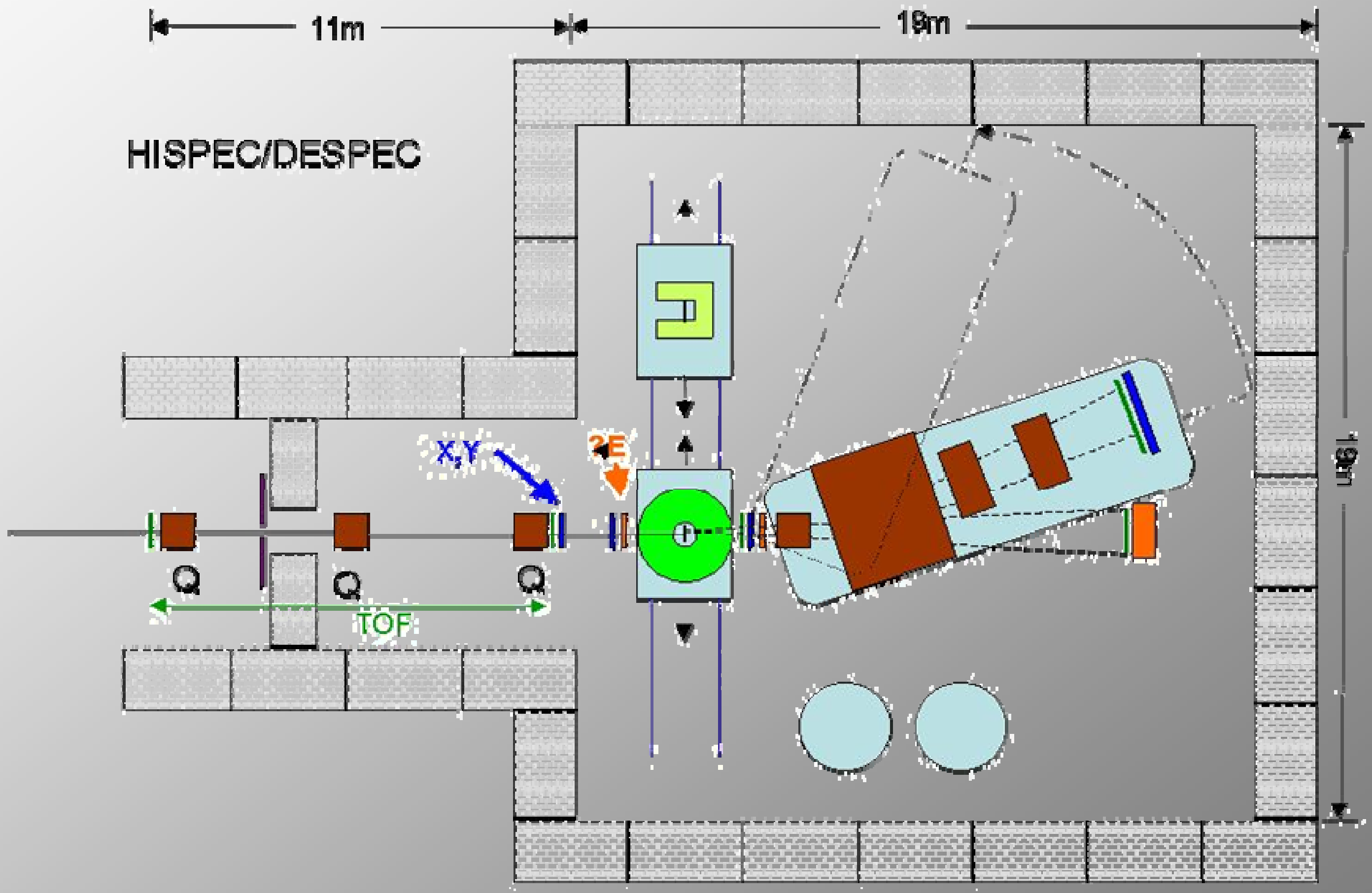
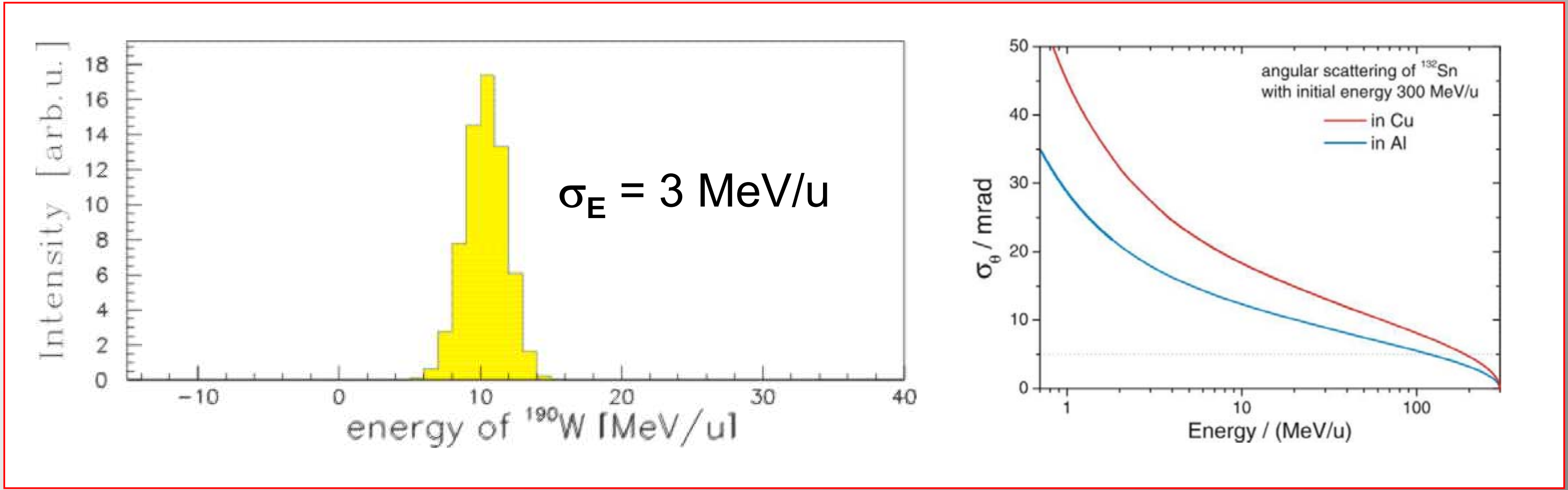
A Separator/Spectrometer for AGATA @ the SuperFRS Low Energy Branch (LEB)

- Beams at the LEB and their properties
- RDT – RT – DT: the relevant detection schemes
- Particle identification/separation
    - Detector only based systems (CATE)
    - Ionoptical devices
        - The intermediate energy regime (ALADIN?)
        - The Coulomb barrier approach (Magnetic spectrometer)

Experimental Area at the Low-Energy Branch of the Super-FRS



Characteristics of low-energy beams: energy and angular spread



Typical numbers:

300 MeV/u:	$\sigma_E \sim 0.3$ MeV/u	$\sigma_\alpha \sim$ 5 mrad
5 MeV/u:	$\sigma_E \sim$ 3 MeV/u	$\sigma_\alpha \sim$ 20 mrad

HISPEC - Letter of Intend @ FAIR: Spectrometer for AGATA

Letter of Intent
for

High-Resolution In-flight Spectroscopy

HISPEC Collaboration

April 7, 2004

Abstract

It is proposed to study the structure of exotic nuclei by high-resolution in-flight spectroscopy, taking advantage of the isotopes produced at the Super-FRS facility at FAIR. Mono-energetic beams in the range 3 MeV/u to 100 MeV/u available at the Low Energy Branch of the Super-FRS will be used for γ spectroscopy employing multiple Coulomb excitation, direct reactions and compound reaction at barrier energies as well as single step Coulomb excitation and fragmentation at inter-mediate beam energies. The set-up will comprise beam particle identification and tracking detectors before an active reaction target surrounded by the 4π Ge γ tracking array AGATA. At intermediate energies beam-like particle tracking and identification by a magnetic spectrometer (e.g. ALADIN) is foreseen. For low energies the HYDE heavy particle array for reaction studies and a complete suite of ancillary detectors including a velocity filter added to the magnet separator is planned.

