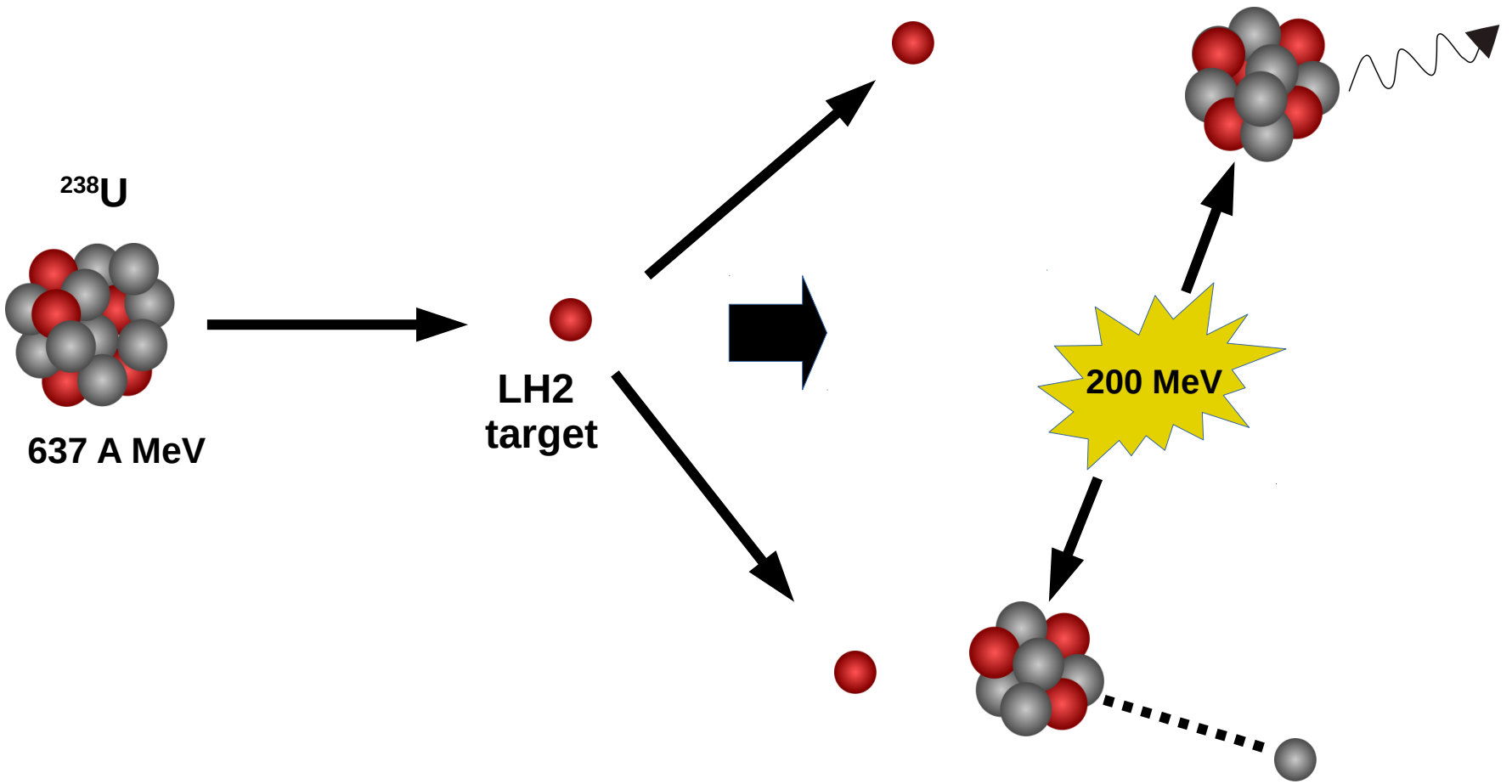
GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

GSI

FAIR Phase 0 Research Program

TUM Members:
Roman Gernhäuser,Lukas Ponnath,Philipp Klenze,Tobias Jenegger

Fission induced by Quasi-Free-Scattering



Beam:^{238}U beam, 637 AMeV beam energy
Intensity: ~ 5E4 particles/s
Expected 238U(p,2pf) cross section: ~ 20 mb
Total Beamtime: ~ 9hours

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 possible

→ Provides unique information about the fission barrier, the dynamics of the fission process and the underlying shell structure

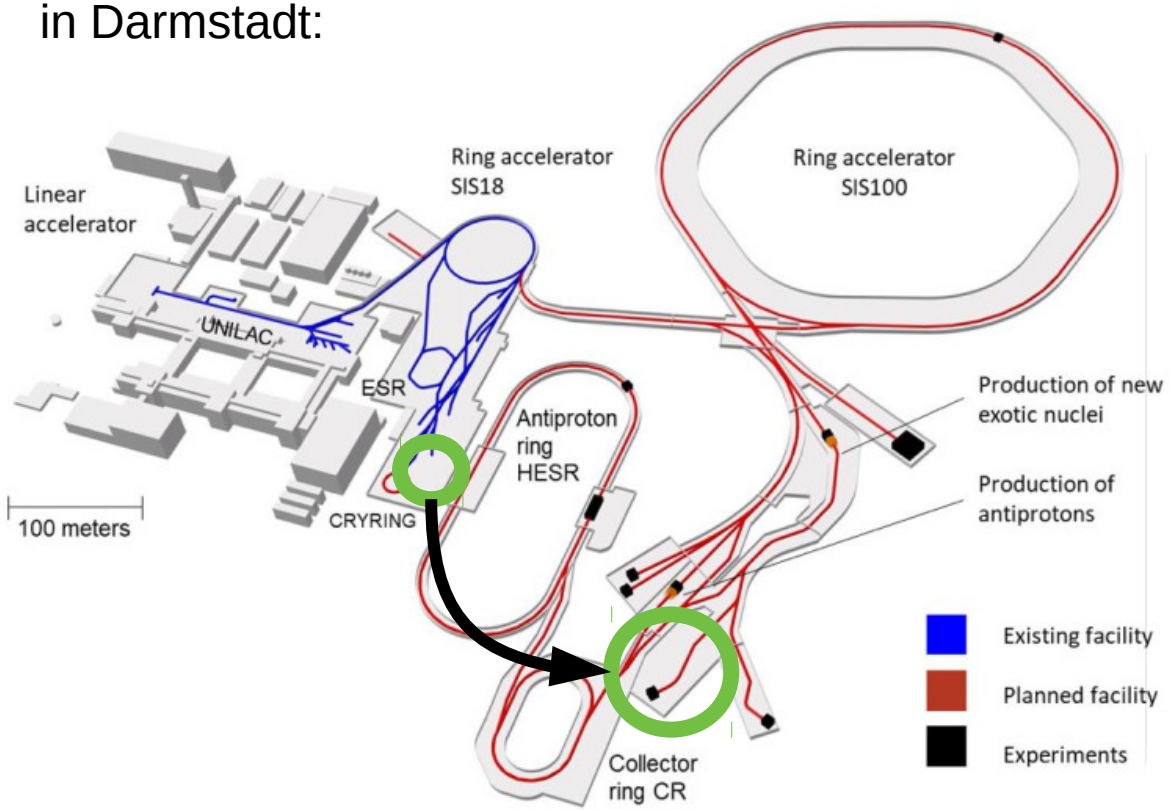
What we require:

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

Dedicated experimental setup needed!

