The PRISMA spectrometer

A brief introduction

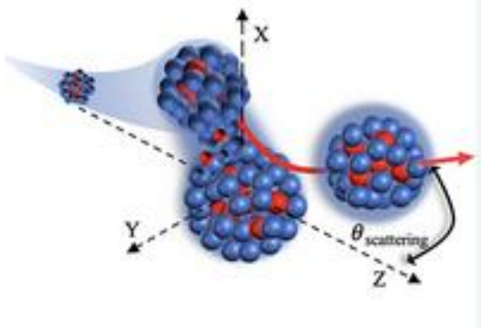
F. Angelini, INFN LNL and UniPD

adapted from
F. Galtarossa, INFN PD

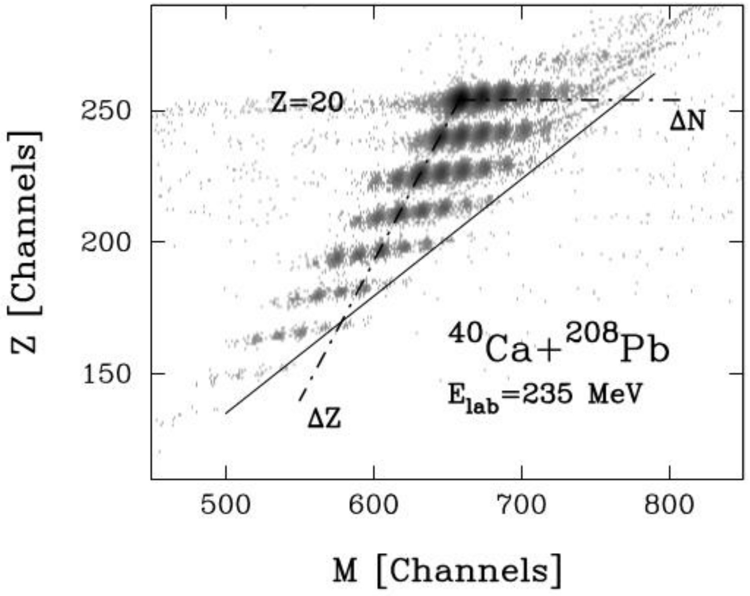
Outline

- What kind of reactions can we study with PRISMA?
- Characteristics of the PRISMA spectrometer
- The different PRISMA detectors
- Main steps of PRISMA analysis
- PRISMA ancillaries (except for AGATA)
- Some recent (small) upgrades

MNT reactions at near-barrier energies

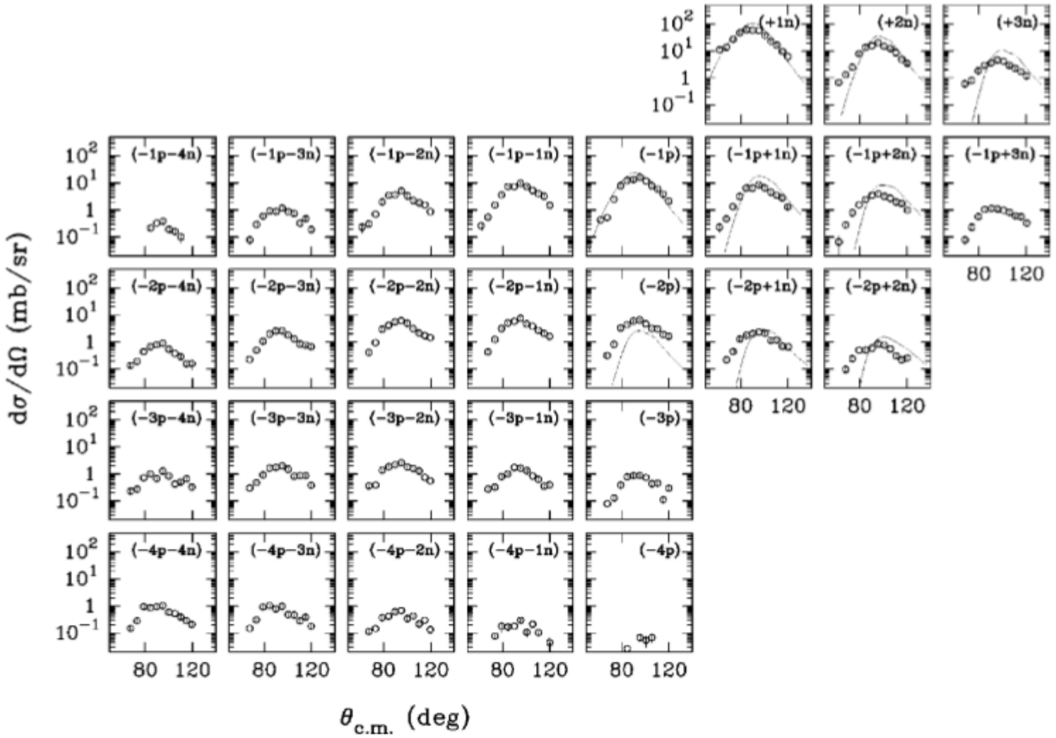


Reaction products close to the reactants



S. Szilner et al., Phys. Rev. C **71** (2005) 044610

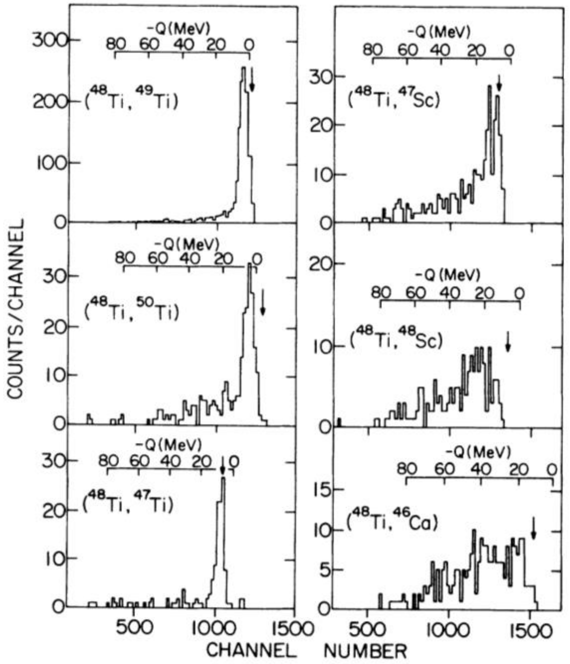
Angular distributions peaked at the grazing angle



L. Corradi et al., Phys. Rev. C **59** (1999) 261

Typical bombarding energies: few MeV/u

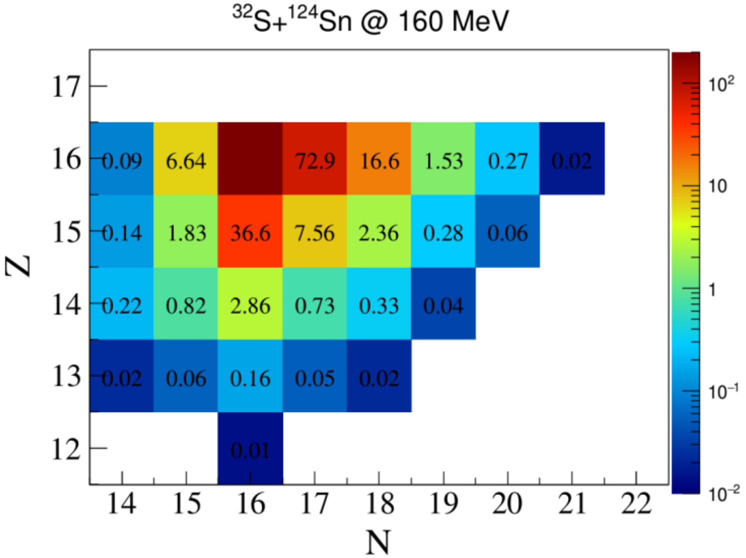
Increasing energy loss components as more nucleons are transferred



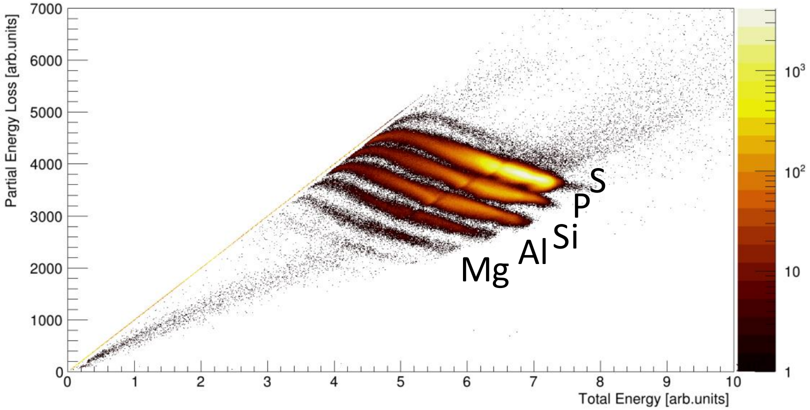
K. E. Rehm et al., Phys. Rev. C **37** (1988) 2629