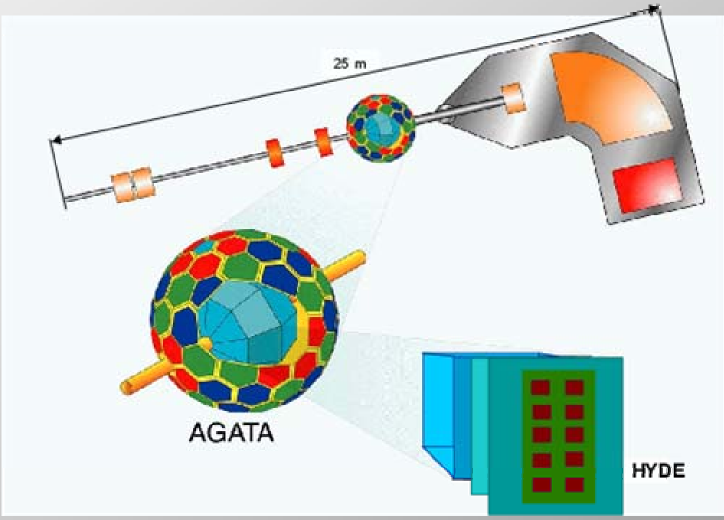


Fig. 1: One of the proposed experimental set-ups, showing the AGATA γ- detector array [2], charged particle detectors and a large acceptance spectrometer. Other detection systems, not shown in this figure, will be used too. The total length of the setup ...

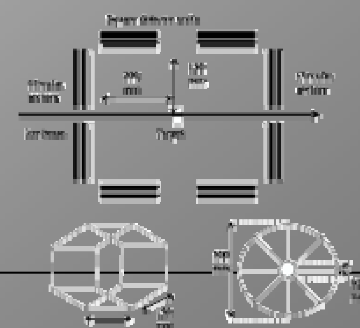
GSI-ESAC / RIB / NUSTAR / HISPEC

2.4 Spectrometer and tracking of outgoing particles

A large acceptance magnetic spectrometer is needed behind the secondary target to determine the mass of the outgoing particle for intermediate energy Coulomb excitation and fragmentation reactions. Since the ion energy is limited to 100 MeV/u existing conventional spectrometers like ALADIN can be used for that purpose avoiding extra cost. As alternative a stacked ΔE-E calorimeter is planned to be developed to circumvent efficiency and selectivity losses of any magnet system imposed by wide charge state distributions. In addition the charge, position and TOF of the outgoing heavy ion needs to be determined. For that purpose thin Si strip detectors or diamond detectors as well as plastic detectors may be chosen as described in section 2.2.

Recoil Decay Tagging (RDT) [7] has proven to be one of the most powerful tools to study the nuclear structure of exotic species. A typical setup consists of a γ-ray detection part and an ion-optical separation and particle identification part [8]. Various set-ups are presently in use in many laboratories, like e.g. the FMA+GAMMASPHERE at ANL, PRISMA+CLARA at LNL, VAMOS+EXOGAM at GANIL, RITU+JUROSPHERE at Jyväskylä. An ion-optical unit, like ALADIN, built behind AGATA, will provide the necessary separation of the wanted species from the background and/or the particle identification. This will be realized with various options. In the first mode it will be used as a magnetic tracking device where the products of transfer reactions will be traced through the set-up. This provides together with energy and energy loss measurement mass and charge of the traced particle(VAMOS, PRISMA). The second mode will allow for the study of fusion or fusion-like products. This separator feature will be realized by adding an electro-static component or a velocity filter (LISE, GANIL), or as a gas-filled separator (RITU). This mode will also allow for γ spectroscopy triggered by decay occurring after the separator via evaporation residue-decay-γ coincidence measurements (RITU+GREAT, SHIP, GSI). The focal plane detection system is similar to the one proposed for decay spectroscopy in the Low Energy Branch and will be developed and used together.

2.5 The HYDE-BALL detector array



HISPEC – Technical Proposal

- **RDT** - Recoil Decay Tagging has proven to be one of the most powerful tools to study the nuclear structure of exotic species. Here the reaction product is identified by its decay after a separator. Additional A/q information could improve the background reduction.

- **RT** - Recoil Tagging uses the Z and A information of the reaction product provided by a spectrometer set-up to obtain spectroscopic information in coincidence with the detected γ-rays in flight.

- **DT** – Decay Tagging provides spectroscopic information on the decay products of long lived nuclei or isomeric states after separation.

For the first and last of these only a **separator** is needed in most cases as A and Z are fixed by characteristic decay information, although additional information on Z and A of the nucleus under investigation could be helpful for further background reduction. For **RT** the set-up has to provide **A and Z**. The reaction schemes used to produce the nuclei of interest are listed in table one. Forward focused reactions like Coulomb excitation and fusion/evaporation ask for the separator to function at 0°. For binary reactions, such as elastic scattering or transfer reactions the access to angles other than 0° and the possibility to rotate the set-up is required. Exotic beams of high quality in energy definition and in spatial properties provided by the NESR can also be used to employ e.g. high-spin isomeric states for both nuclear structure investigations as well as reaction studies. For the latter in particular separation and/or A/Z identification are essential.

HISPEC – Request for Input

In our technical proposal we have specified very roughly the features we would expect from a magnetic **spectrometer/separator** used in conjunction with AGATA at the LEB. There we also specified that decision which type of device would be the most suitable which depends very much on the application we think of. The following three scenarios were discussed:

1. **RDT** - Recoil Decay Tagging: Here the reaction product is identified by its decay after a separator. Additional A/q information could improve the background reduction.

2. **RT**- Recoil Tagging: It uses the Z and A information of the reaction product provided by a spectrometer set-up to obtain spectroscopic information in coincidence with the detected γ-rays in flight.

3. **DT** – Decay Tagging: Here spectroscopic information on the decay products of long lived nuclei or isomeric states is obtained after separation. A and Z is provided by characteristic decay information.

We also pointed out that the various scenarios ask for different requirements. For point **1** and **3** a **separator** would be the sufficient solution, as A and Z are fixed by characteristic decay information, although additional information on Z and A of the nucleus under investigation could be helpful for further background reduction. For RT we would need a **spectrometer** providing A and Z of the species under investigation. Especially forward focused reactions like Coulomb excitation and fusion/evaporation ask for the separator function of the set-up at 0°.

Rotation of the set-up as an additional requirement would be necessary for binary reactions, like elastic scattering or transfer reactions the access to off 0° angles. Exotic beams of high quality in energy definition and in spatial properties provided by the NESR can also be used to employ, e.g. high-spin isomeric states for both nuclear structure investigations as well as reaction studies. Especially for the latter separation and/or A/Z identification are essential.