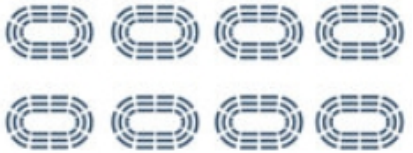
R³B @ GSI

R³B as part of the
Facility for **A**ntiproton and **I**on **R**esearch (**FAIR**)
in Darmstadt:



- 2 mio. m³ of earth excavated
- 600,000 m³ of concrete
- 65,000 tons of steel

5,000 single family homes



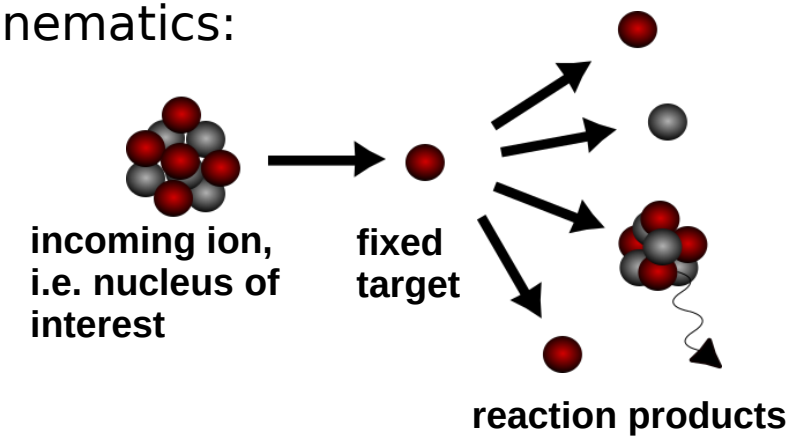
eight Frankfurt soccer stadiums

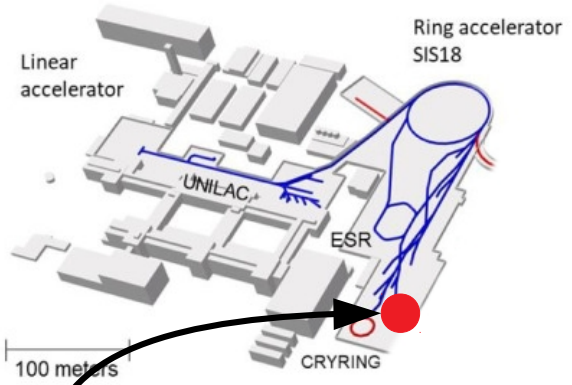
nine Eiffel Towers

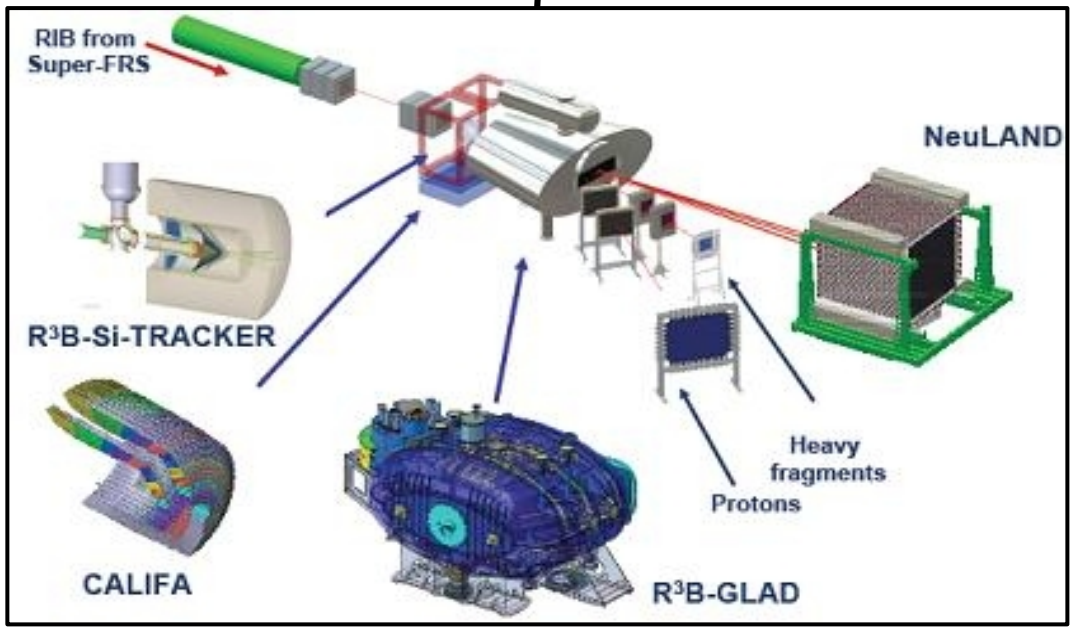
R³B Experiment @ GSI

Reactions with Radioactive Relativistic Beams

- Physics program on exotic nuclei in inverse kinematics:



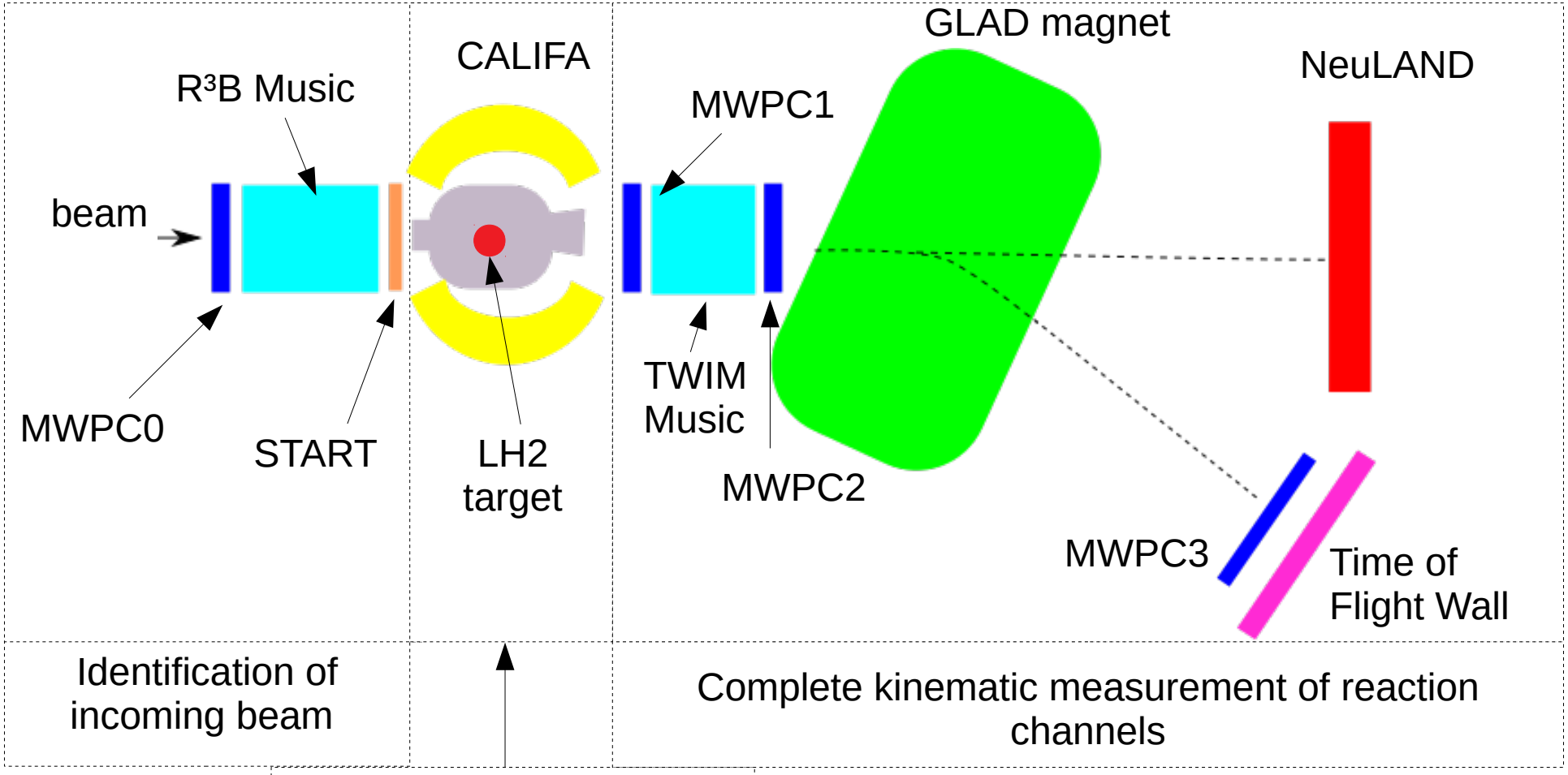




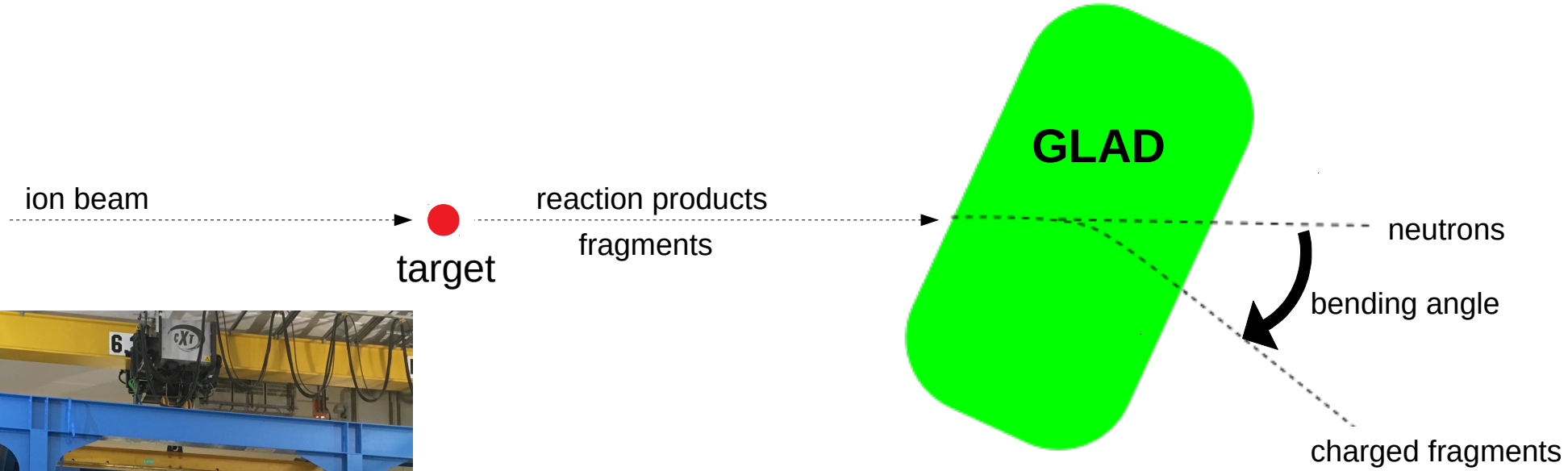
- In flight production of exotic nuclei from fragment separator Super-FRS
- **kinematically complete measurements**
- Flexible setup, extensive physics schedule (despite pandemic restrictions)

R³B Setup for Pilot Experiments (2021)