The AGATA-PRISMA commissioning

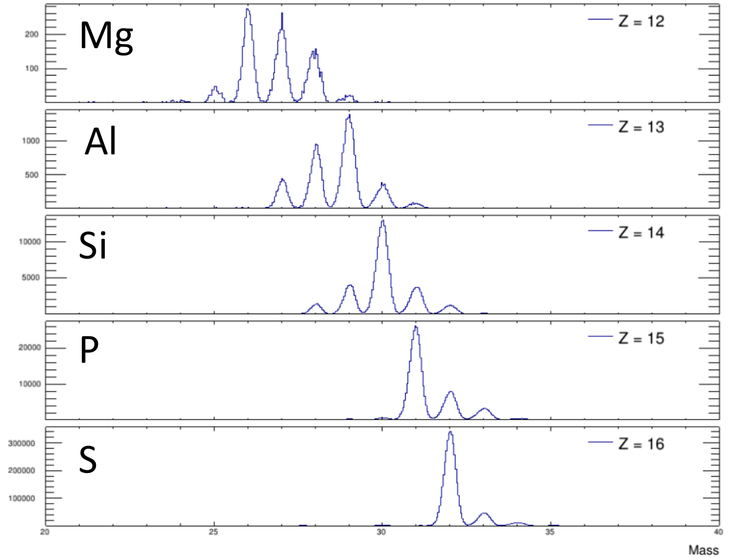
Multinucleon transfer reaction



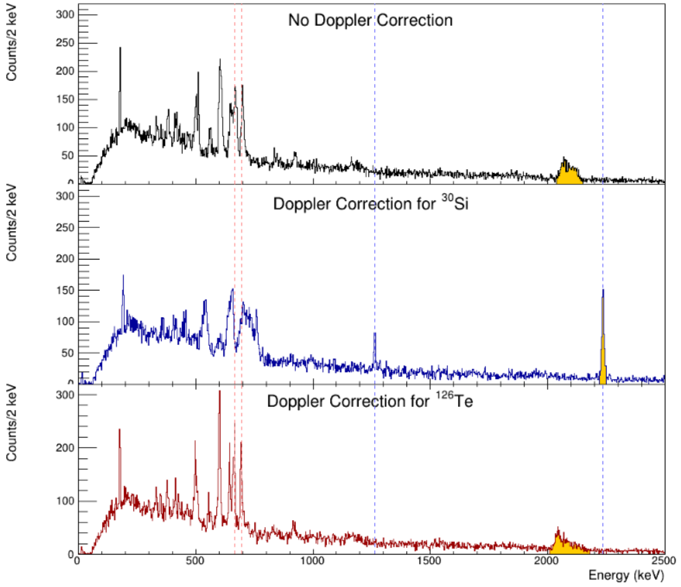
Nuclear charge identification

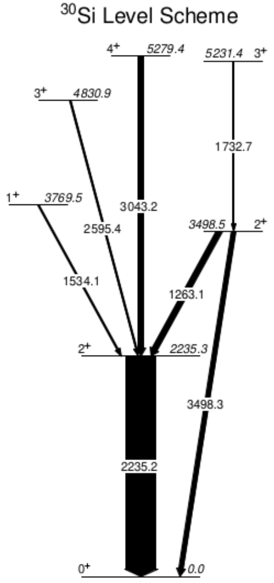


Mass identification

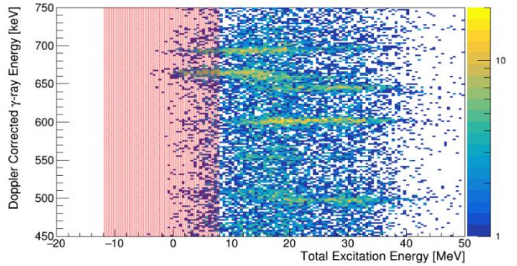


Event-by-event Doppler correction

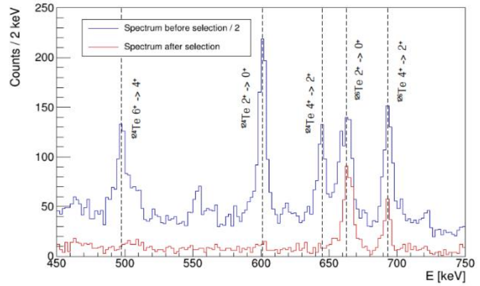




Use the Q value to control n-evaporation



Spectroscopy or lifetime measurements

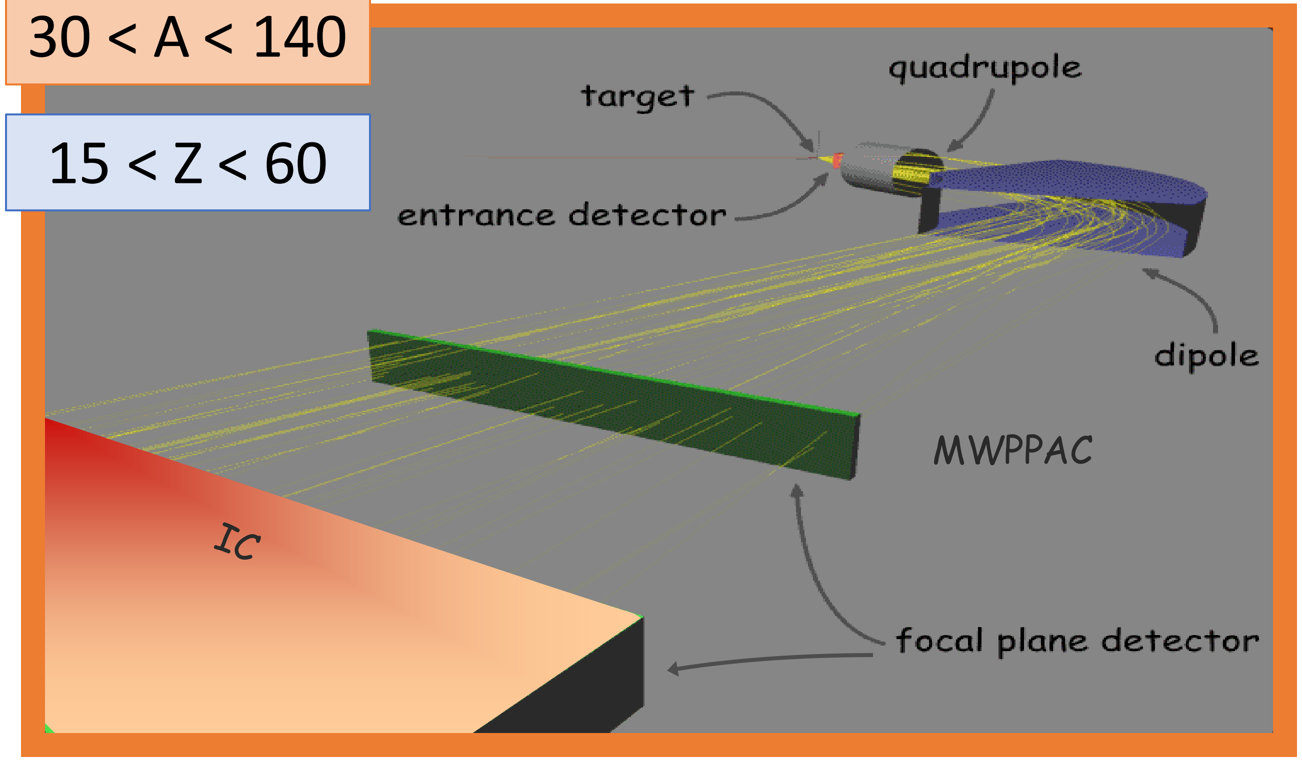


E. Pilotto, Master Thesis, Università di Padova (2022)
F. Angelini, Master Thesis, Università di Padova (2022)

Trajectory reconstruction

30 < A < 140

15 < Z < 60



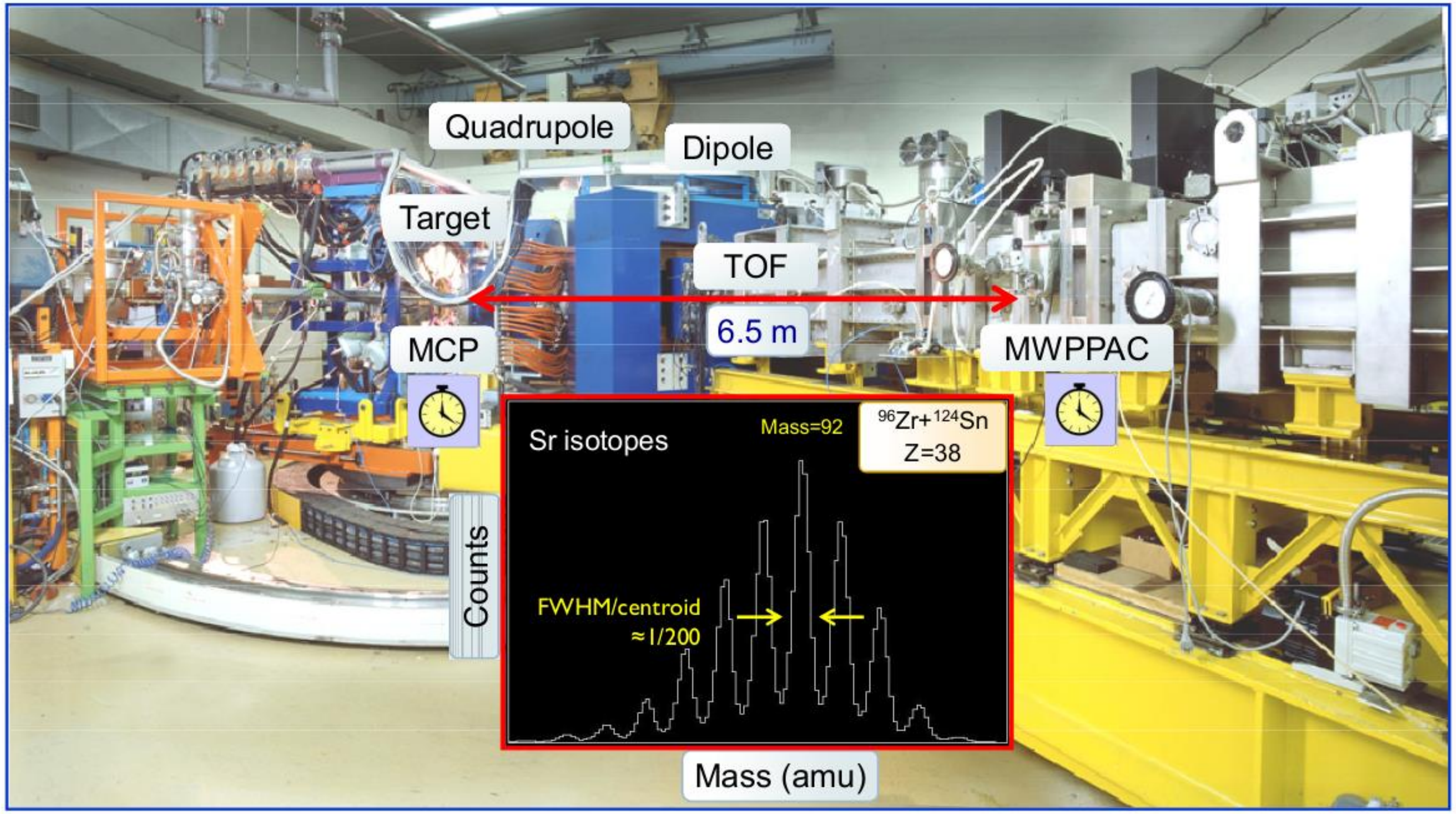
A physical event is composed of:

- Entrance position (x,y) -> (θ,ϕ) — MCP detector
- Position at the focal plane (x',y') — MWPPAC detector
- Time-of-Flight (ToF) — Δt MCP-MWPPAC
- Energy (ΔE-E) — Ionization Chamber

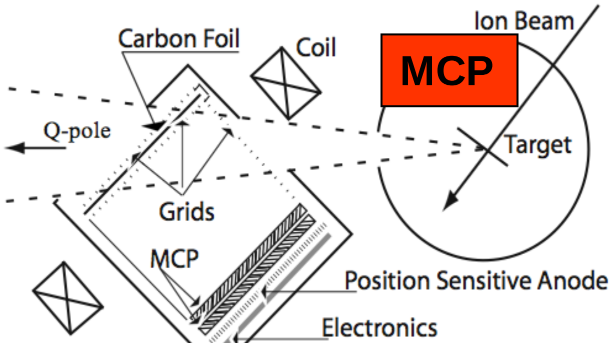
Solid angle ΔΩ	~ 80 msr
Angular acceptances	Δθ ≈ ±6°; Δϕ ≈ ±11°
Energy acceptance	±20%
Momentum acceptance	±10%
Mass resolution	ΔA/A ≈ 1/300
Nuclear charge resolution	ΔZ/Z ≈ 1/60
Maximum Bρ	~ 1.2 Tm
Dispersion	Δp/p ≈ 4 cm/%
Distance target-FPD	~ 6.5 m
IC Energy resolution	~ 1%
MCP and MWPPAC x,y position resolutions	~ 1 mm
MCP and MWPPAC timing resolutions	~ 350 ps
Maximum rate at the FP	~ 3 kHz
θ_{PRISMA} (AGATA standard position)	20° < θ < 88°
θ_{PRISMA} (AGATA close position)	35° < θ < 88°

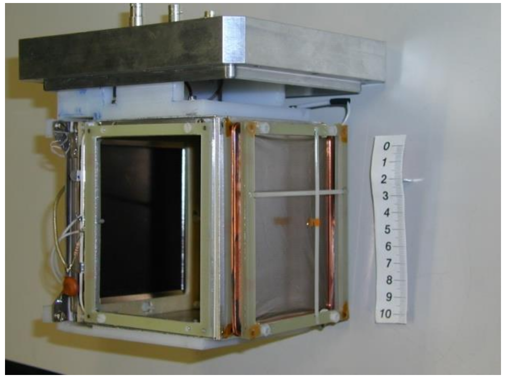
Trajectory reconstruction

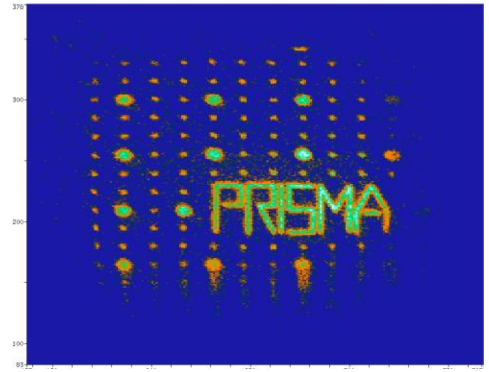
X, Y entrance position -> Mass resolution, Q-value resolution, Doppler correction
ToF and position resolution -> Mass resolution, Doppler correction
ToF offset determination -> Doppler correction
Z resolution -> Atomic number identification

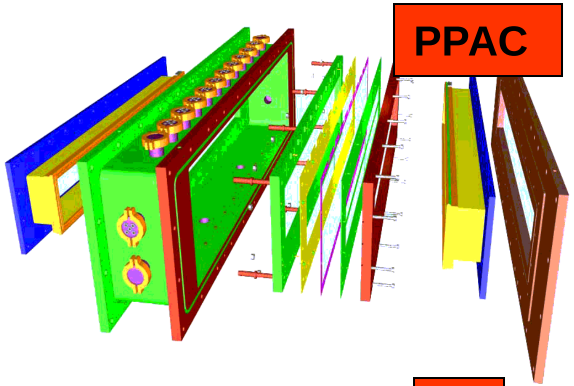


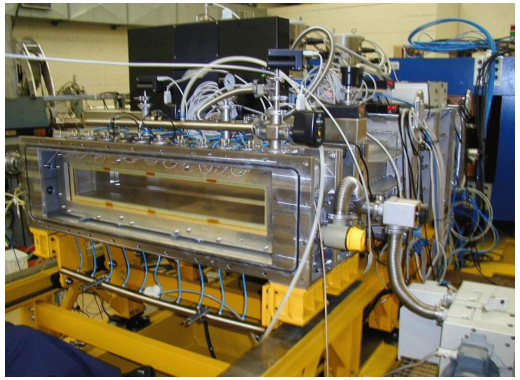
PRISMA detectors

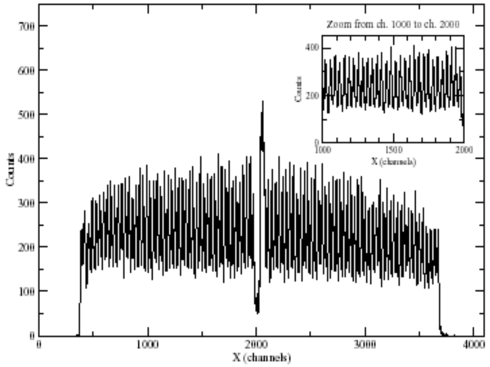


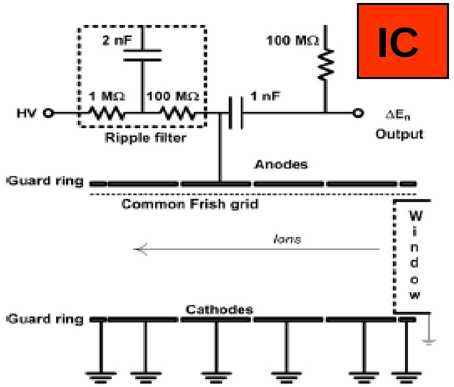


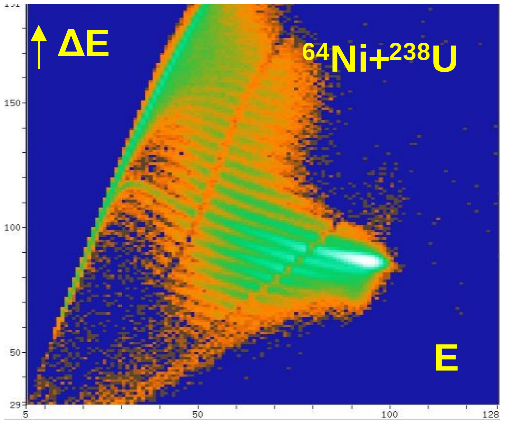












PRISMA MCP

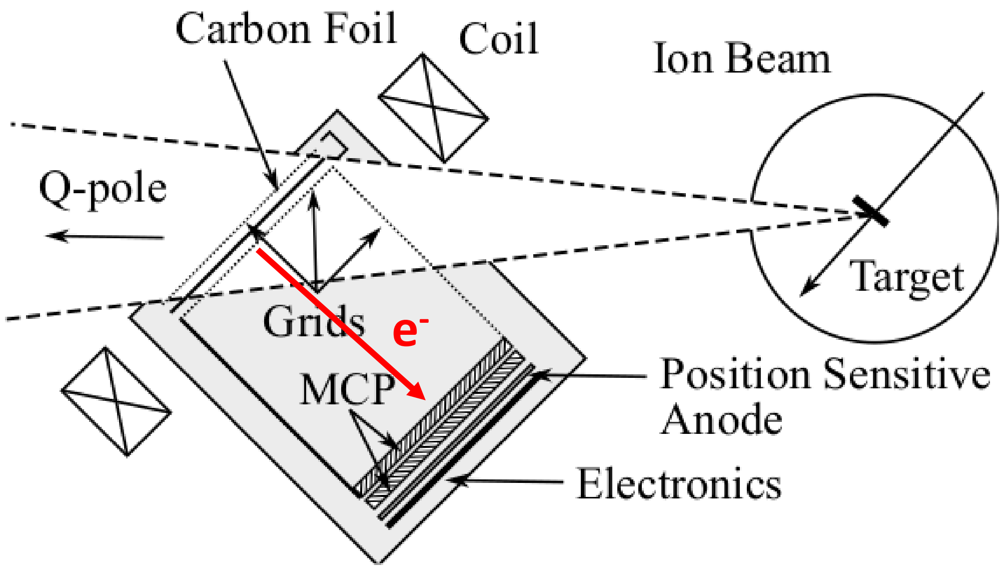
- Active area: 8x10 cm^2 (Ω = 80 msr)

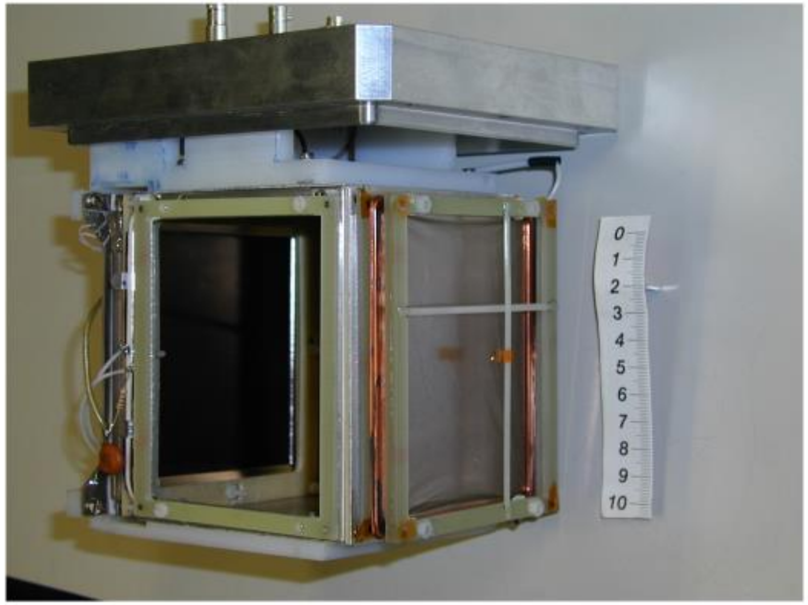
-> full coverage of PRISMA spectrometer at d = 25 cm from target