HISPEC – Request for Input

Moreover the NUSTAR PAC report is now available. There is stated that the magnetic spectrometer has to be defined more precisely:

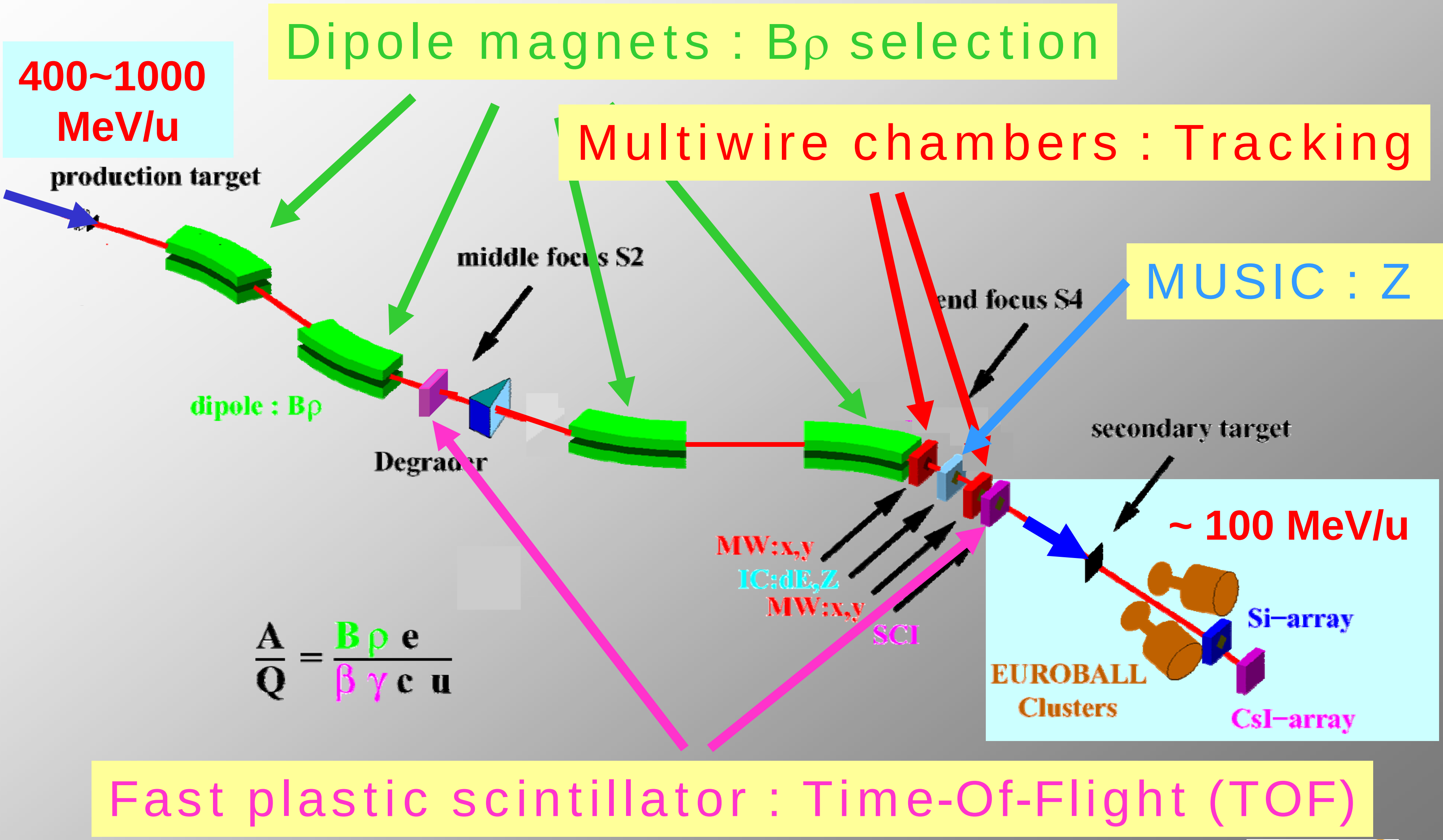
"...The collaboration has made the case for a large solid angle magnetic spectrometer; ***however, this case is too general and does not specify which physics problems it will address****. The spectrometer also has to adapt to the large momentum spread of any recoil products. This proposal should have laid out a better structure for the development of the technically challenging instrumentation for slowed down beams. It is important that this R&D be pursued, but a better framework has to be found, and the collaboration should work more cohesively towards this direction..."*

This is an additional push which should urge us to define now what we want to use the spectrometer for...

Please let us have your input regarding your requirements a.s.a.p.

Best regards,
Dieter

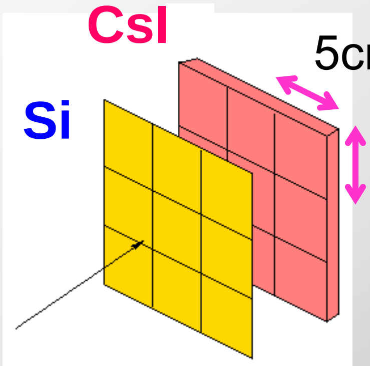
RISING @ the FRS



$$\frac{A}{Q} = \frac{B\rho e}{\beta \gamma c u}$$

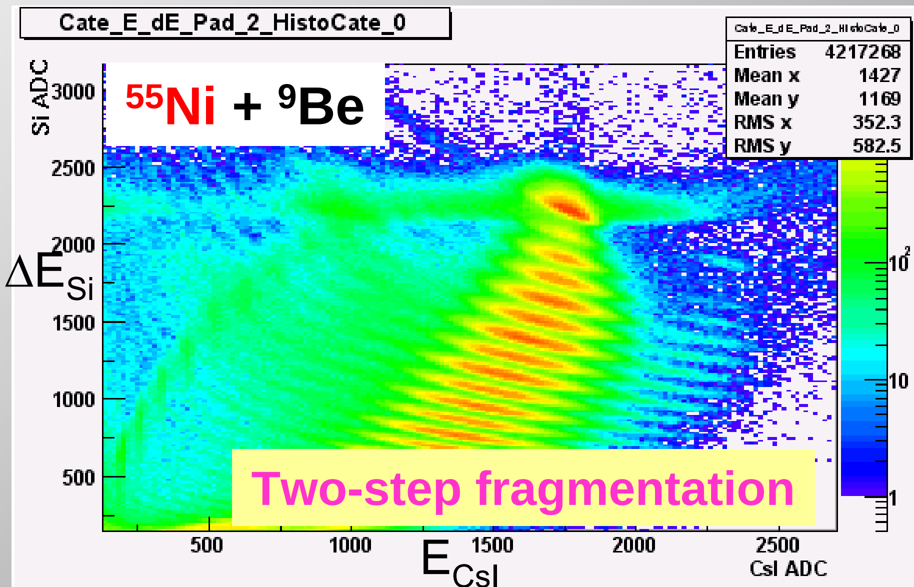
Identification of the Outgoing Particle

CAlorimeter TElescope array



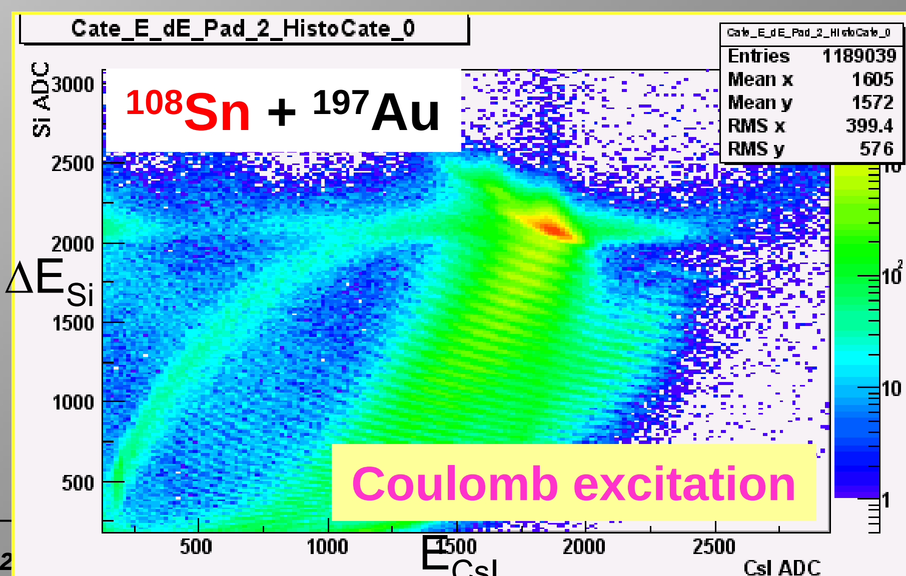
CATE-Si
- position sensetive
- 0.3 mm thick Si
- ΔE measurement