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

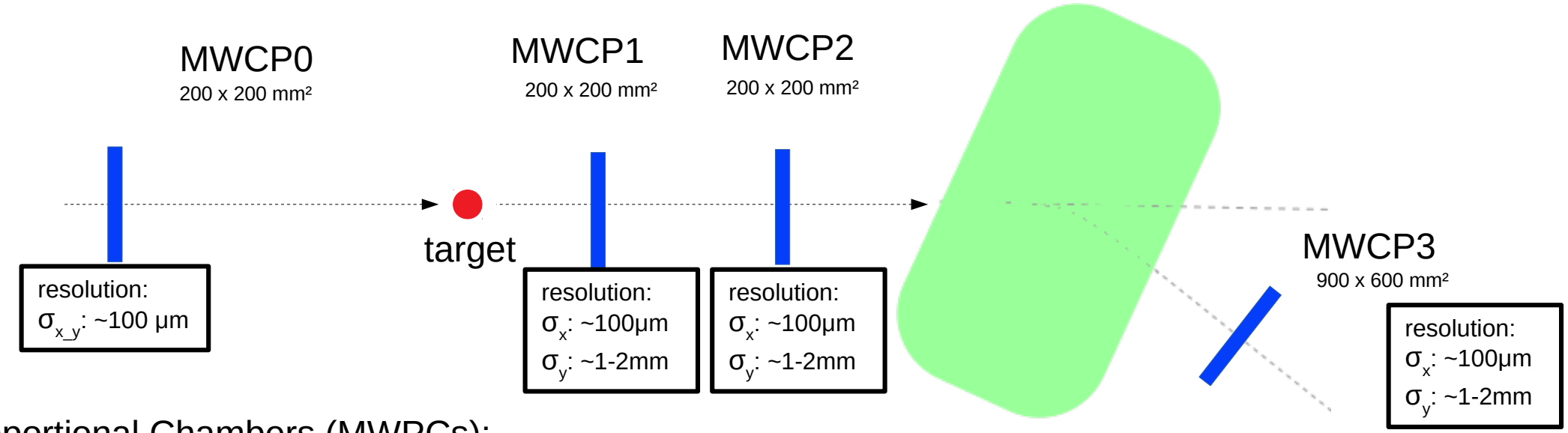


GLAD Superconducting Dipole Magnet



- Mass spectrometer
- large aperture (+-80 mrad) for neutrons
- high bending range from 0° - 40°
- With tracking detectors: momentum resolution Δp/p of around 10^{-3}

Tracking Detectors



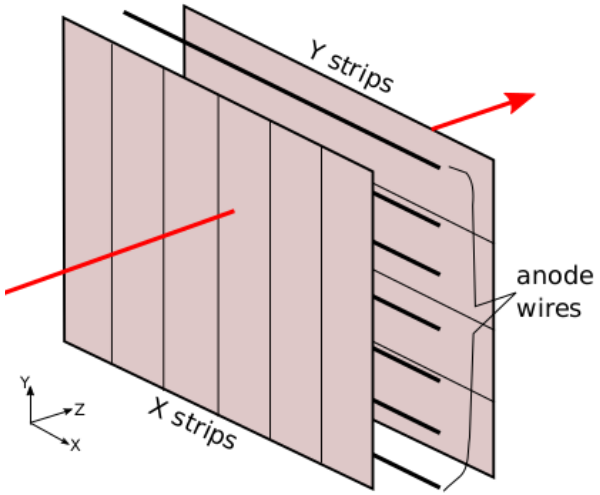
Multi Wire Proportional Chambers (MWPCs):

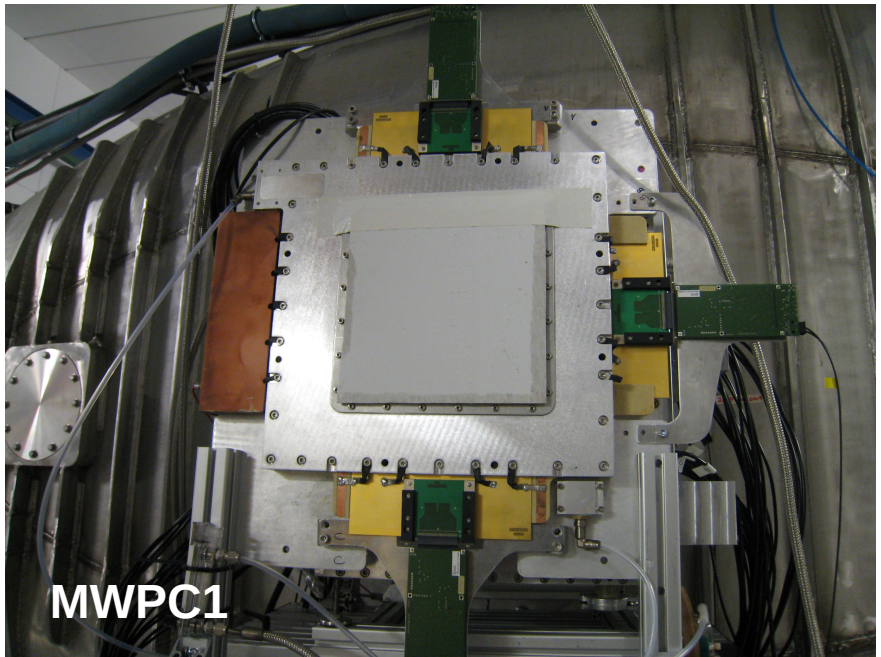
→ horizontal wires: 50 µm diameter, 2.5 mm spacing

→ vertical/horizontal pads:
Al-deposited on a 12 µm Mylar foil,
5/3.125 mm width (vertical/horizontal)