- Timing resolution for TOF ~ 350 ps
- C foil: 20 $\mu g/cm^2$ thick (100 nm!)
- E_{acc} = 30-40 kV/m
- Parallel magnetic field: B ~ 120 G to limit the spread of electron cloud preserving particle position information
- 3 signals: X, Y, time

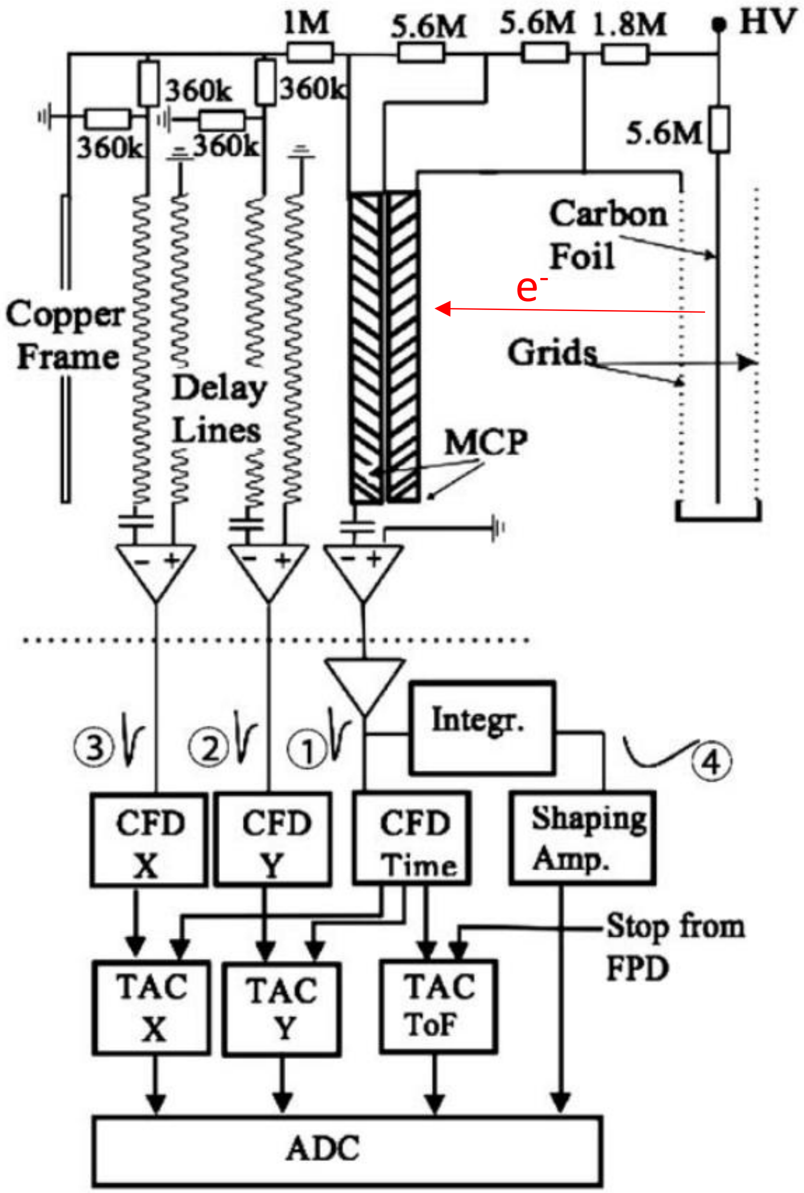
For the analysis: only 2 signals for the MCP (X, Y)

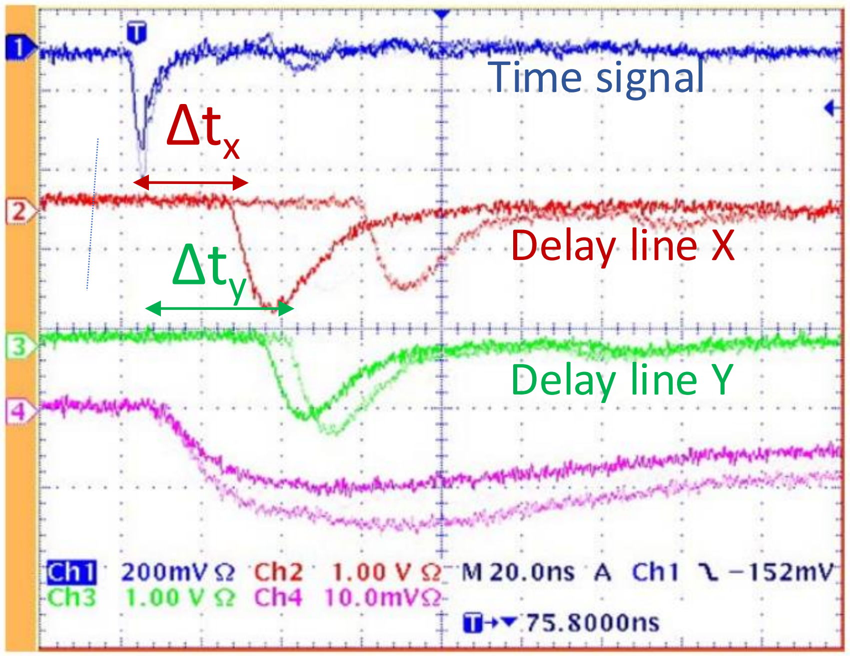
G. Montagnoli et al., NIM A **547** (2005) 455-463



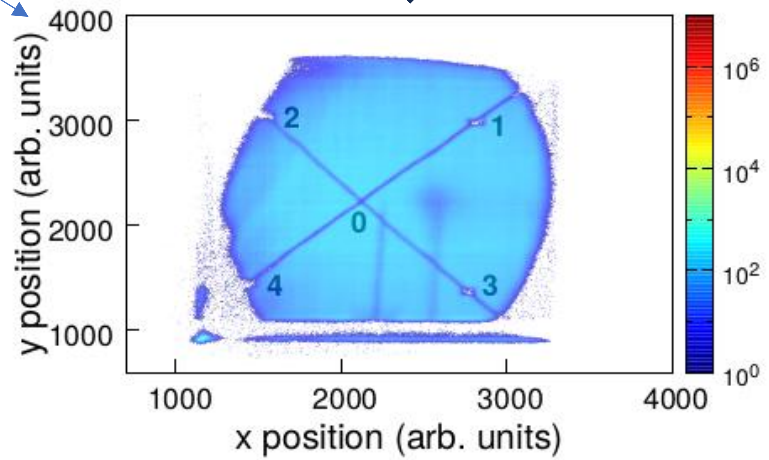


PRISMA MCP



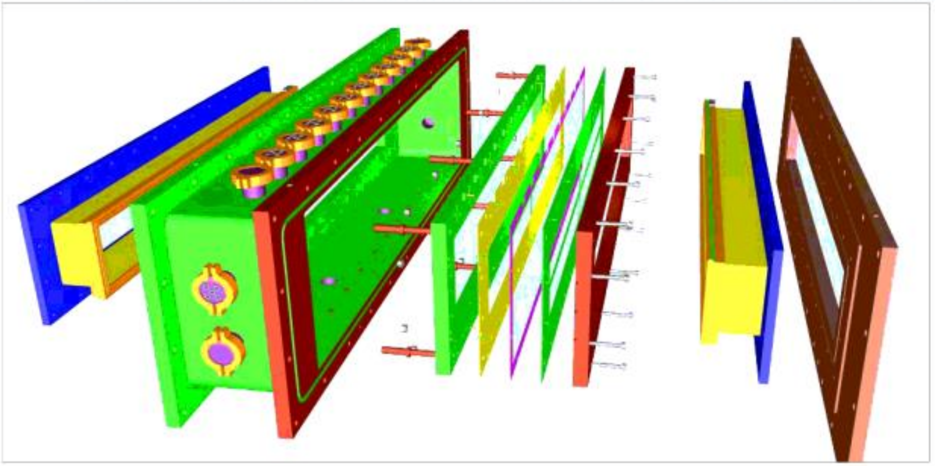


Raw MCP matrix

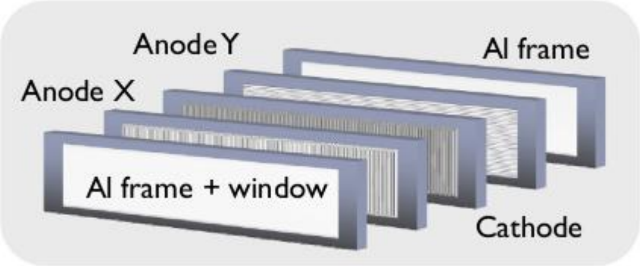


PRISMA MWPPAC

Focal Plane Detector

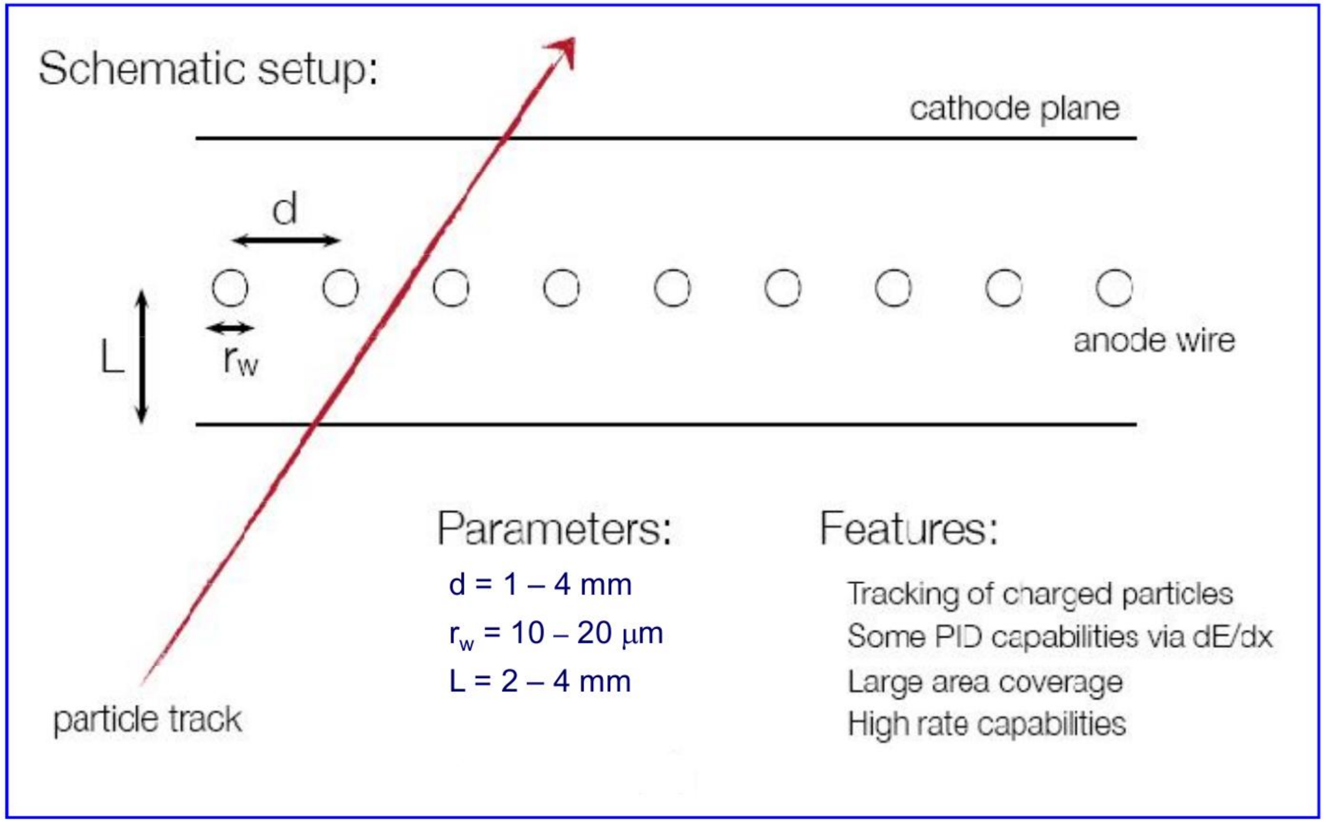


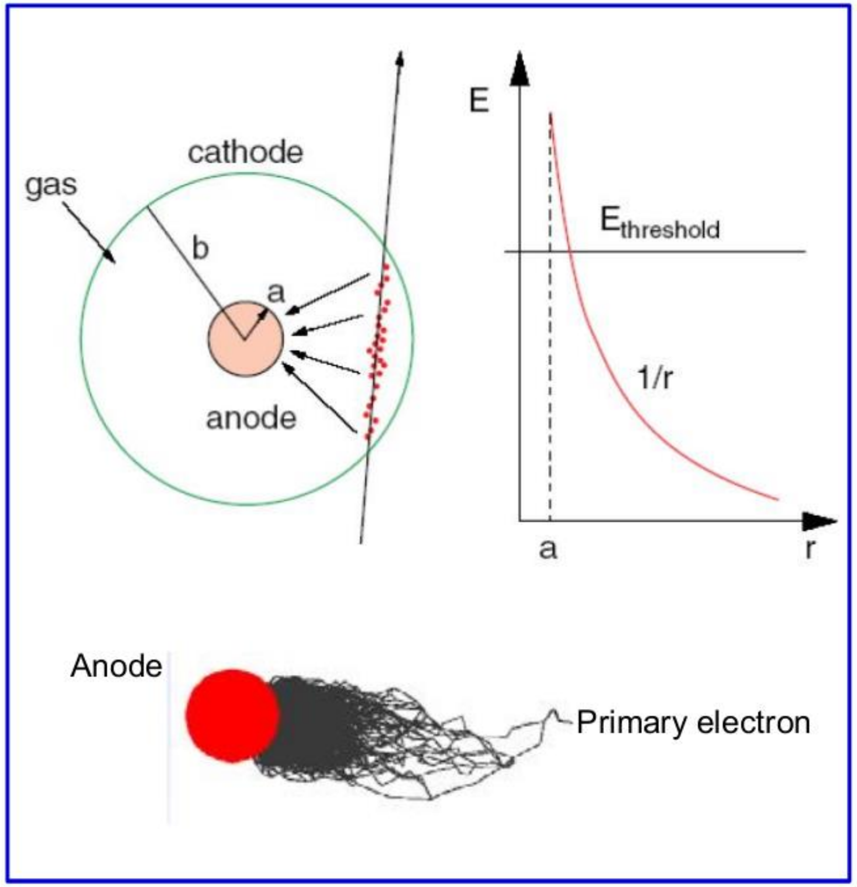
S. Beghini *et al.*
NIM **A551** (2005) 364



- **Active area:** 100 cm x 13 cm
- **3 electrode structure**: central cathode + 2 anode wire planes (X and Y) $d_{A\text{-}C}$ = 2.4 mm
- **cathode:** 3300 wires of 20μm gold-plated tungsten - 0.3 mm spacing - 10 independent sections of 10x13 cm^2 negative high voltage: 500-600 V
- **X plane**: 10 sections of 100 wires each, 1mm spacing
- **Y plane**: common to all cathode,130 wires, 1 m long, 1mm steps
- **spatial resolution**: ΔX ~ 1mm, ΔY ~ 2mm (FWHM)
- **stop signal for TOF**
- **10 x 3 signals** (X_{left}, X_{right}, timing) **2 signals** (Y_{up}, Y_{down})
- **Filling gas**: C_4H_{10} **Pressure**: 7 mbar