CATE-CsI
- CsI + PIN diode
- Stop beams
- E measurement

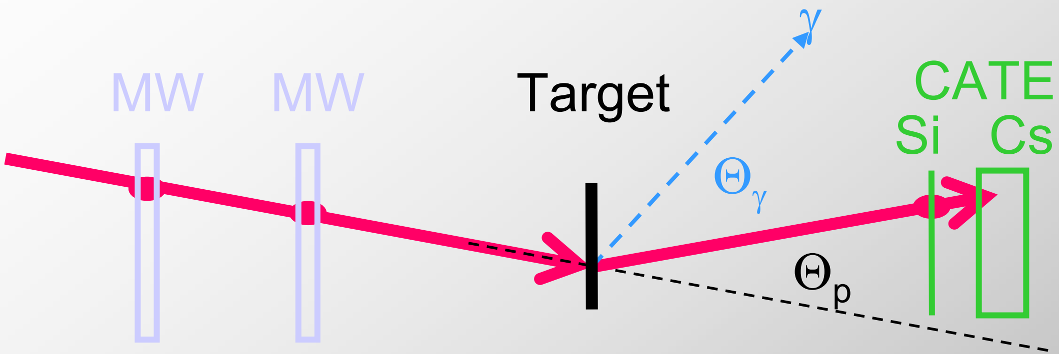


ΔE vs E → Z ΔZ : 1.6%

ΔE + E → A ΔA : ? %



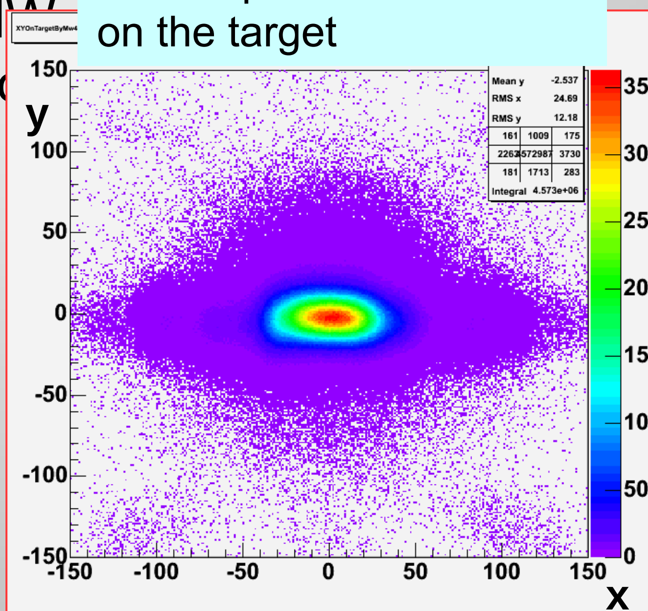
Tracking of incoming & outgoing particles