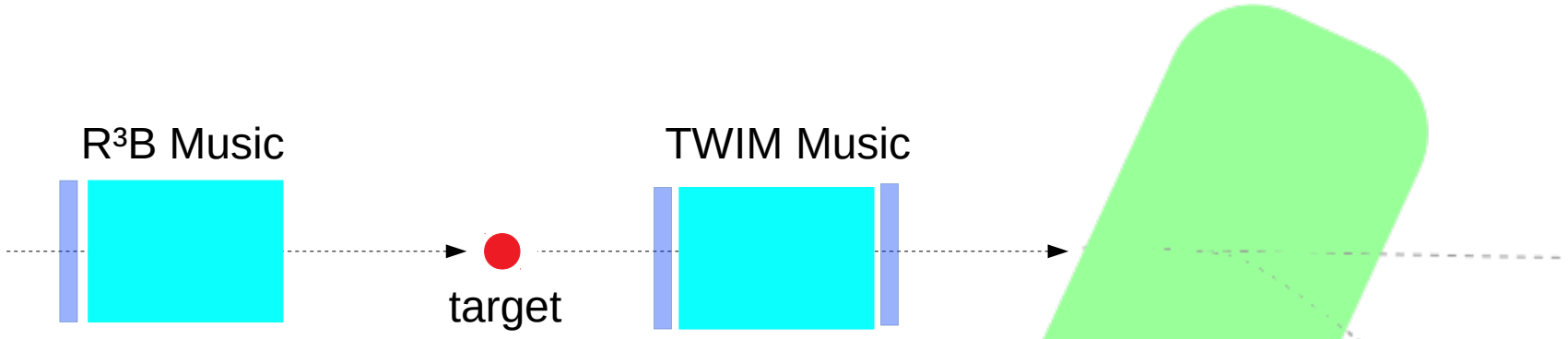
→ gas mixture: 84% Ar, 16% CO2

→ pad readout





Charge Measurement – Ionization Chambers



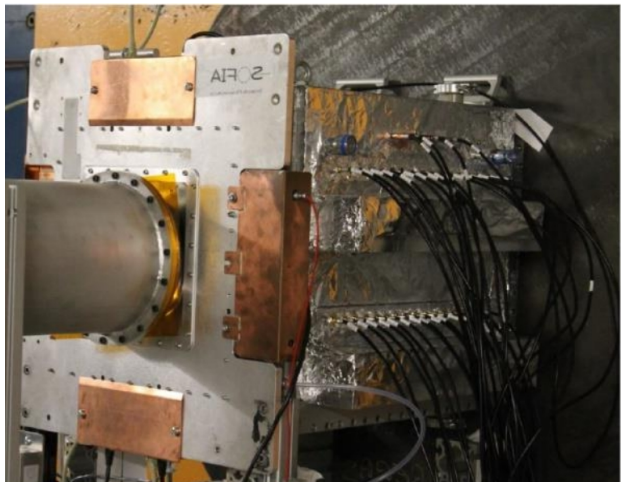
43 x 48 x 55 cm³

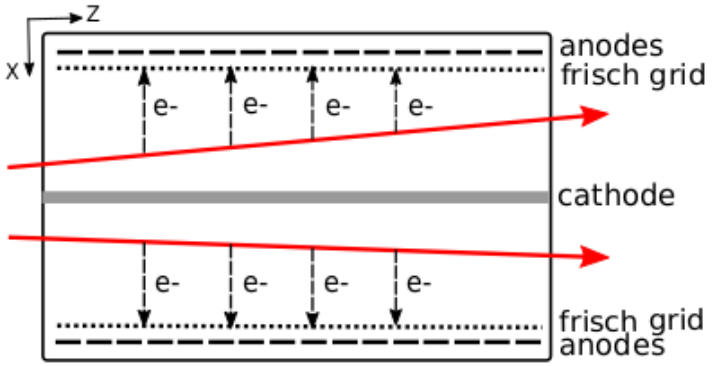
Double ionization chamber

Frisch grid for better signal quality and time resolution

Gas mixture:

Ar 25%, CH4 75%



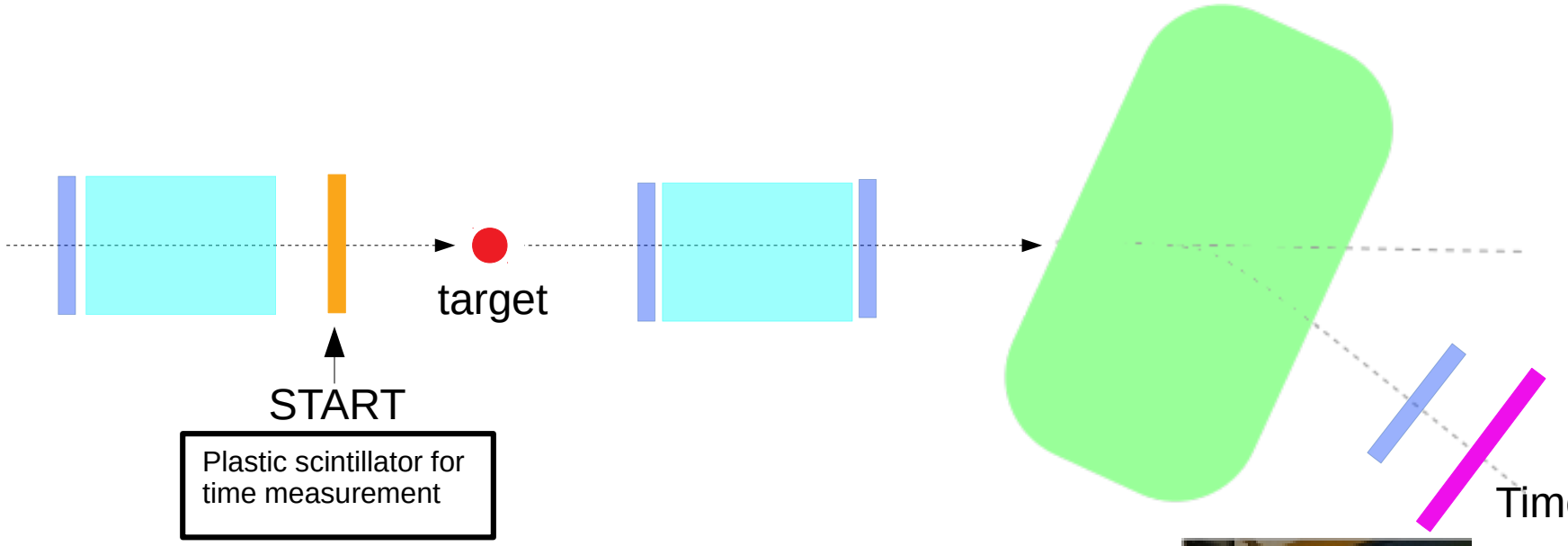


Role of TWIM MUSIC is twofold:

→ charge identification of each FF via energy loss measurement (ΔE/E < 5% FWHM)

→ tracking of the FF (ΔX = 40um)