MWPC (Multi-Wire Proportional Chamber





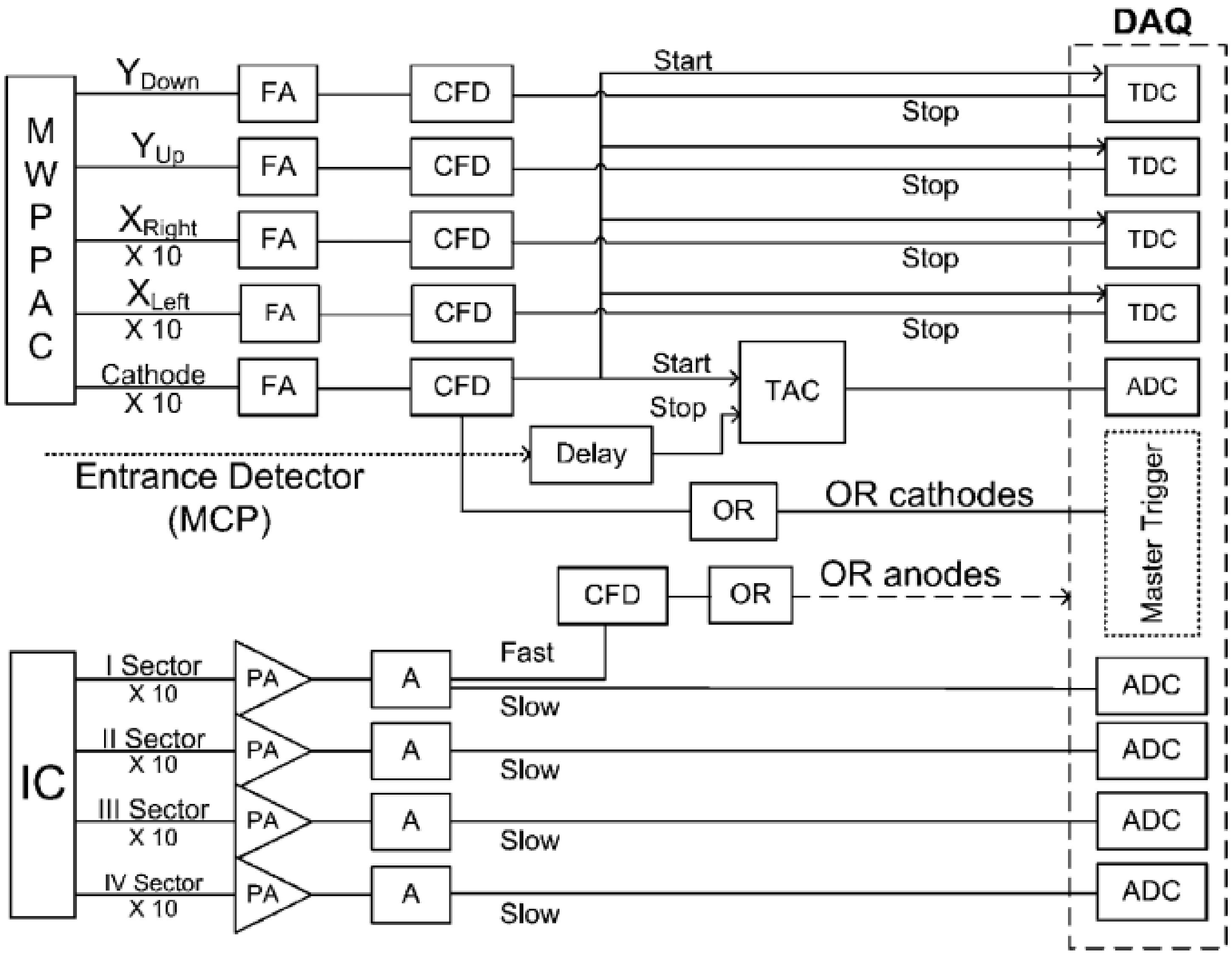
E. Fioretto

PRISMA MWPPAC

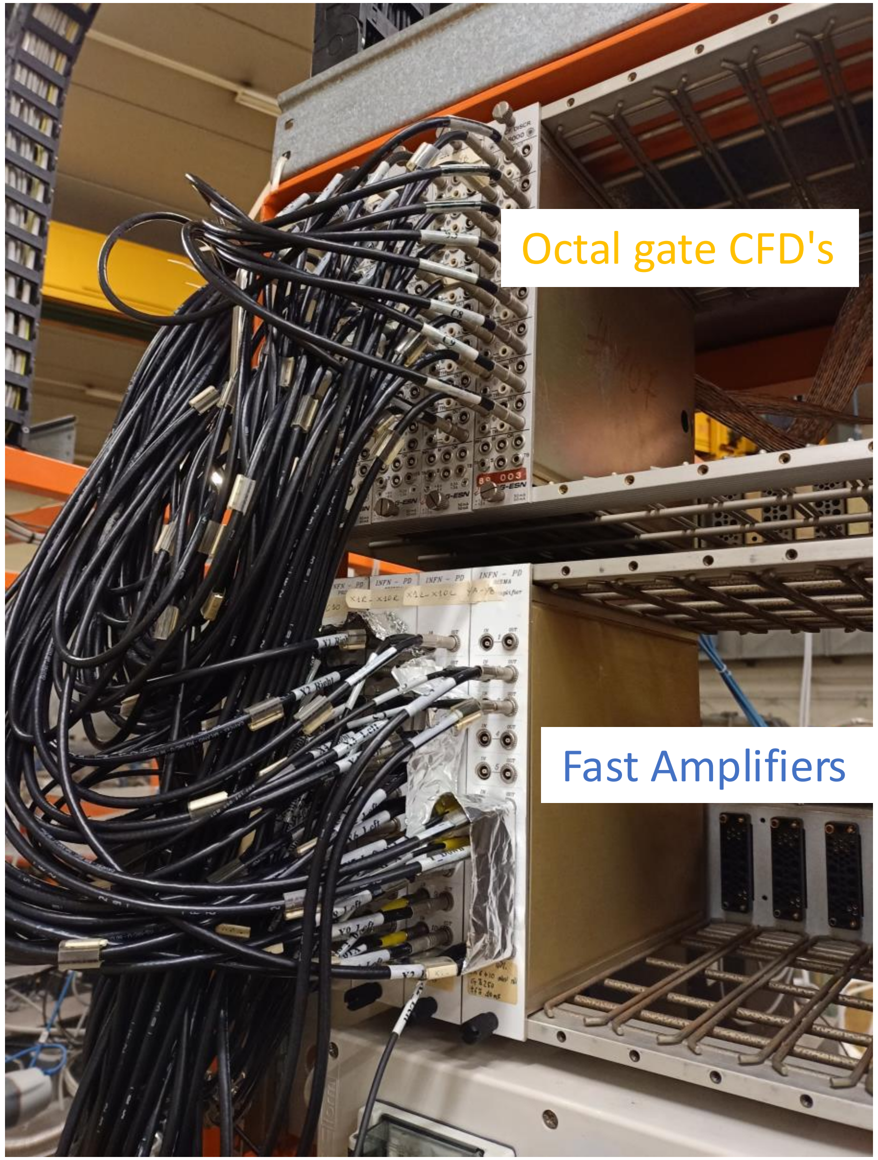
For the analysis: 42 signals for the PPAC!