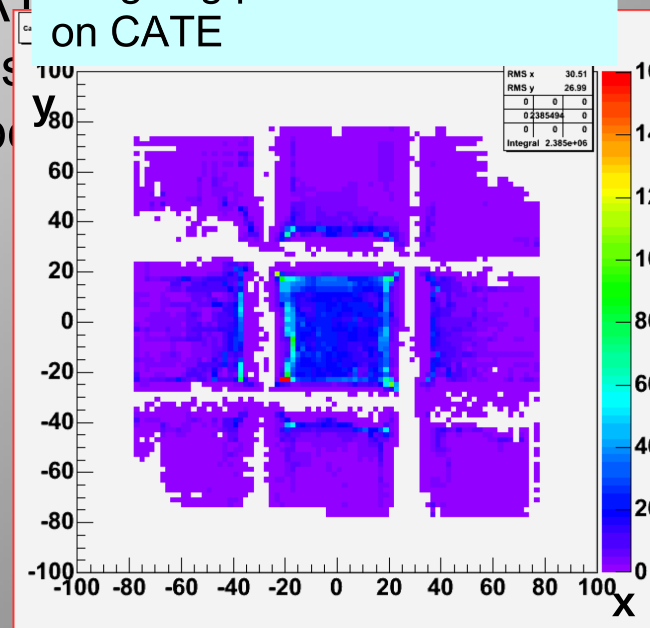
Impact parameters

Event-by-event Doppler correction

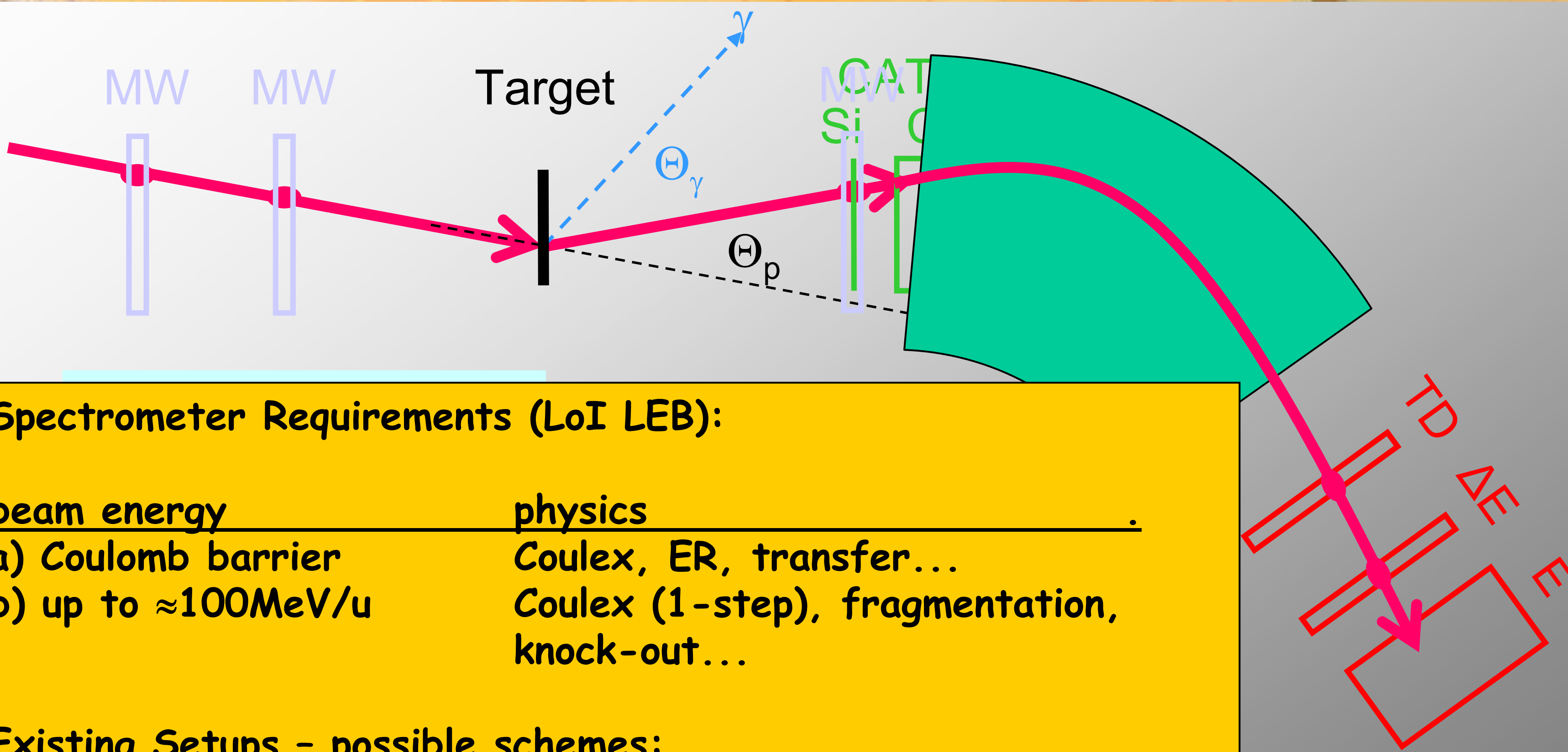
Beam spot reconstruction on the target



Outgoing particle distribution on CATE



Spectrometer for Particle Identification/Separation



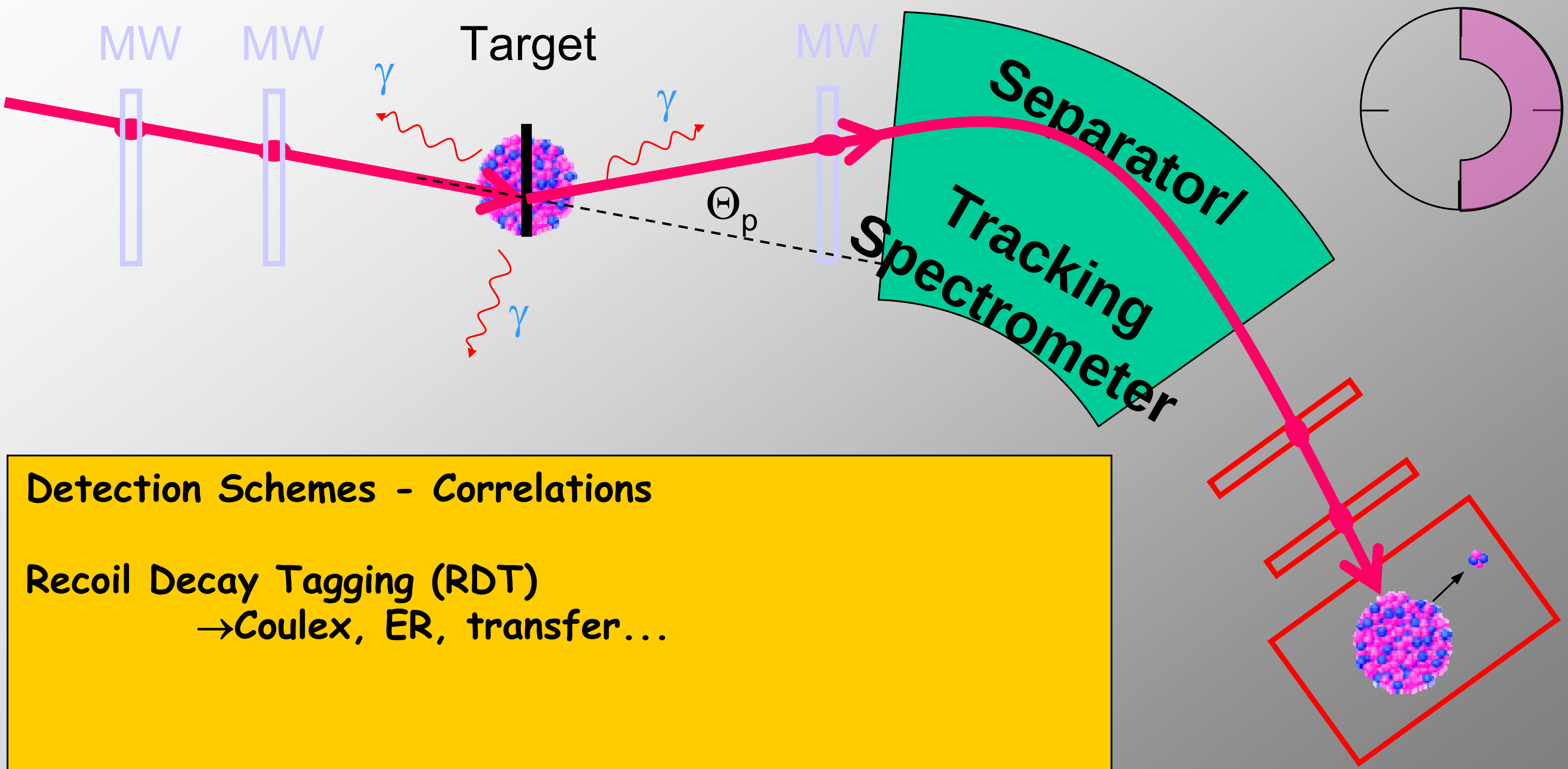
Spectrometer Requirements (LoI LEB):

beam energy	physics
a) Coulomb barrier	Coulex, ER, transfer...
b) up to ≈100MeV/u	Coulex (1-step), fragmentation, knock-out...

Existing Setups – possible schemes:

- VAMOS – tracking spectrometer + separator (v-filter)
- PRISMA – tracking spectrometer (future: gas-filled?)
- FMA – mass spectrometer
- RITU – gas-filled separator
- SHIP – separator (v-filter)