Time Measurement – START & TOFW

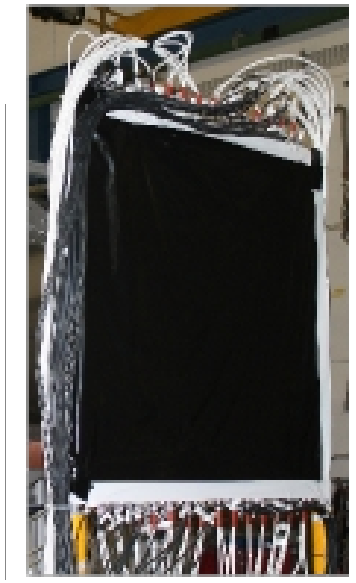


Particle Identification: $B*\rho = \frac{\beta*\gamma*M}{q}$

→ ToF measurement: START to TOFW

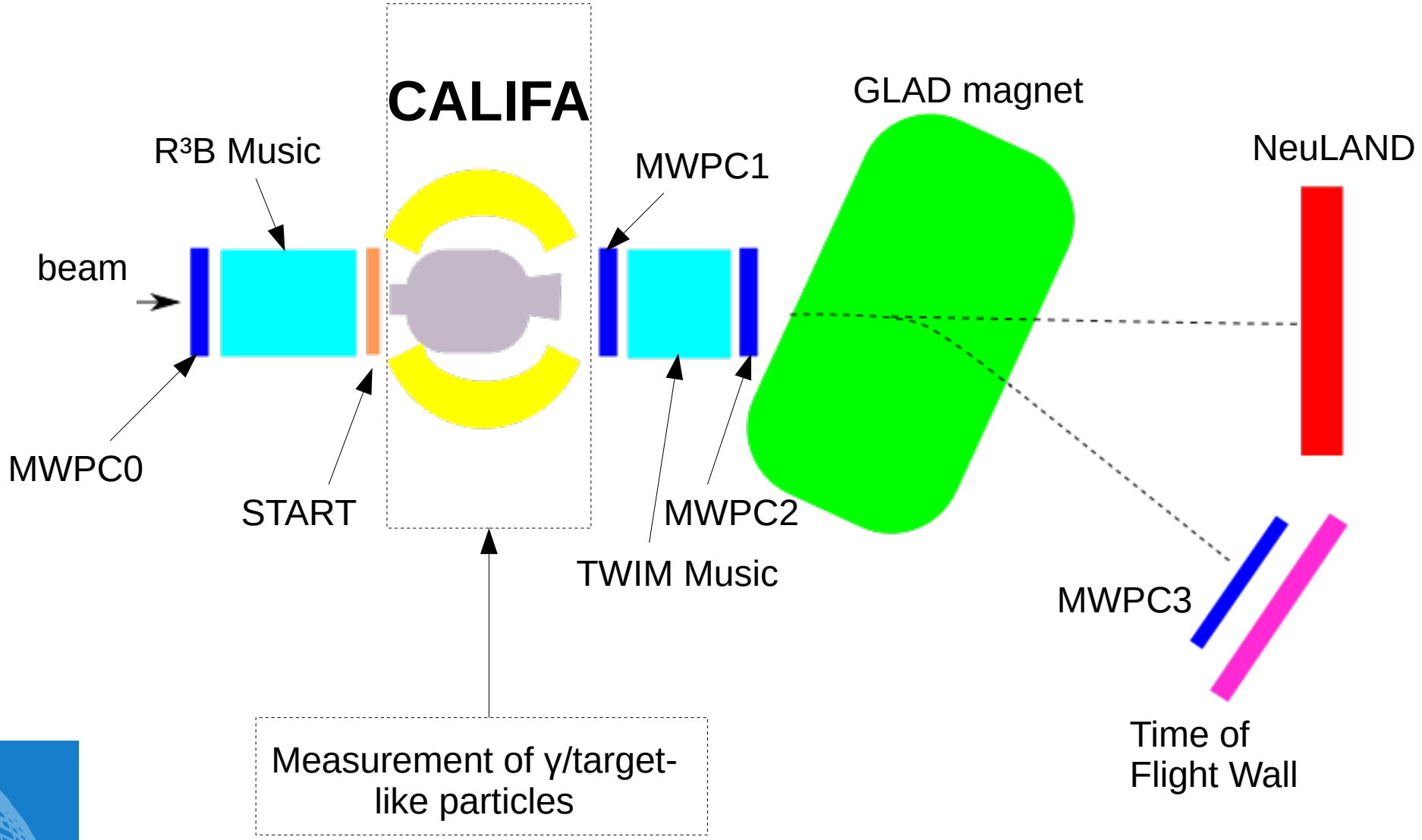
→ flight-path reconstruction: tracking detectors

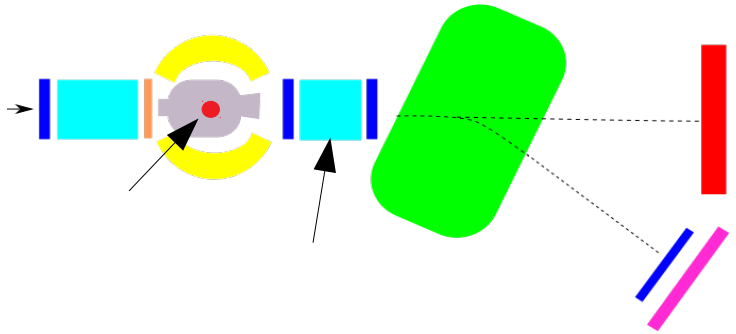
→ charge measurement: TWIM MUSIC



27 vertical scintillators (each 30 x 600 x 5 mm)

time and position measurement


CALIFA
GLAD magnet
NeuLAND
R³B Music
MWPC1
beam
MWPC0
START
MWPC2
TWIM Music
MWPC3
Time of
Flight Wall
Measurement of γ/target-
like particles



bea
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TWIM
MUSIC

CALIFA Detector @ R³B

CALorimeter for the **I**n **F**light detection of γ-rays and light charged p**A**rticles

Endcap:

iPhos:

512 CsI(Tl) crystals

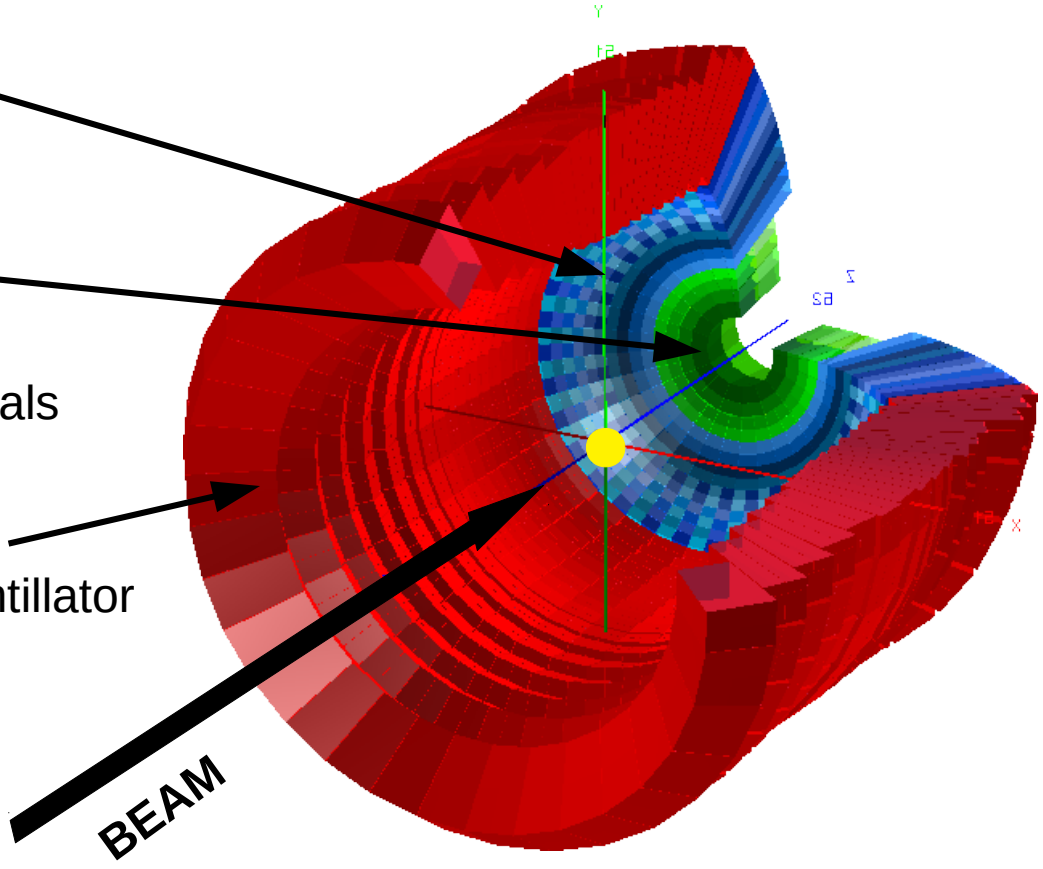
CEPA:

96 LaBr3 &

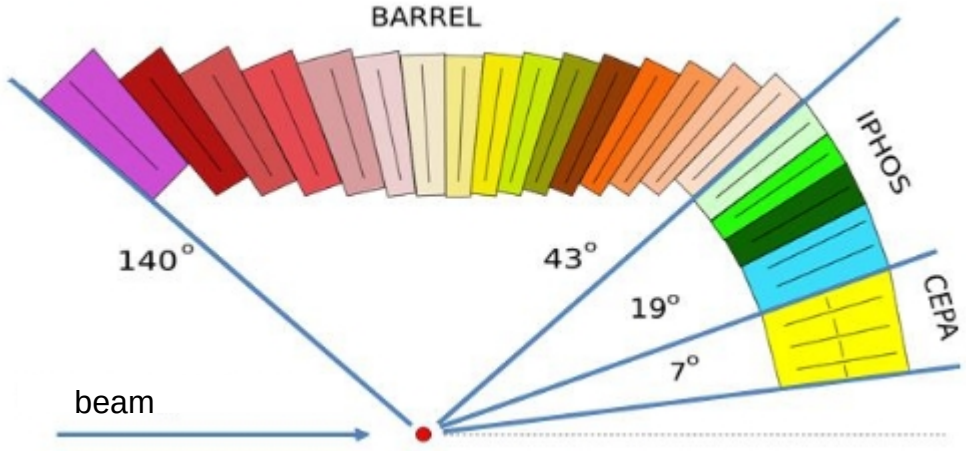
LaCl3 crystals

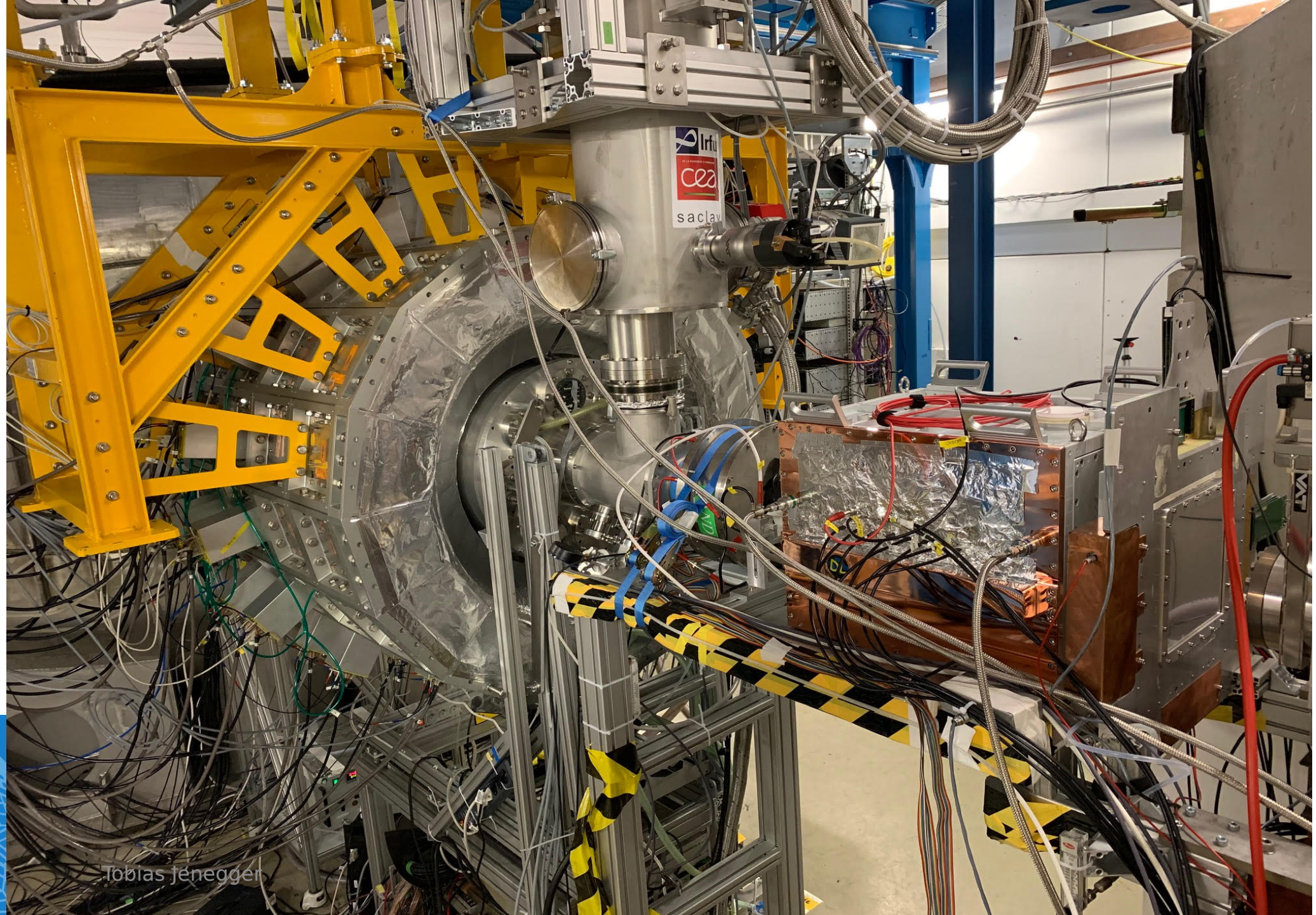
Barrel:

1952 CsI(Tl) scintillator crystals



Requirements:
-high dynamic range:
100 keV γ-rays – 700 AMeV charged particles
-high efficiency
-high granularity → Doppler correction
-particle identification