MWPPAC

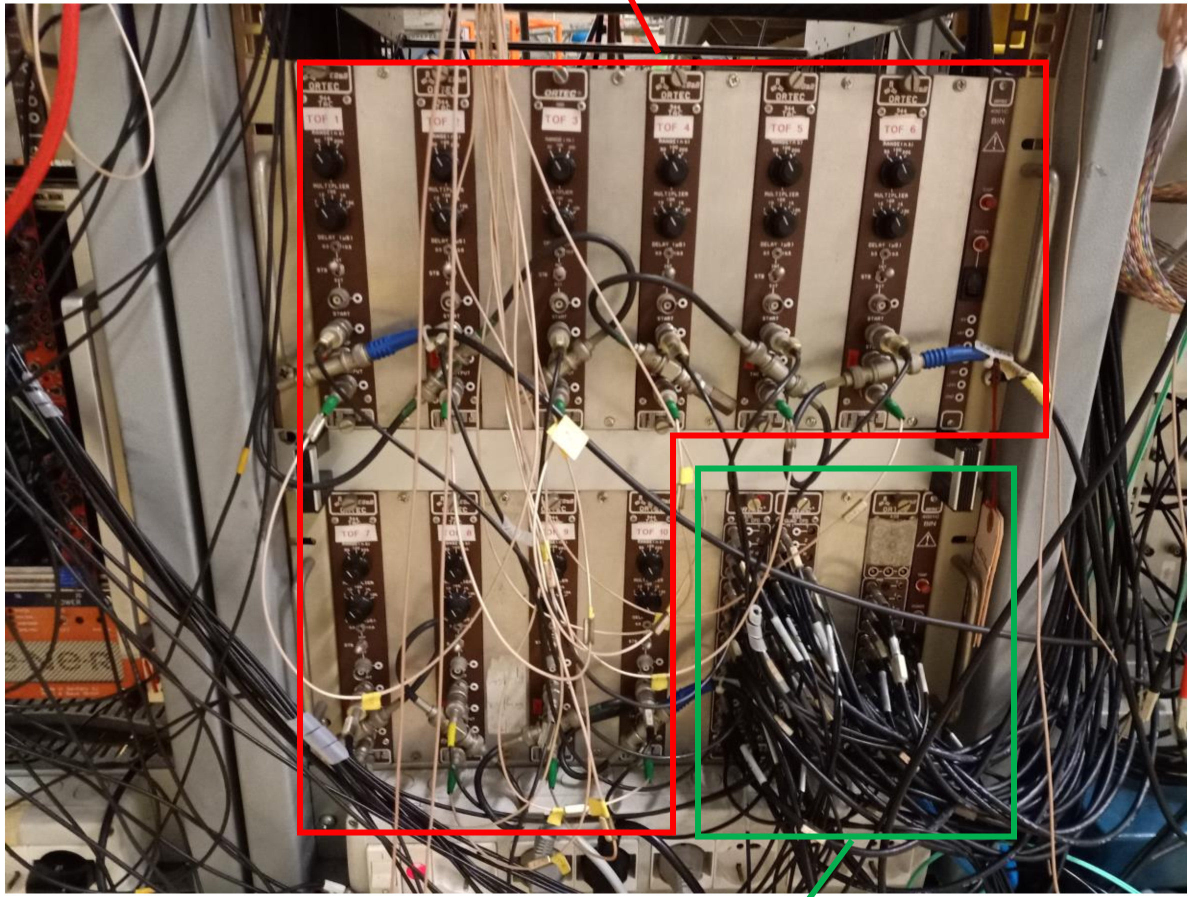
Fabio



PRISMA MWPPAC



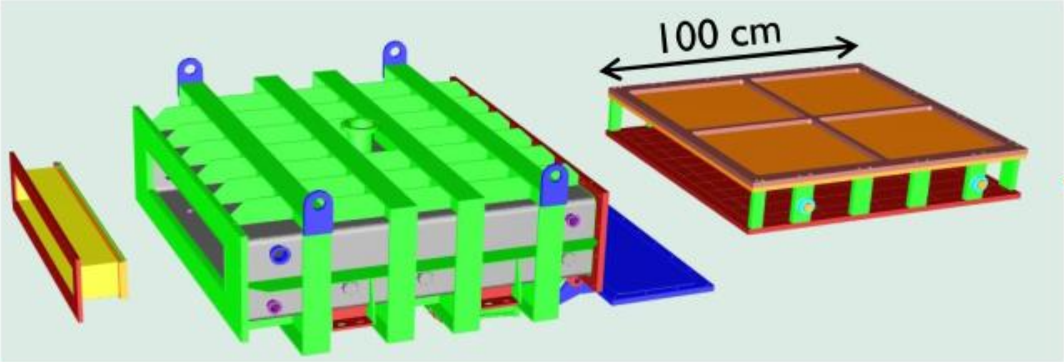
TAC's for ToF determination

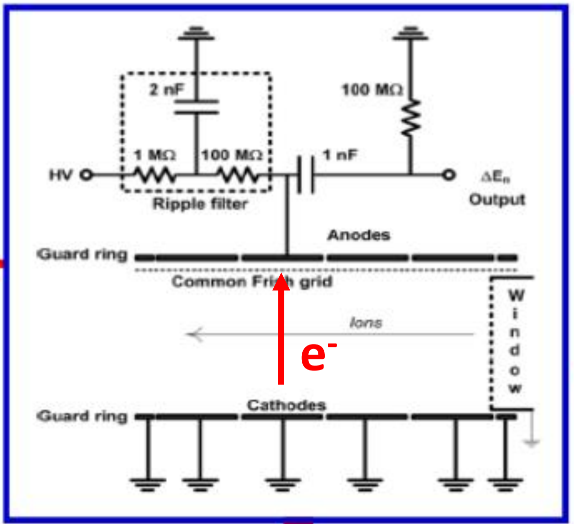


CFD's for timing signals from the cathode

PRISMA IC

Multi-anode transverse field IC

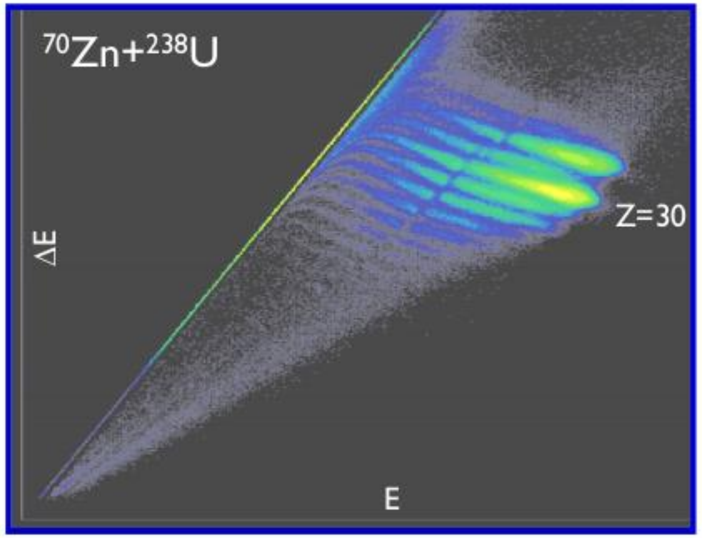




10x4 sections
10x25 cm²

E.Fioretto et al.
LNL Ann. Rep. **2002**, p.148

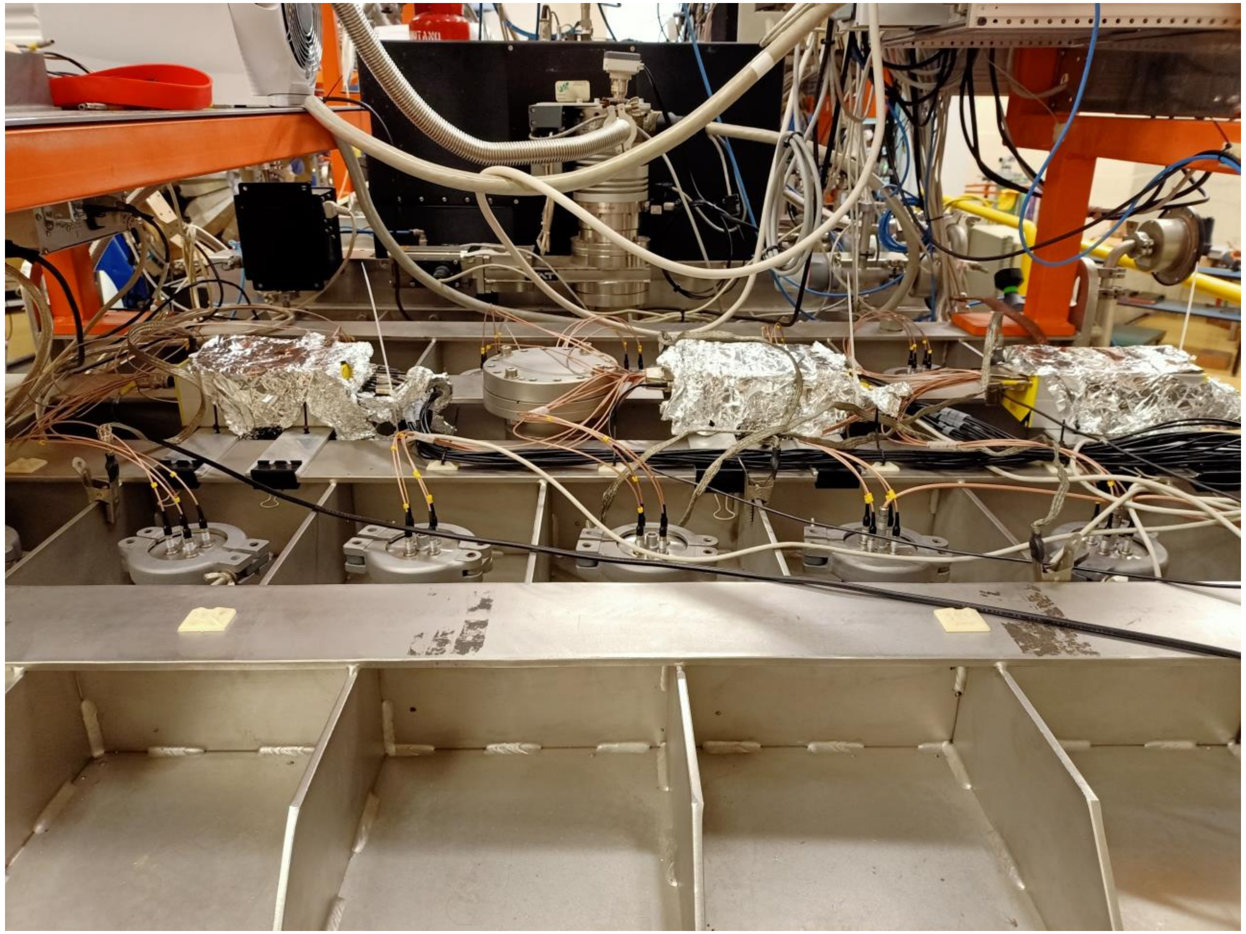
ΔE/E < 2%
ΔZ/Z/ ~ 1/60 for Z=20



E. Fioretto

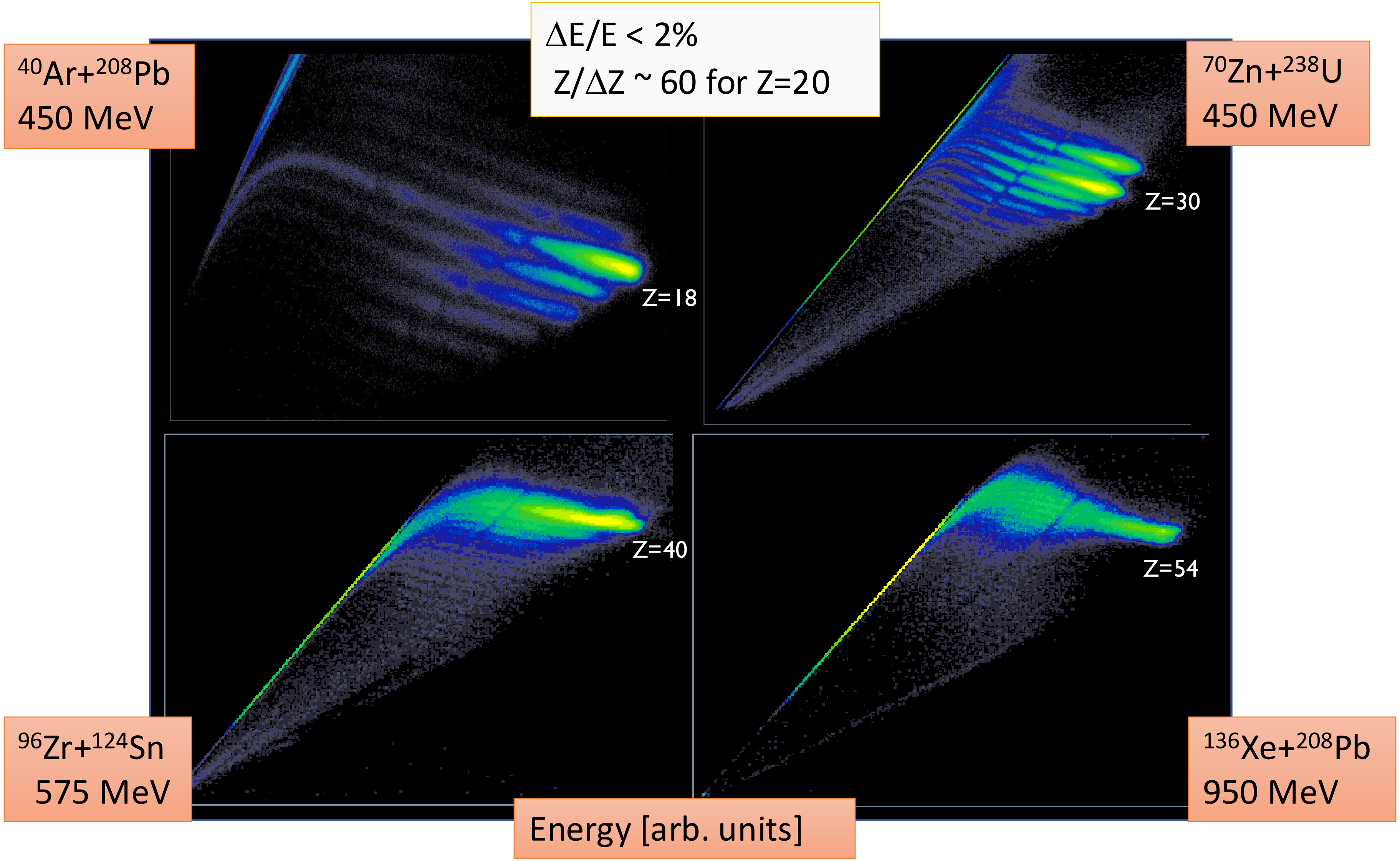
PRISMA IC

Pre-amplifiers on top of the IC

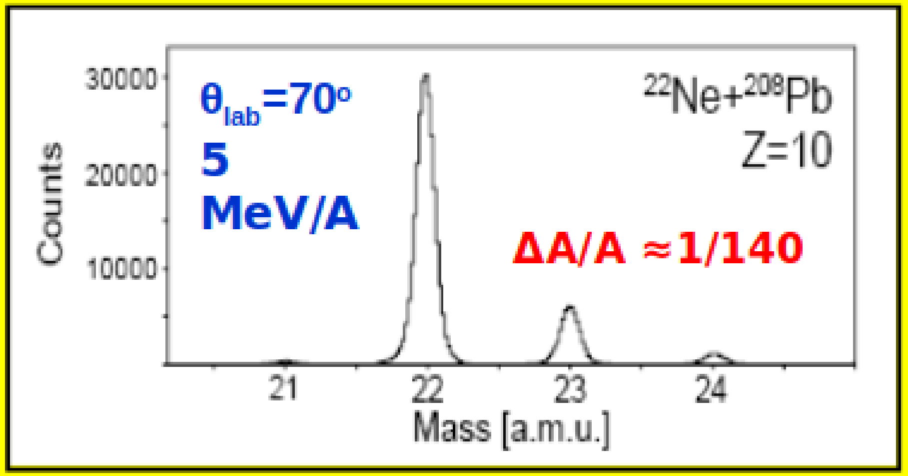


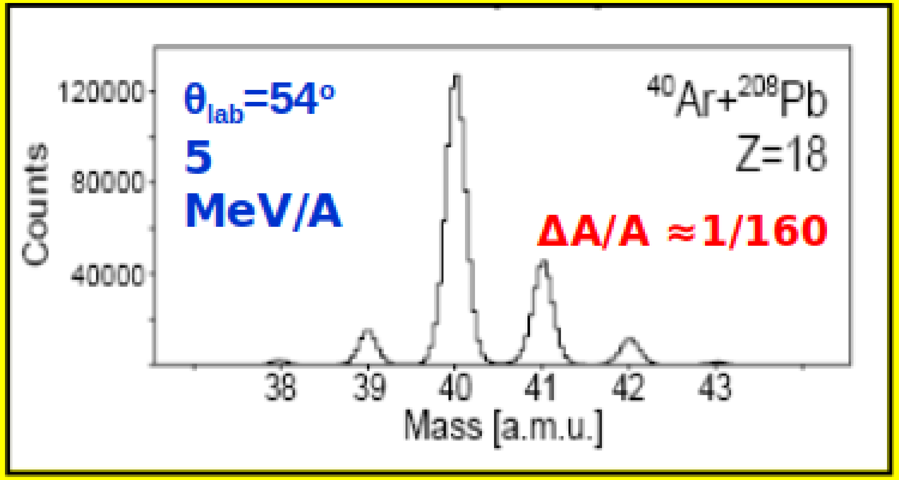
Mesytec amplifiers (gain set)

Nuclear charge identification

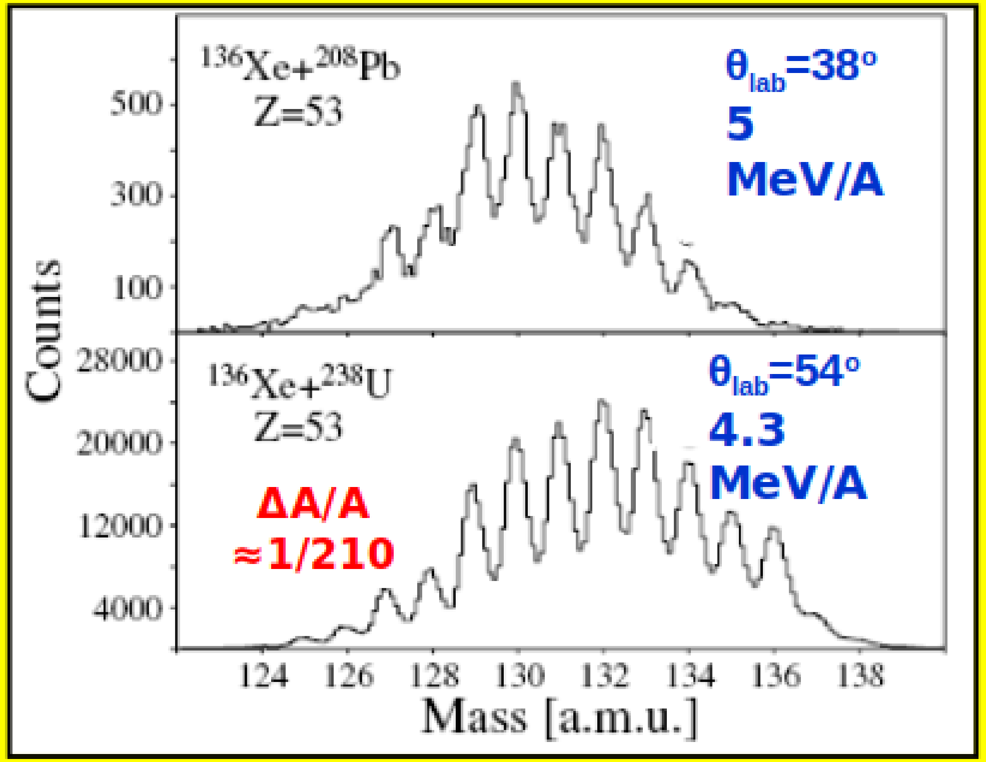


Mass resolution obtained after trajectory reconstruction

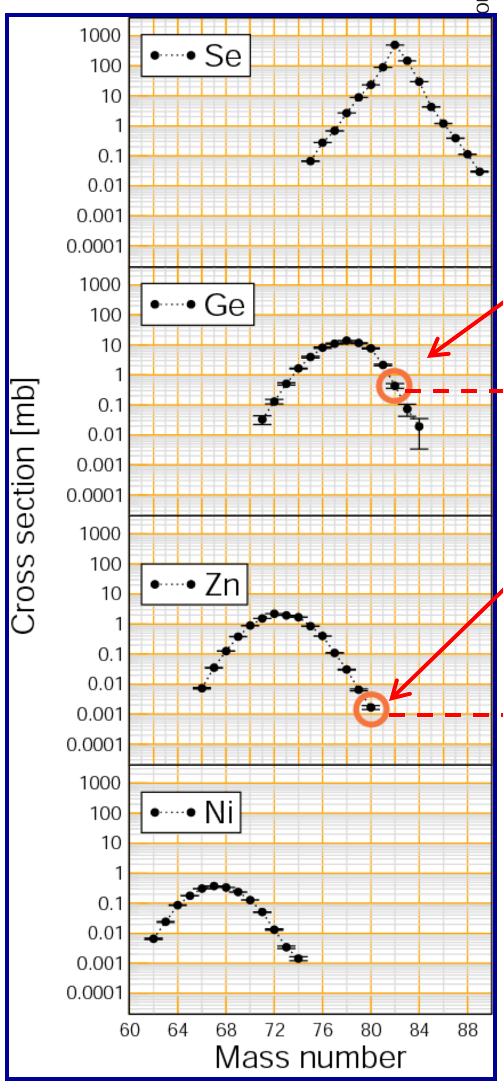


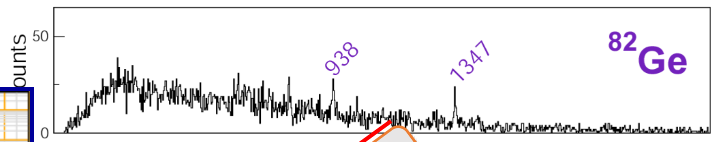


the obtained mass resolutions for the different ions are close to the values expected taking into account detector resolutions (positions and timing)