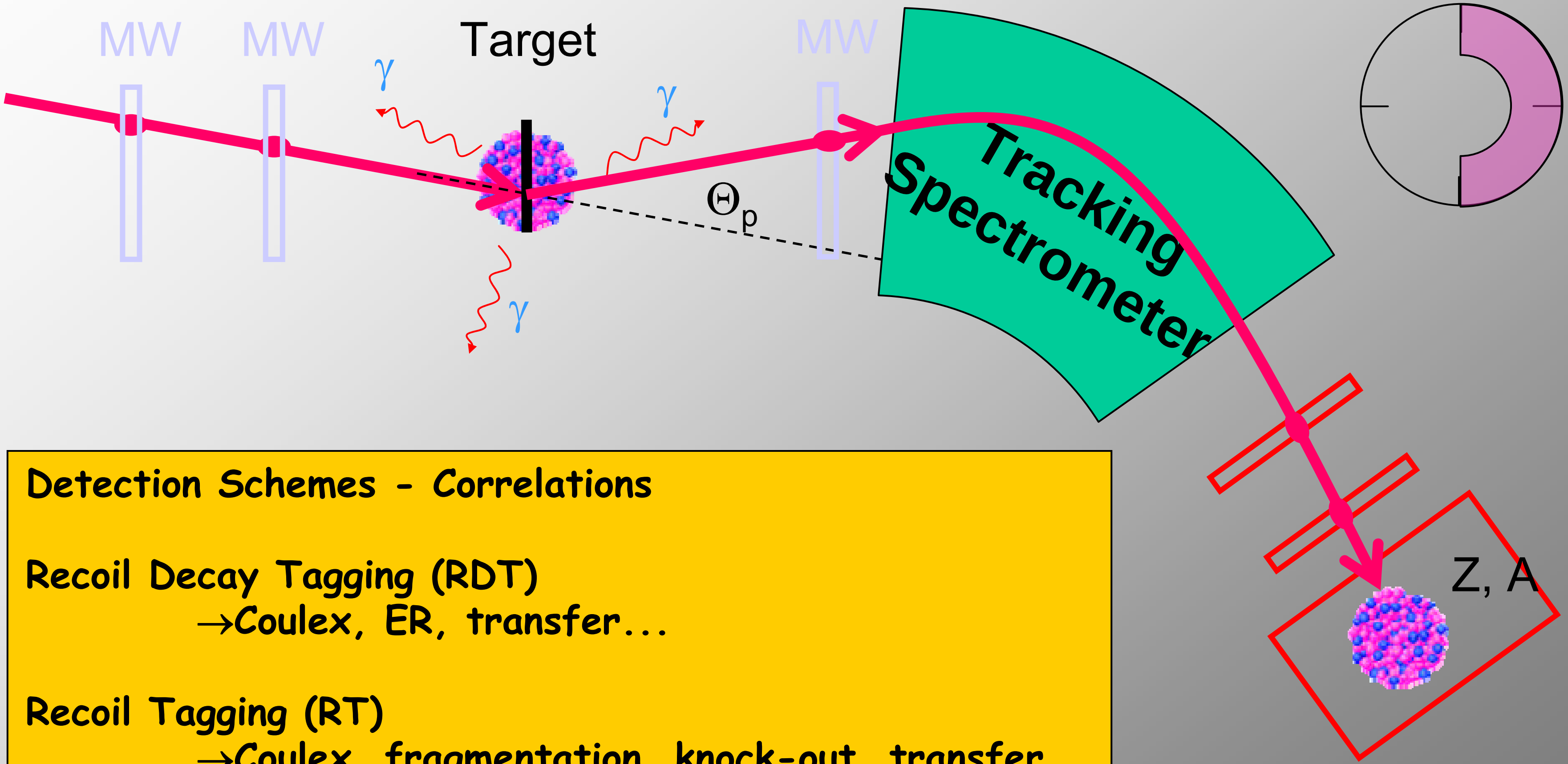
RDT – RT - DT



Detection Schemes - Correlations

Recoil Decay Tagging (RDT)
→Coulex, ER, transfer...

RDT – RT - DT

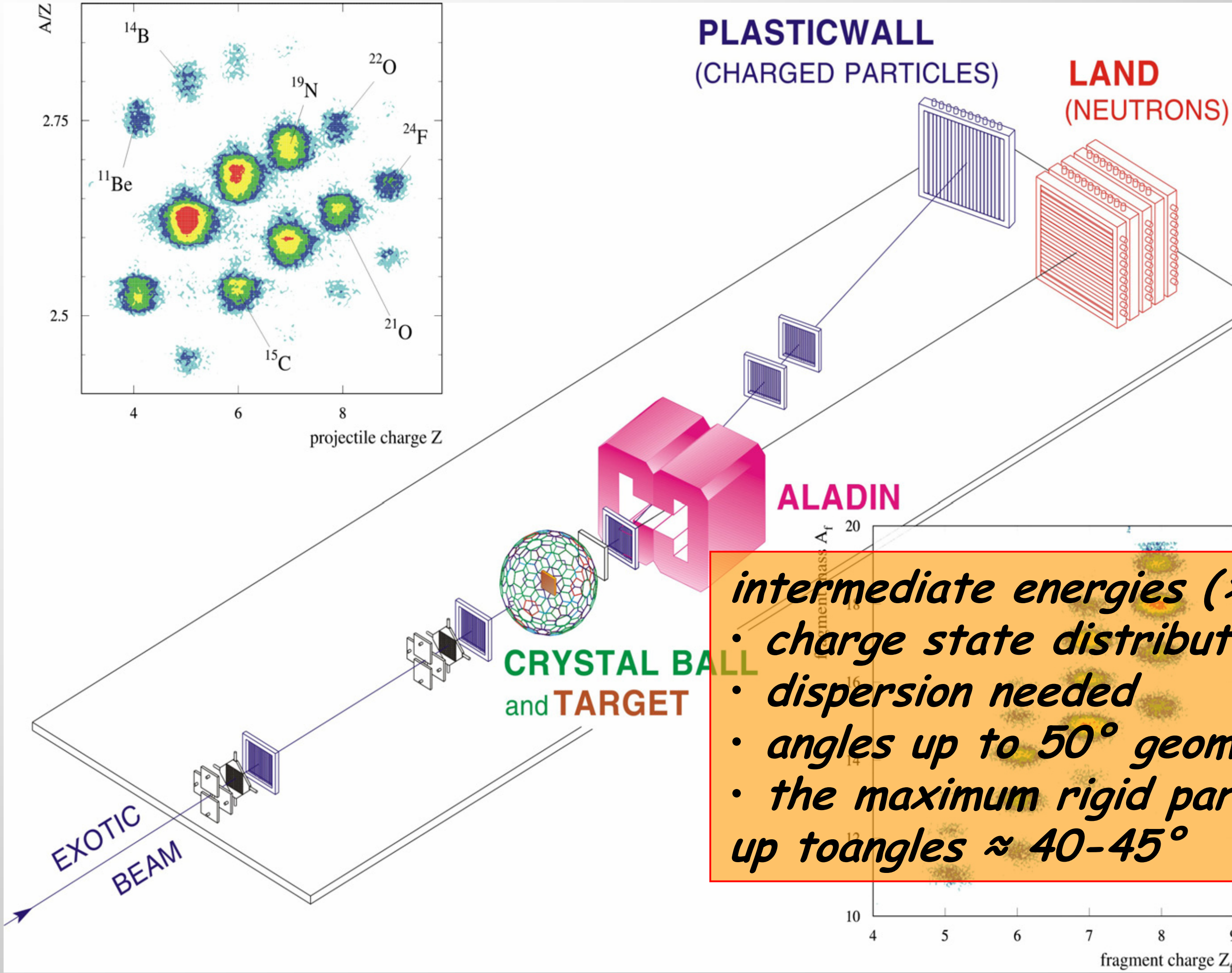


Detection Schemes - Correlations

Recoil Decay Tagging (RDT)
→Coulex, ER, transfer...

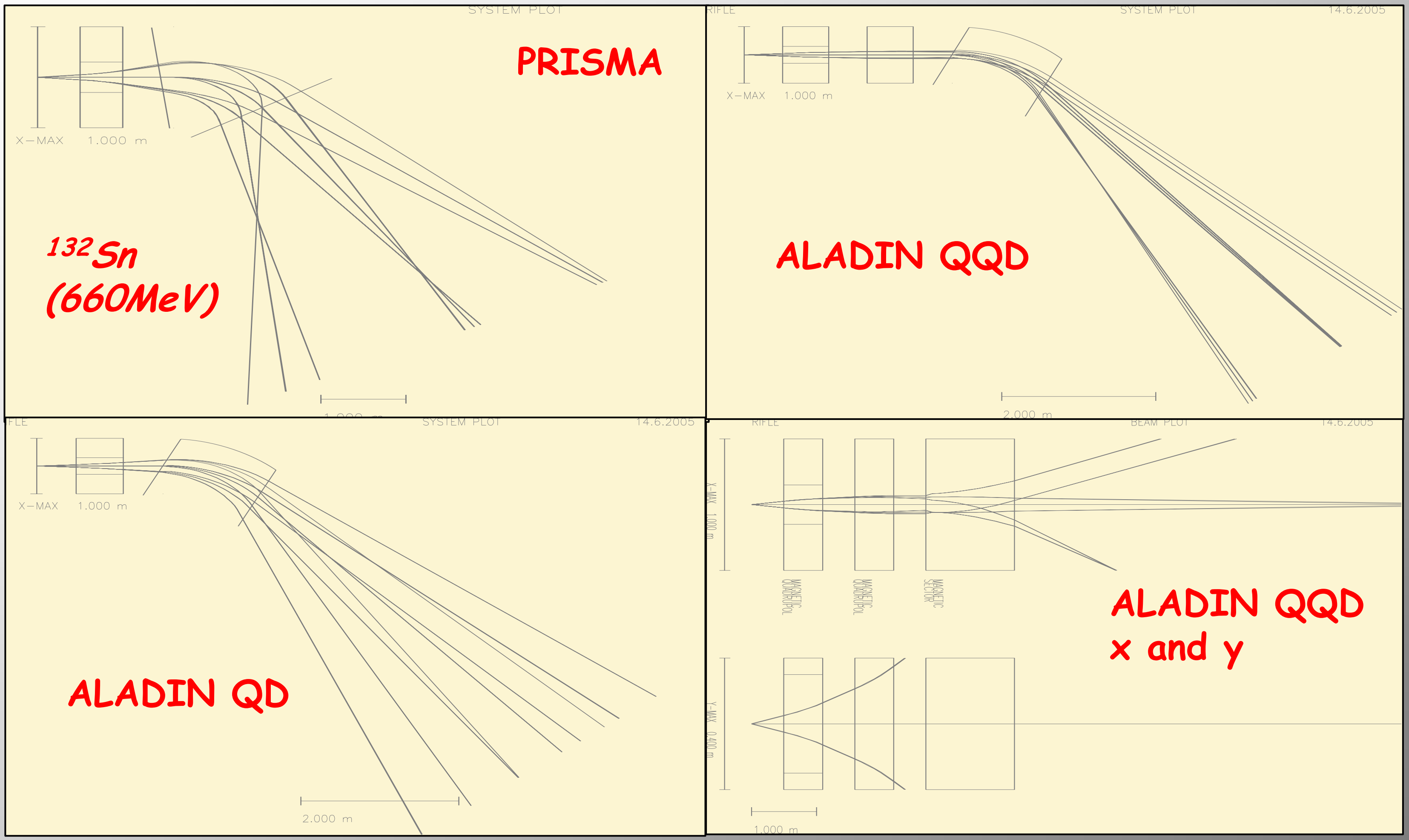
Recoil Tagging (RT)
→Coulex, fragmentation, knock-out, transfer...