Irfu
cea
saclay

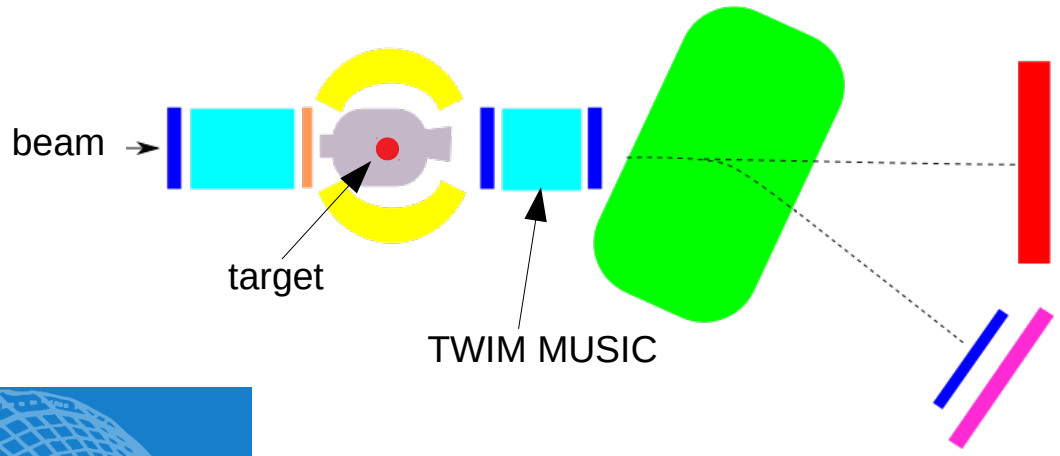
Identification of Fission Process

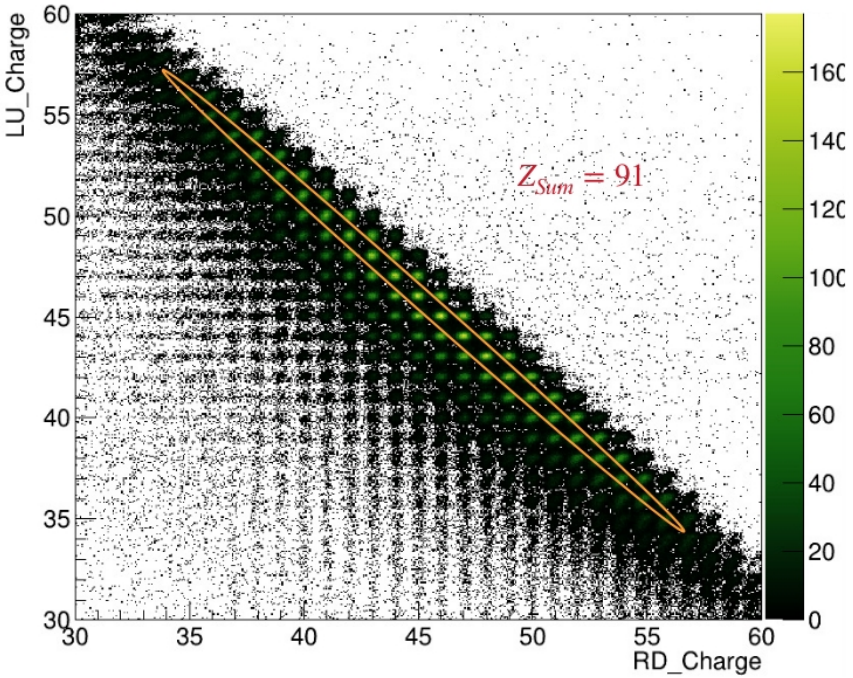
TWIM MUSIC Charge Identification:

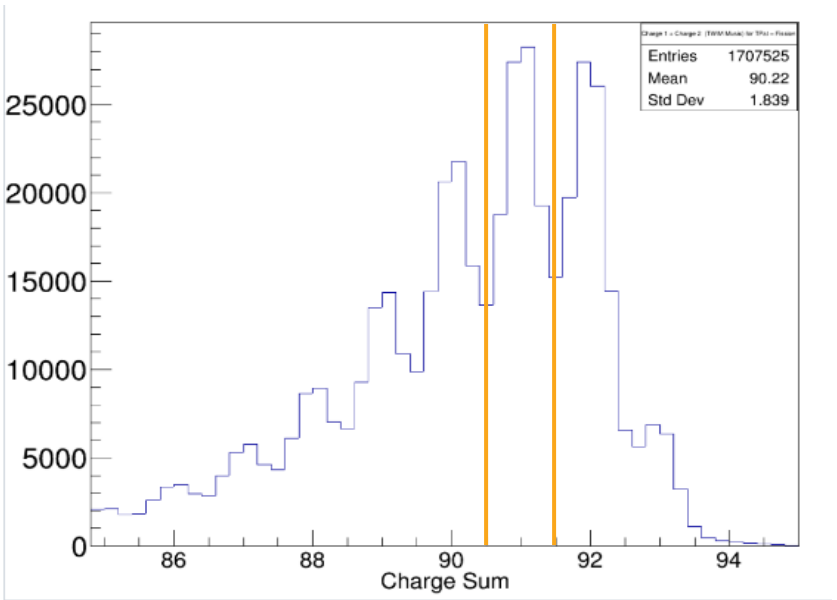
→ two fission fragments (FF)

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

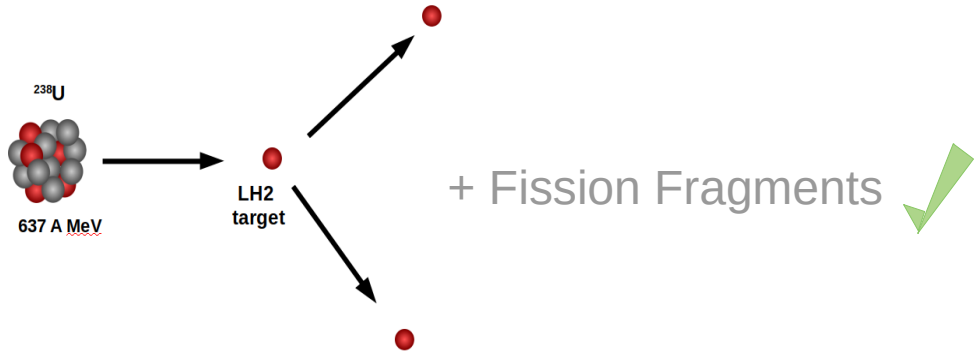
quasi-free scattered proton







Identification of QFS Process



+ Fission Fragments ✓

Select events with (p,2p) condition:

→ two hits with E_{p1},E_{p2} > 100 MeV

→ E_{Σ} < 600 MeV

→ Coplanarity: Δφ = 180° +- 30°

→ Multiplicity ??

→ WRTS??

Insert theta distr exp.

Insert theta distr. sim

Gamma spectrum in CALIFA

Idea: cut on one FF with Z=50 (tin)
Look at the gamma specrum → interesting to understand how energies are shared between the FF

→ show the interesting isotopes of tin
→ show the cuts you did and the gamma spectrum

Outlook

→ calibration of TWIM Music, track reconstruction is essential for clear separation of isotopes
→ make also full energy reconstruction
→ fission barrier /spectra of excited FF

Thank you!

CALIFA @ Technical University of Munich (TUM)

Roman Gernhäuser, Lukas Ponnath, Philipp Klenze, Tobias Jenegger

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Backup