Cross section sensitivity





PRISMA+CLARA

Nuclear structure studies

~ 0.6 mb

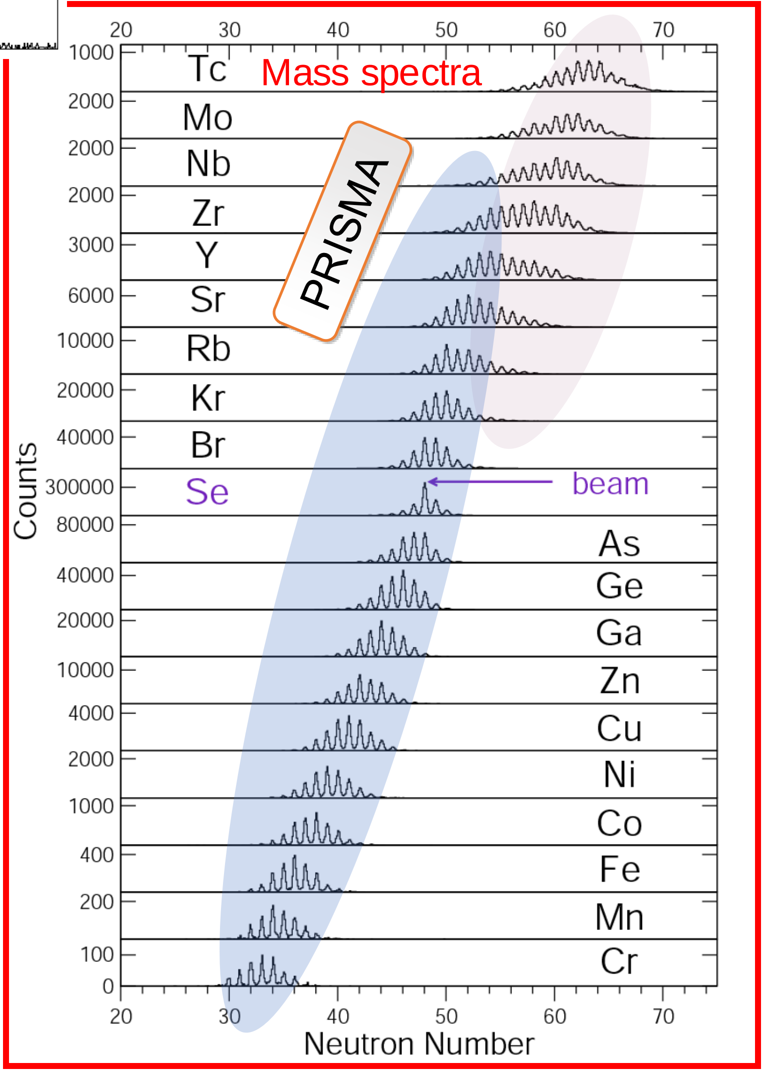
^{80}Zn

Nuclear dynamics studies

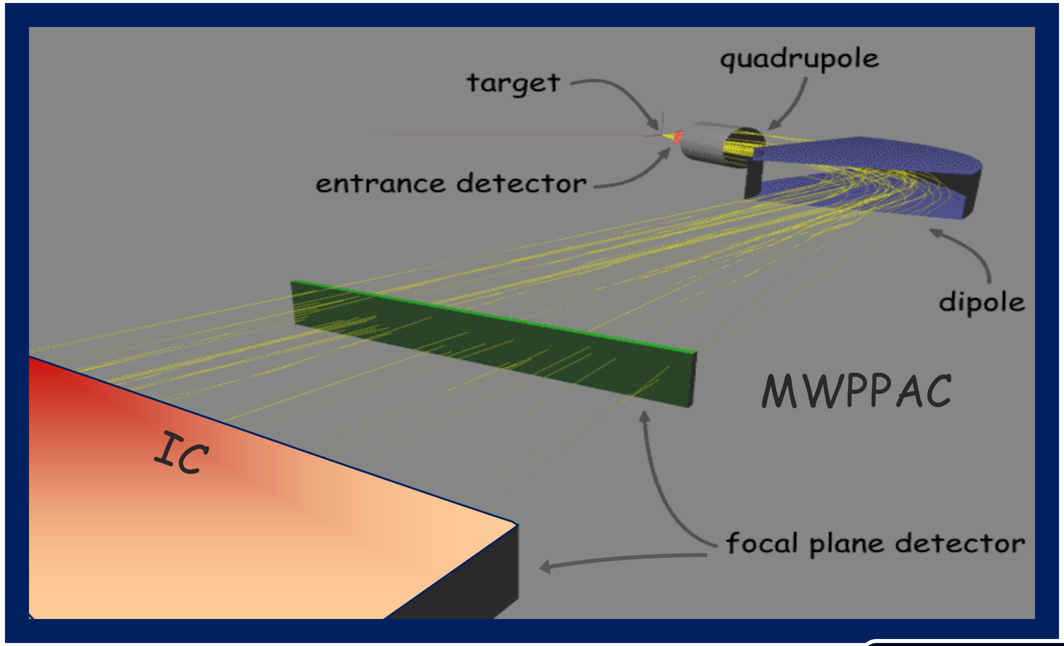
~2 μb

PRISMA @ 64°

^{82}Se+^{238}U @ 505 MeV



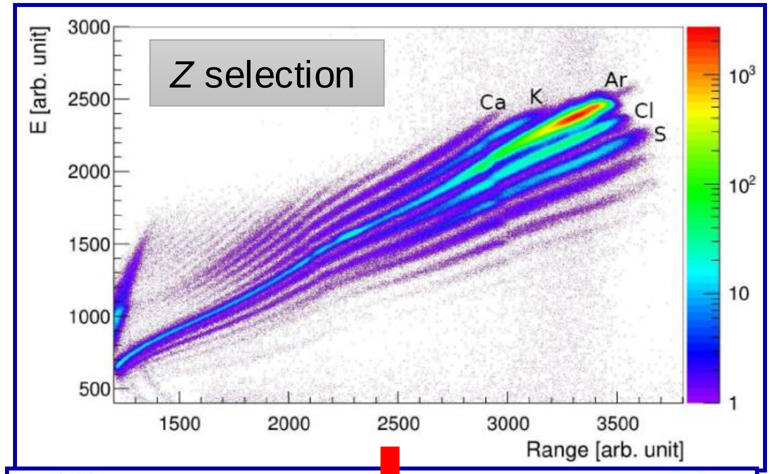
Analysis steps



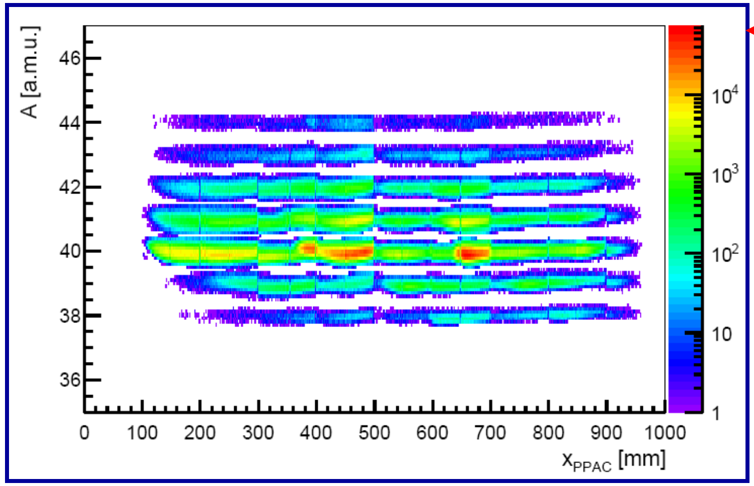
A physical event is composed by the parameters:

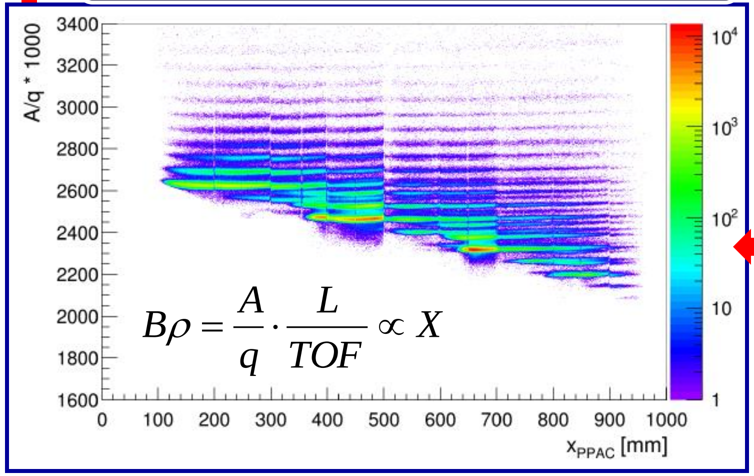
- **position at the entrance** — **x, y**
- **position at the focal plane** — **X, Y**
- **time of flight** — **TOF**
- **energy** — **ΔE, E**

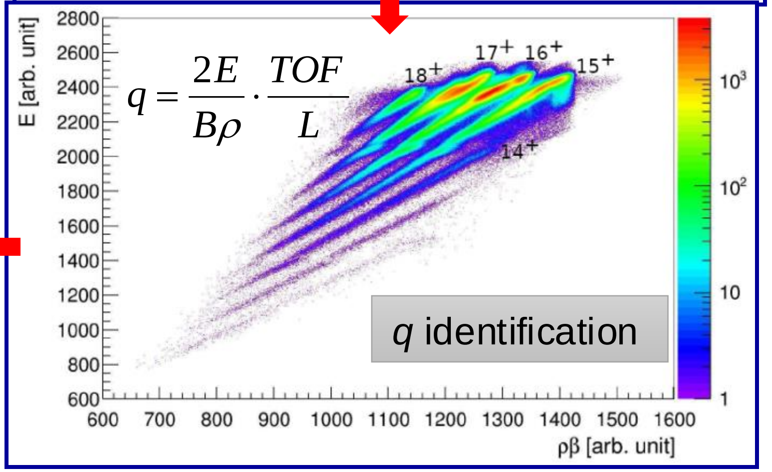
Courtesy of T. Mijatović



^{40}Ar+^{208}Pb @ 260 MeV







Analysis steps

1. Check thresholds and 2D gates (MCP, MWPPAC)
2. Set Z gates in the E-ΔE matrix
3. Set the ToF offset and align the MWPPAC sections in ToF
4. Set Q gates in the E-Rβ matrix
5. Calibrate the A/Q (assign a mass to each A/Q)
6. Apply the calibration to sum the different Q and obtain the mass spectra
7. Check with the gamma Doppler correction how well you set the ToF
8. Repeat from point 3 an indefinite number of times
9. Further processing to improve resolutions -> Expert mode!

Structure of PRISMA data

Array called *theMap[240]*:

- 0-59 for MCP (but only 3 used, 0: X; 1: Y)
- 60-119 for MWPPAC (all used but the yup and ydown are repeated)

0: Yup; 1: Ydown; 2: Xleft; 3: Xright; 4: Cathode; 5:ToF

- 120-179 for IC (40 used -> 10 pads x 4 sections)
- 180-239 for IC Sides (8 used)

These numbers can be seen in the Look-Up Table (LUT).

Board number (ADC or TDC)

Channel number (0-31)

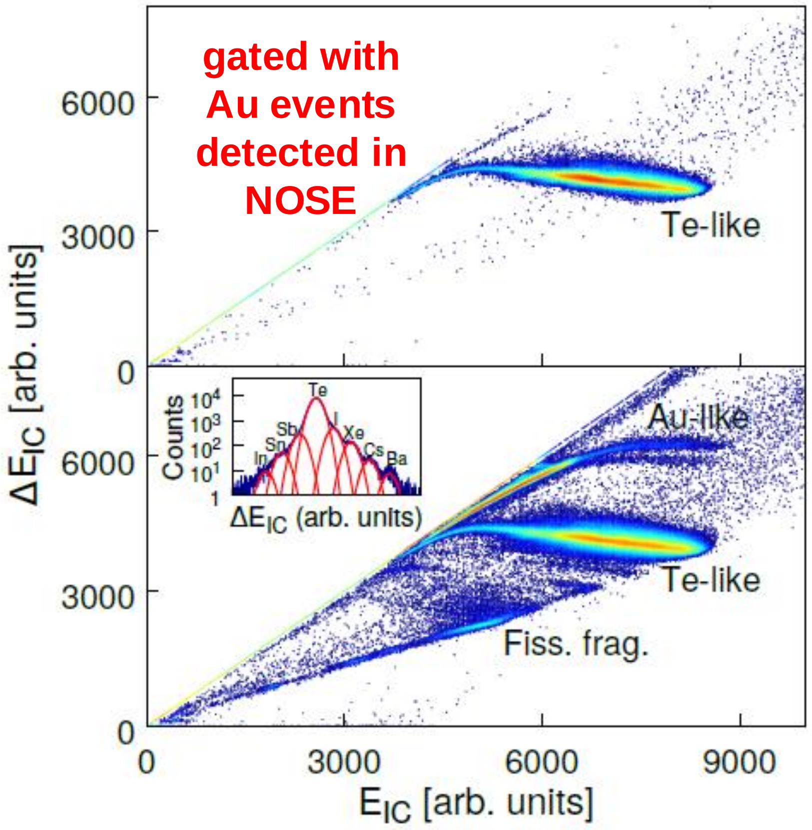
Position in theMap

Description

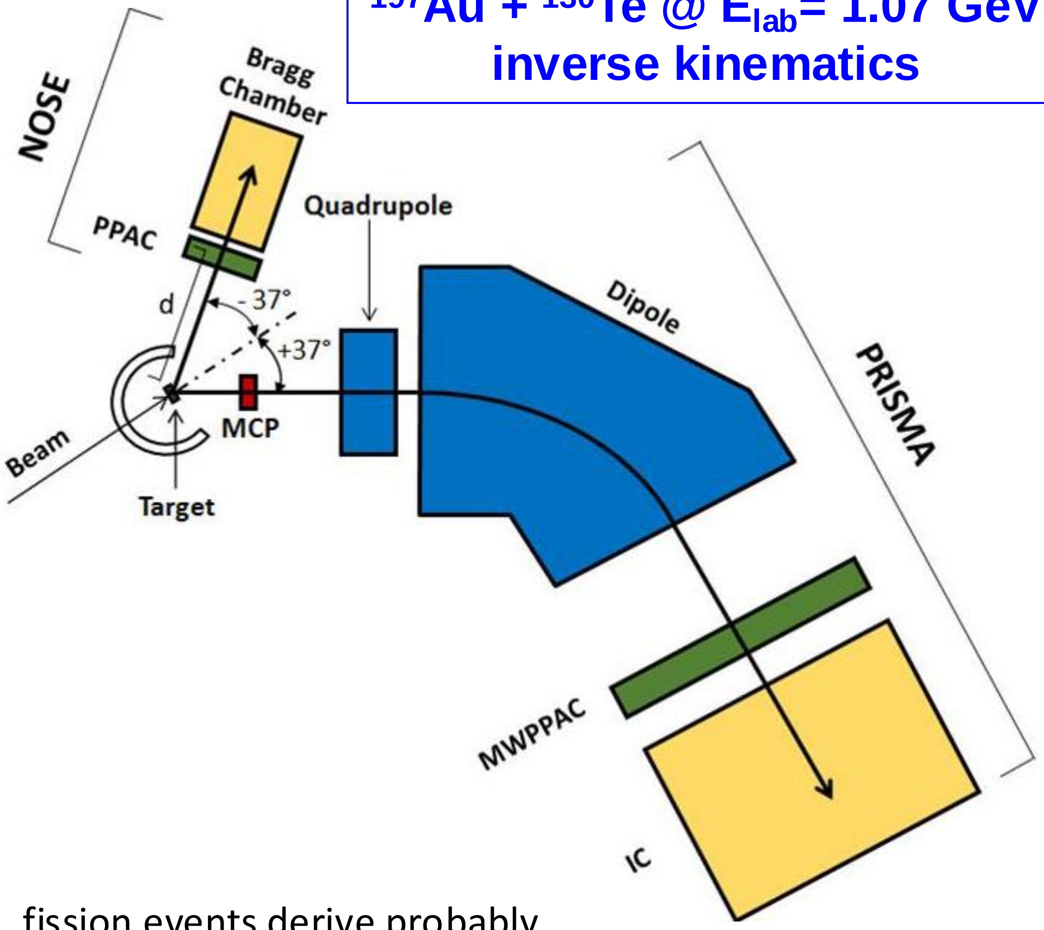
5	0	168	IC_8_DE_A
5	1	169	IC_8_DE_B
5	2	170	IC_8_DE_C
5	3	171	IC_8_DE_D
5	4	174	IC_9_DE_A
5	5	175	IC_9_DE_B
5	7	176	IC_9_DE_C
5	6	177	IC_9_DE_D
5	8	180	SIDE_0_DE_A
5	9	181	SIDE_0_DE_B
5	10	182	SIDE_0_DE_C
5	11	183	SIDE_0_DE_D
5	12	186	SIDE_1_DE_A
5	13	187	SIDE_1_DE_B
5	14	188	SIDE_1_DE_C
5	15	189	SIDE_1_DE_D
5	16	0	MCP_X
5	17	1	MCP_Y