ALADIN @ the GSI LAND set-up

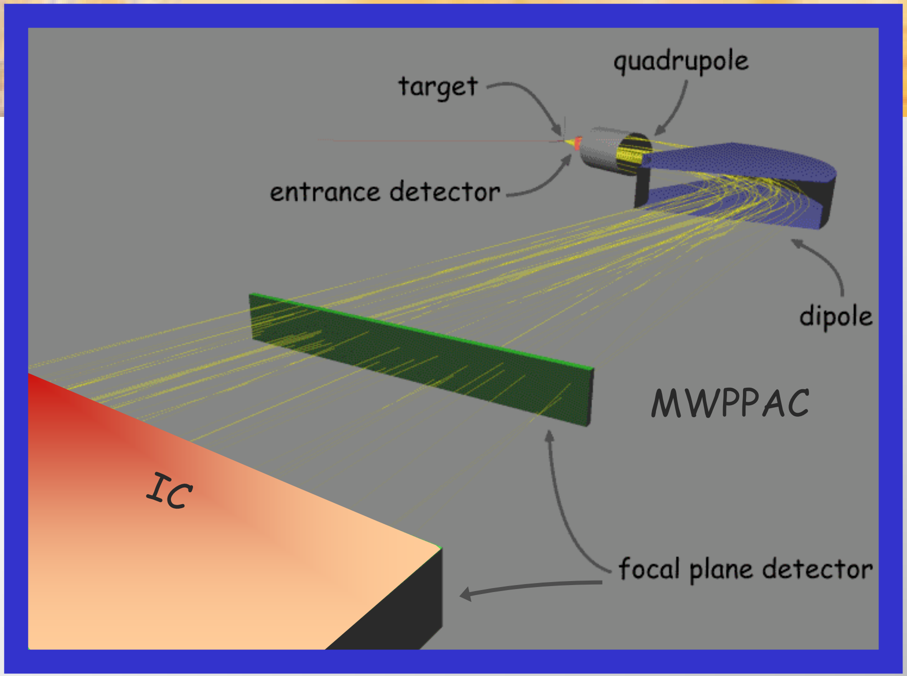


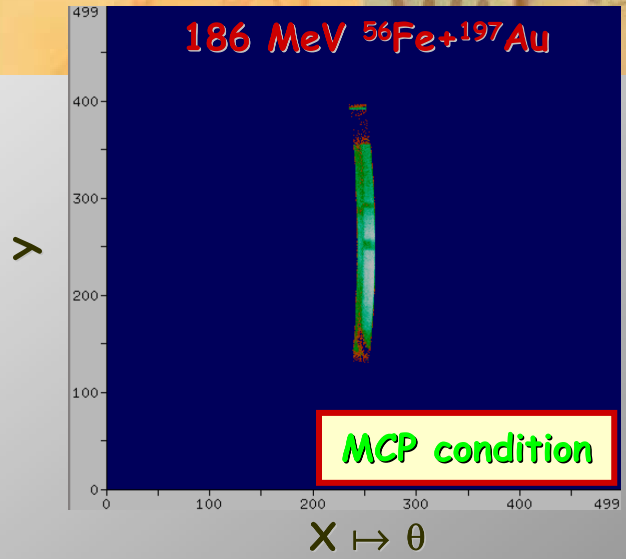
intermediate energies (>100MeV)
- *charge state distribution*
- *dispersion needed*
- *angles up to 50° geometrically possible*
- *the maximum rigid particles can be bend up toangles ≈ 40-45°*