PRISMA + ancillaries: second arm

PRISMA spectrometer used in high resolution kinematic coincidence with a second time-of-flight system (NOSE)



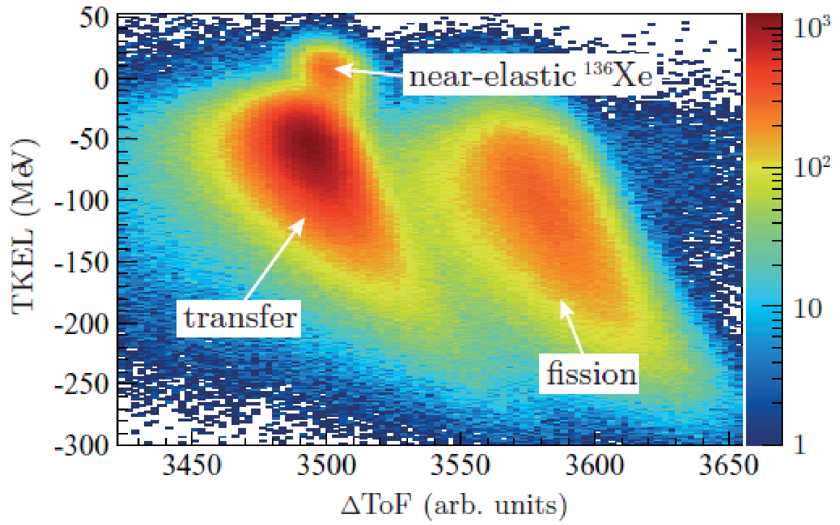
$^{197}Au + ^{130}Te$ @ E_{lab}= 1.07 GeV inverse kinematics

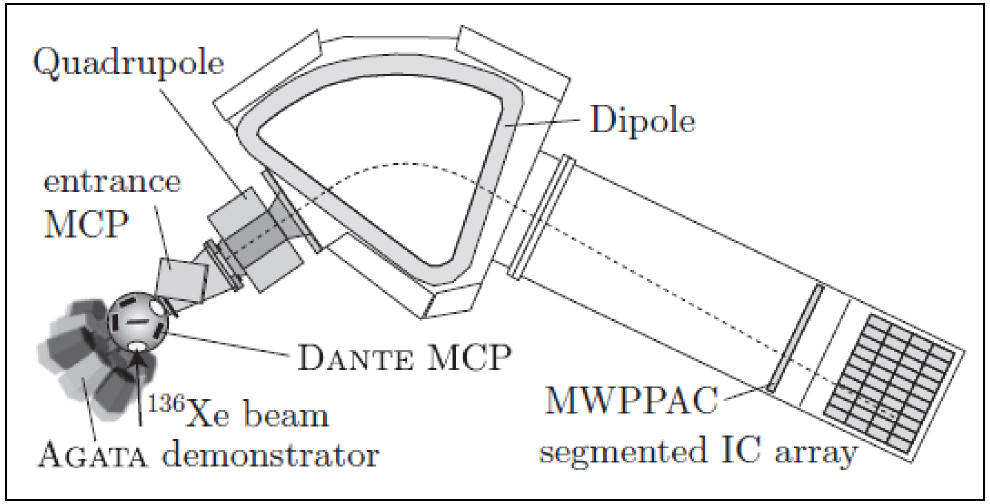


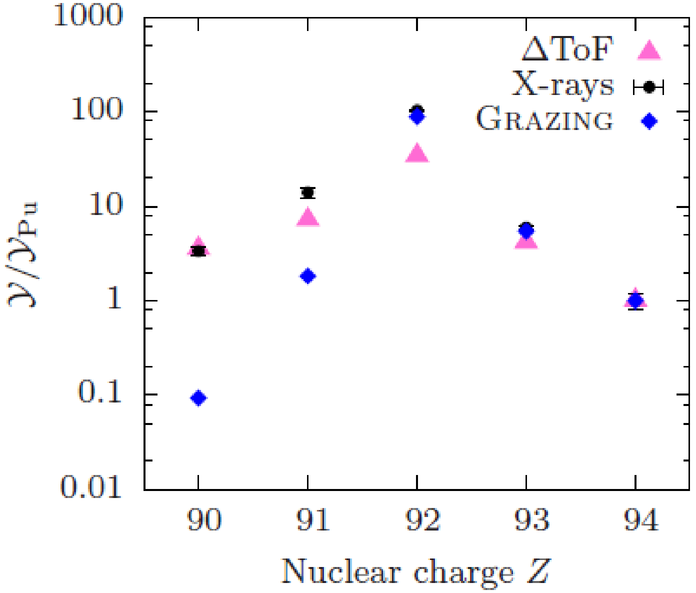
fission events derive probably from transfer induced fission or quasi fission

F. Galtarossa et al., Phys. Rev. C97(2018)054606

PRISMA + ancillaries: DANTE







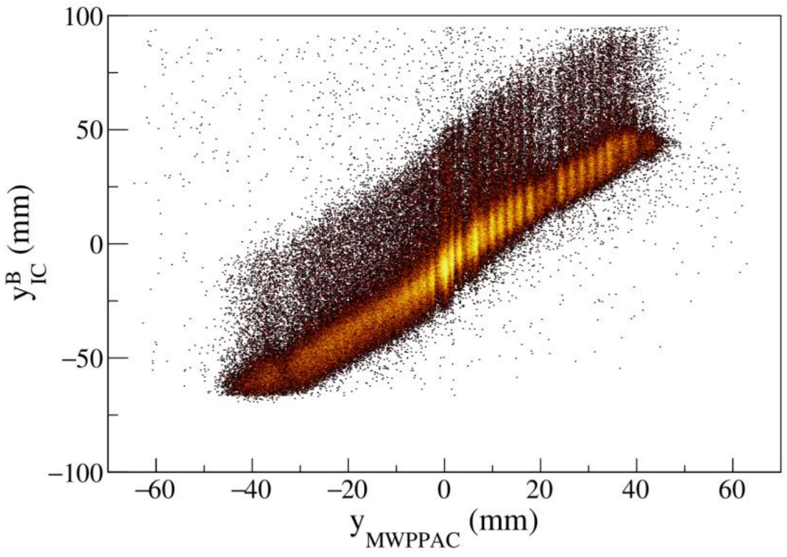
via a kinematic coincidence PRISMA-DANTE one could extract the yield of mass integrated actinide nuclei, which turns out to be in good agreement with that derived from X-ray analysis

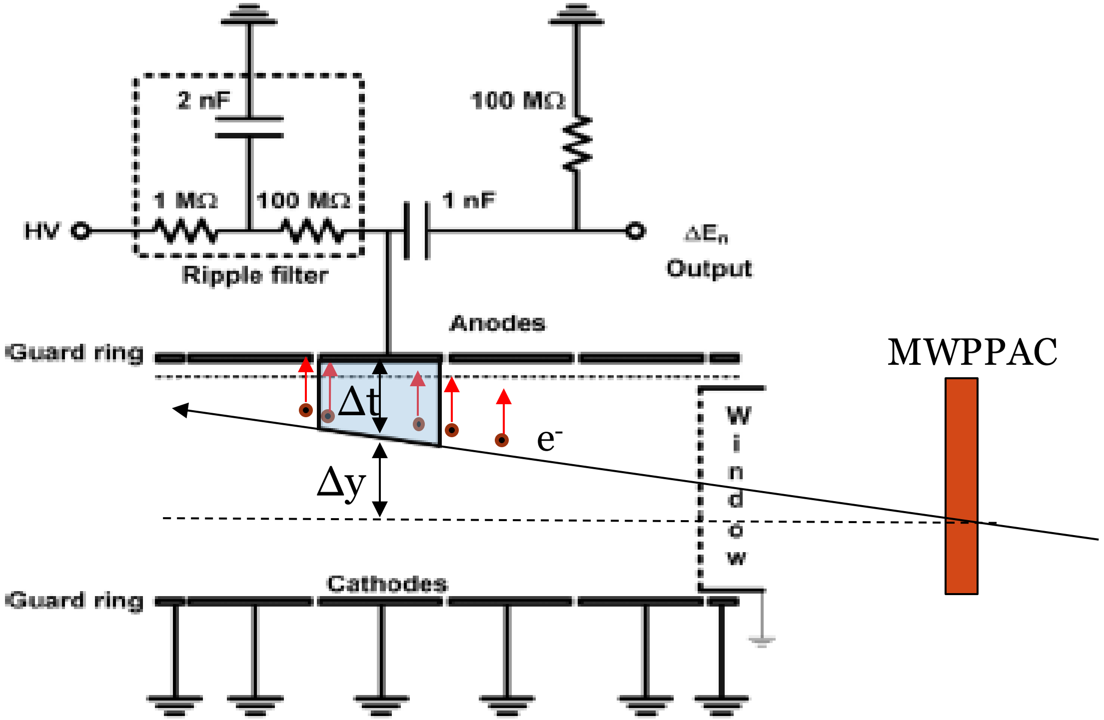
A.Vogt et al., PRC92(2015)024619

TAC drift time spectrum taken in tests with ^{58}Ni @ 225 MeV

start: MWPPAC cathode
stop: IC anode

Preliminary test performed

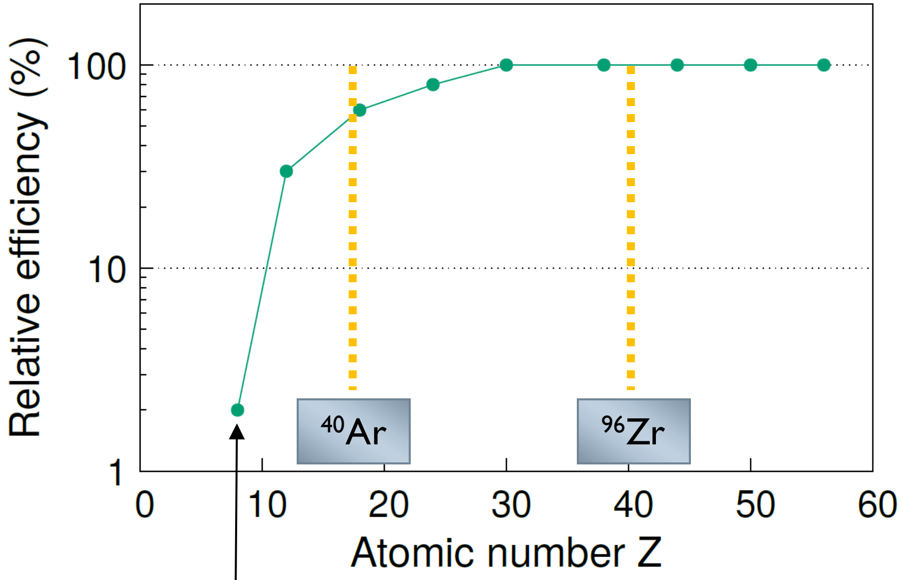




The time difference between the MWPPAC cathode and the IC anode essentially reflects the electrons drift time inside the chamber (~ 1-5 µs) -> new TDC's with larger range

Information on the Y coordinate should help better control the ion trajectories

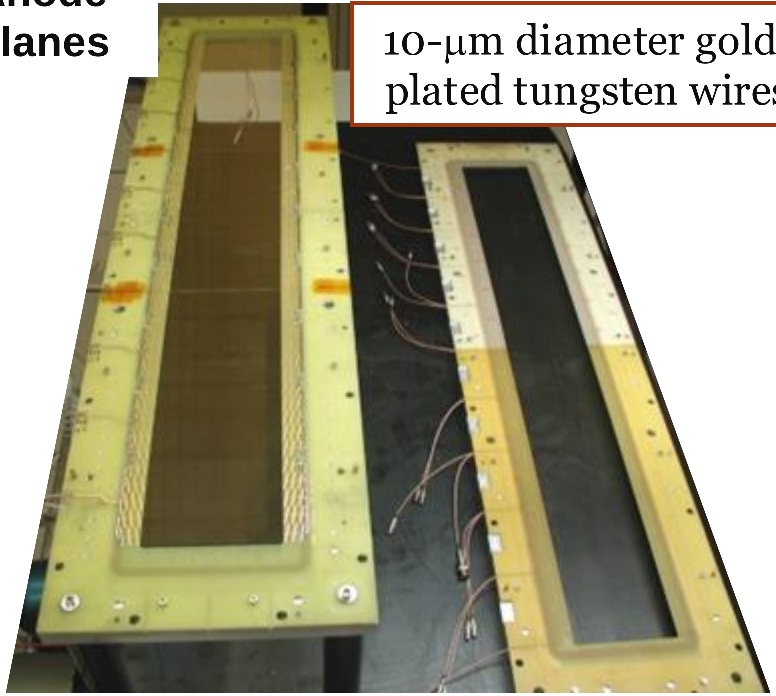
This information is contained in the IC_drift variable in the PrismaTree (only for some experiments)



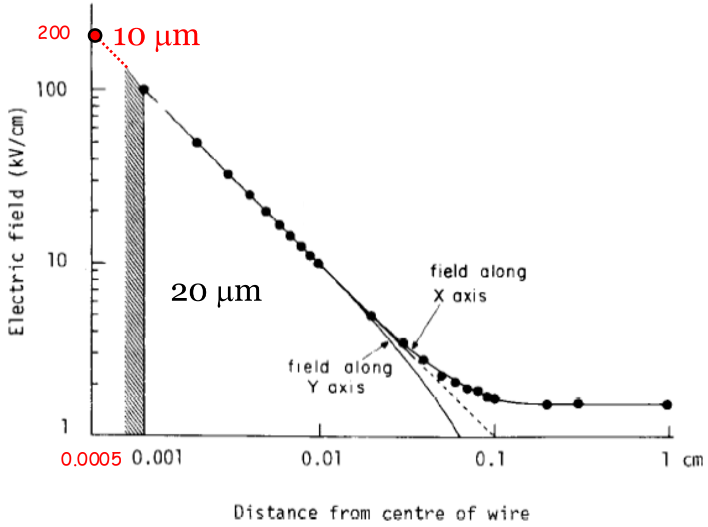
Due to the attenuation of the low anode signals by the delay lines

Anode planes

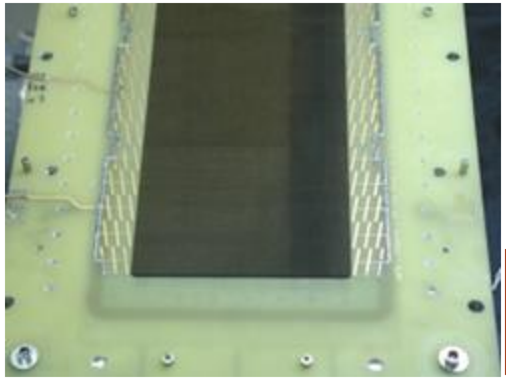
15 cm



10-μm diameter gold-plated tungsten wires



Detector efficiency improved from few % to about 40% for ^{16}O @ 50 MeV



Cathode

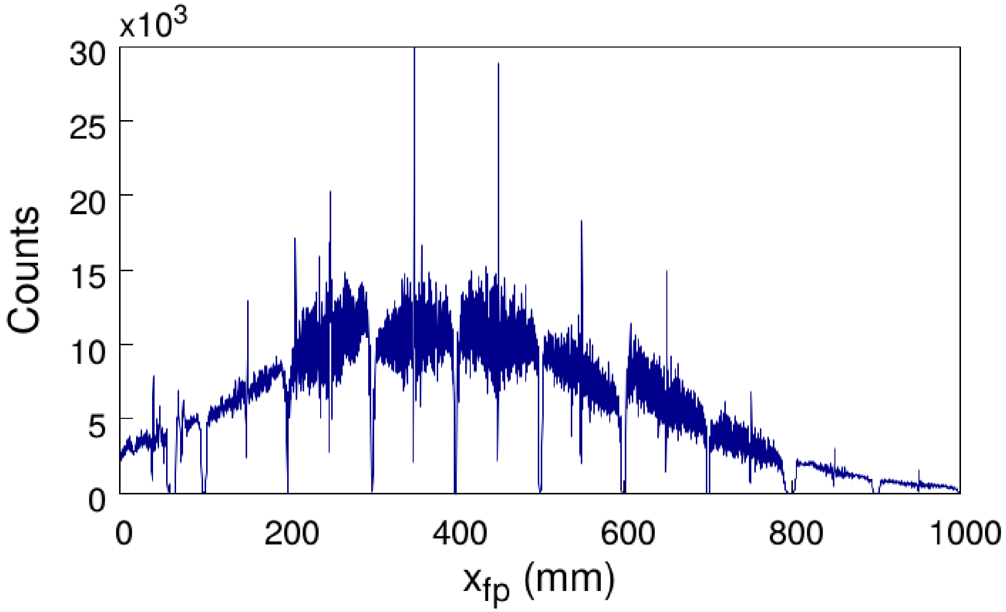
3300 gold plated tungsten wires

ToF efficiency: ions for which the ToF is > 0 / number of ions in a given Z gate.
Position efficiency: ions with an assigned mass number / number of ions in a given Z gate

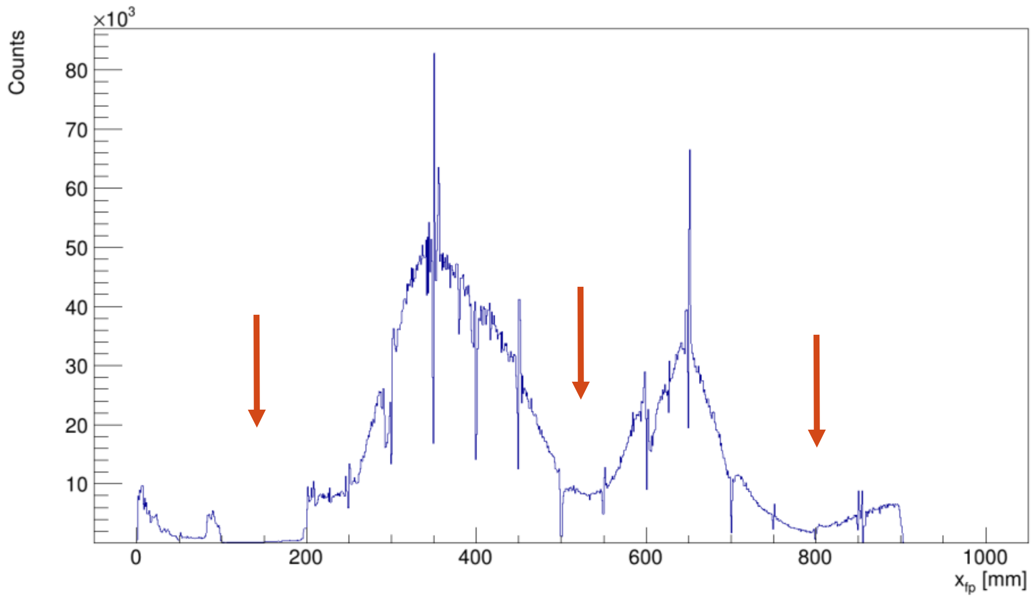
With the actual MWPPAC you may find low efficiency for some sections, so "strange" structures in the focal plane position spectrum

X_{fp} position spectra

$^{197}Au+^{130}Te$ @ 1070 MeV



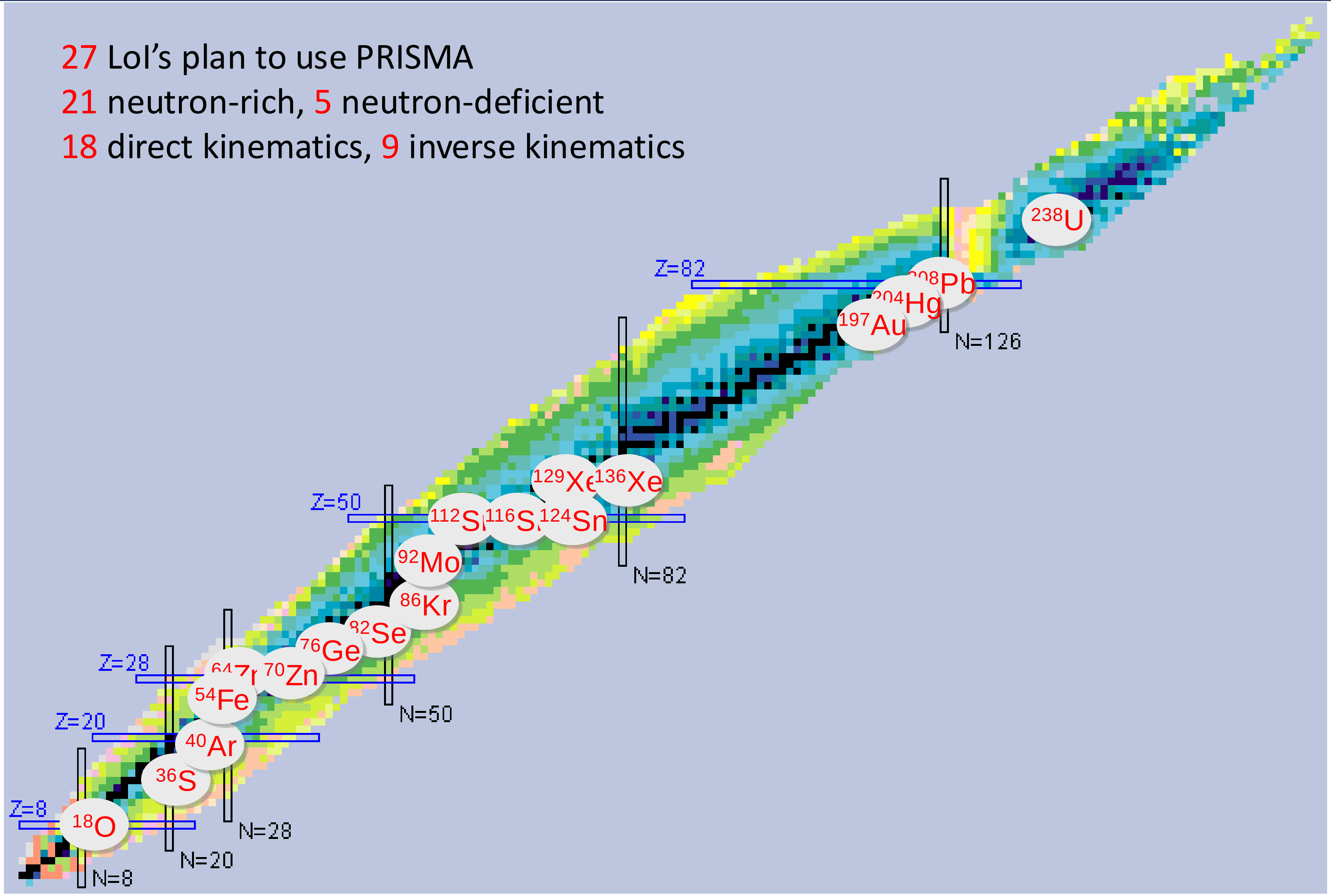
$^{32}S+^{124}Sn$ @ 160 MeV



Not always clear whether it is the effect of the spacing of the different charge states (only 2-3 charge states on the fp for light ions) or an inefficiency of the section

LoI's for PRISMA (1st AGATA pre-PAC)

27 LoI's plan to use PRISMA
21 neutron-rich, 5 neutron-deficient
18 direct kinematics, 9 inverse kinematics

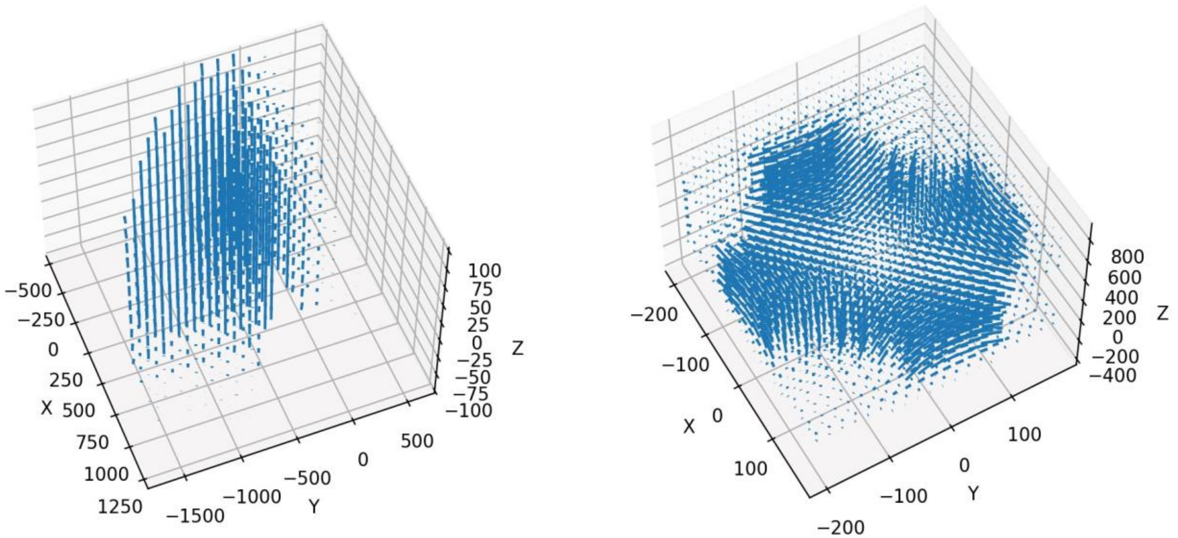


Magnetic fields and trajectory mapping

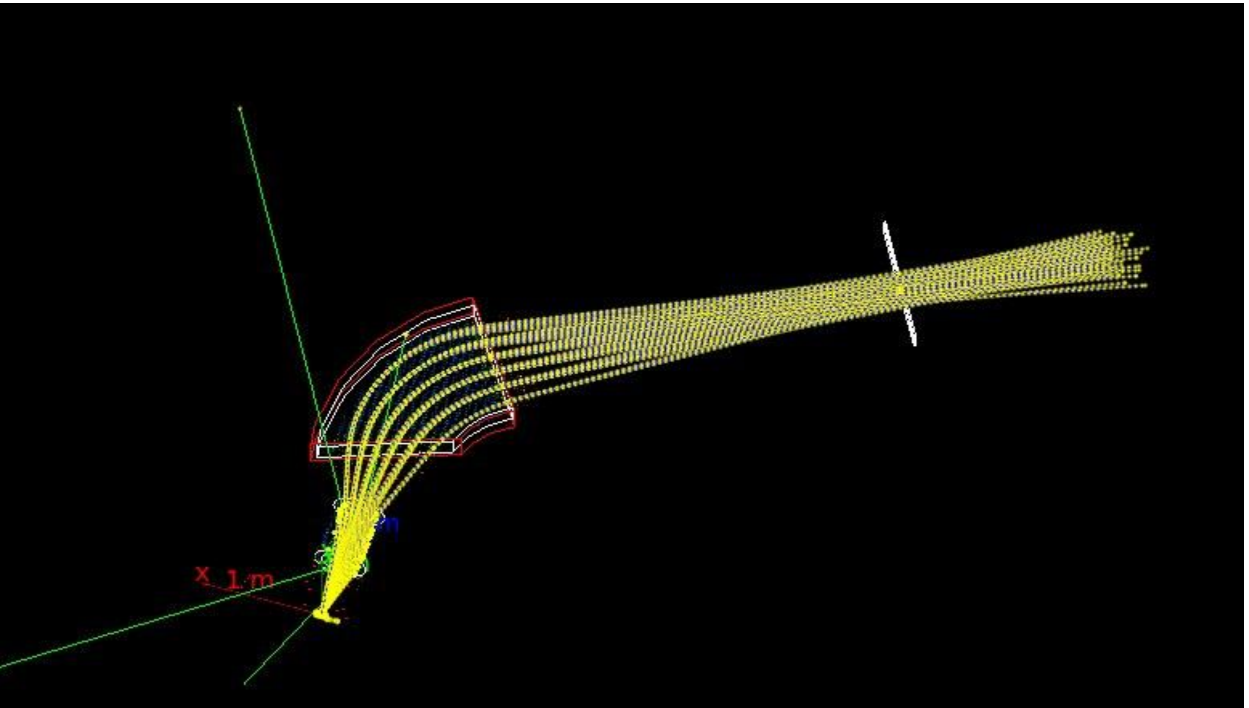
Reconstruction is **approximated**.
Can we have a more **accurate** treatment of **magnetic fields**?

Mapping of trajectories (Brho, Theta, Phi) with solution of the equations of motion

Associate **closest Brho** to the measured positions
-> no need to propagate the trajectory event-by-event



Elaborated from A. Latina's PhD thesis



We have started developing a **GEANT4 simulation** with realistic field maps of quadrupole and dipole.

Challenging to extract an **effective mapping** of the trajectories

<u>Room for development if anyone is interested!</u>

Later we will see more details on the analysis