ALADIN @ the GSI LAND set-up

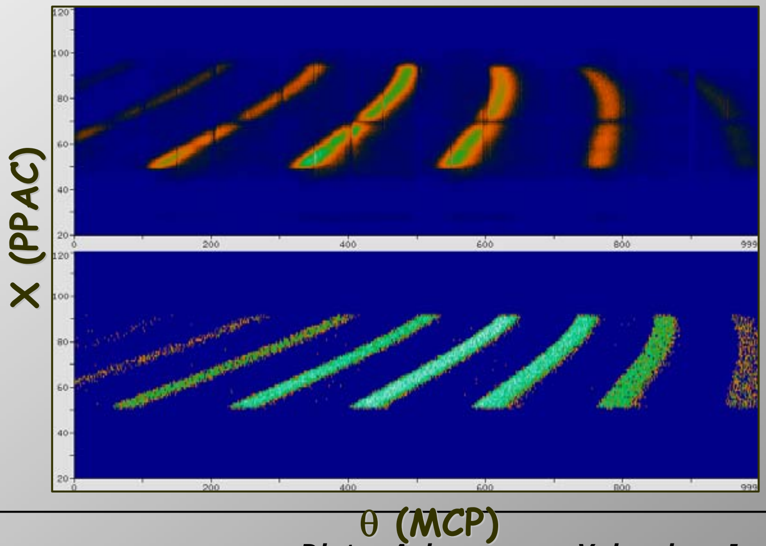


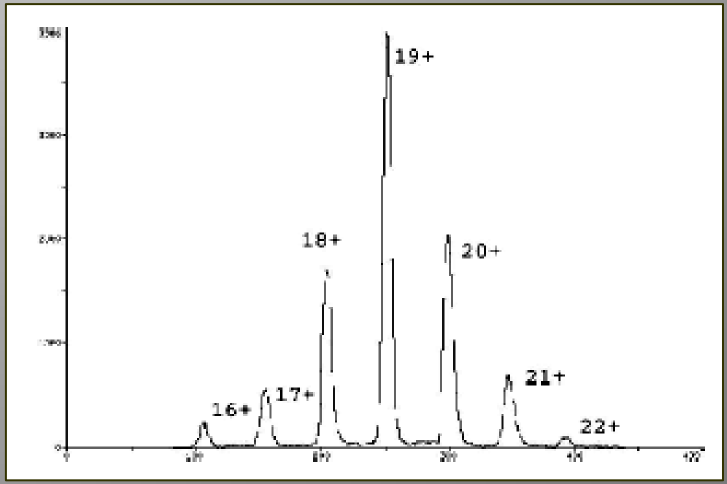
PRISMA SPECTROMETER - PERFORMANCE



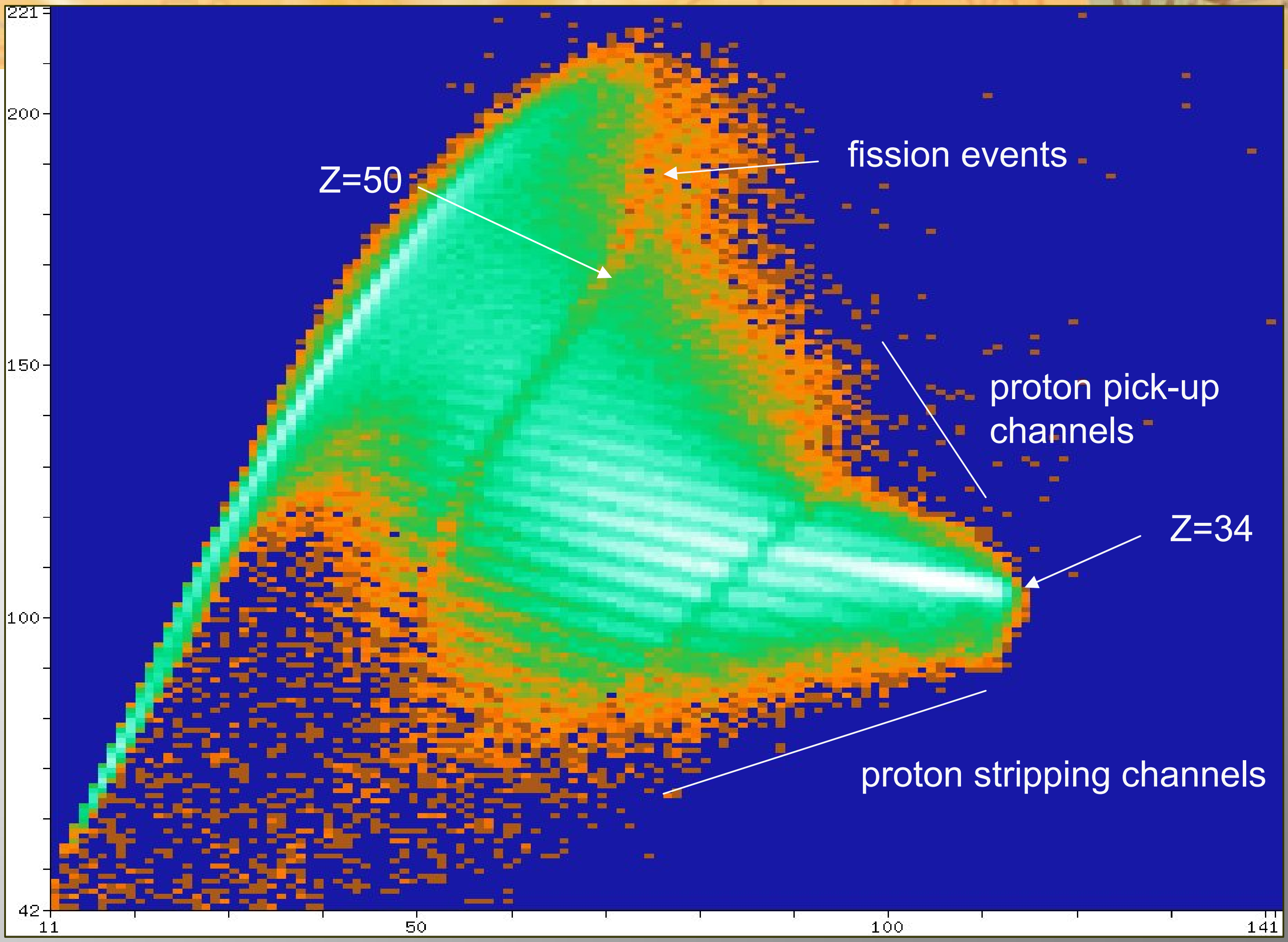


Charge state distribution





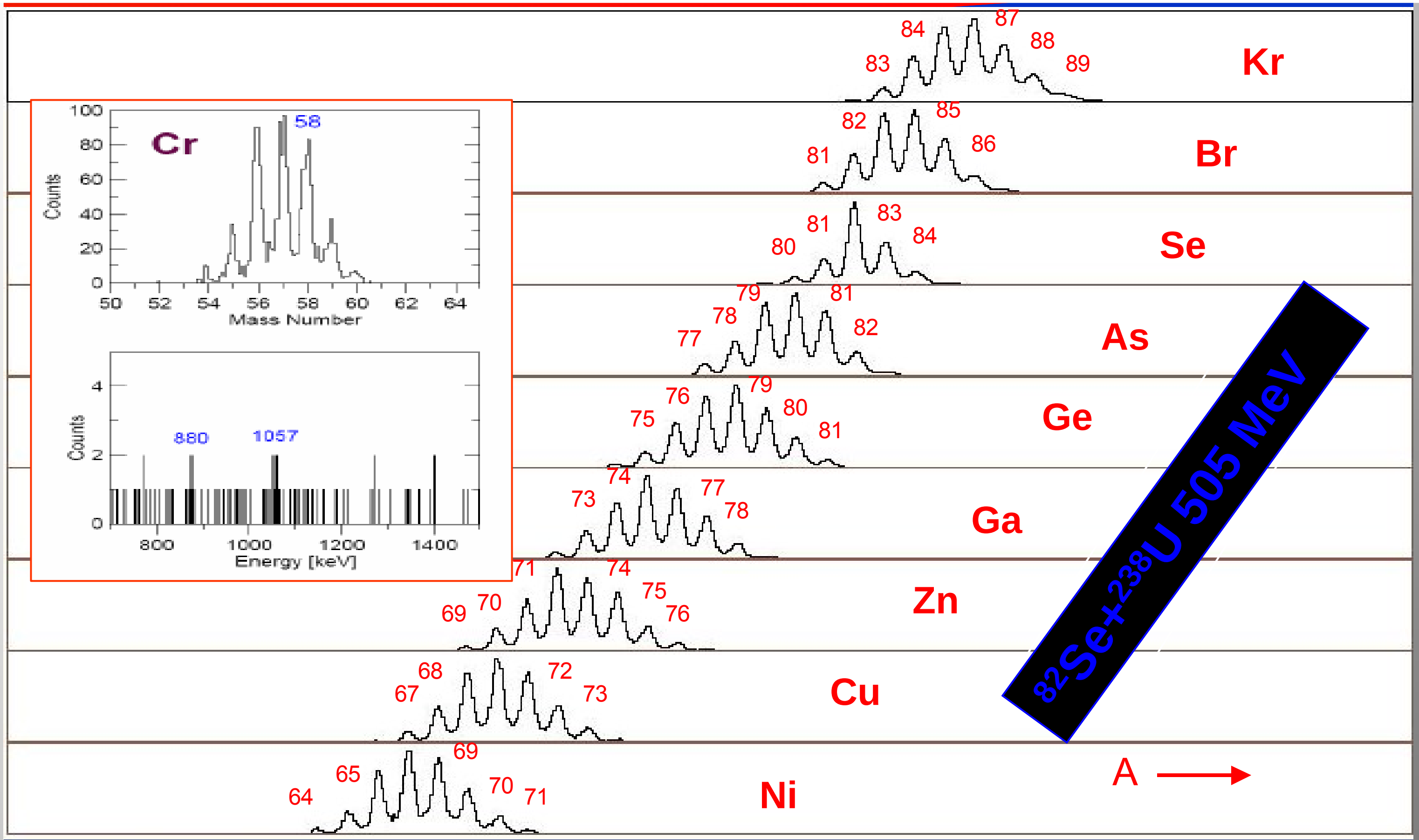
$^{82}Se+^{238}U$ E=505 MeV, 64^0



Δ E

E

Mass distributions of transfer products

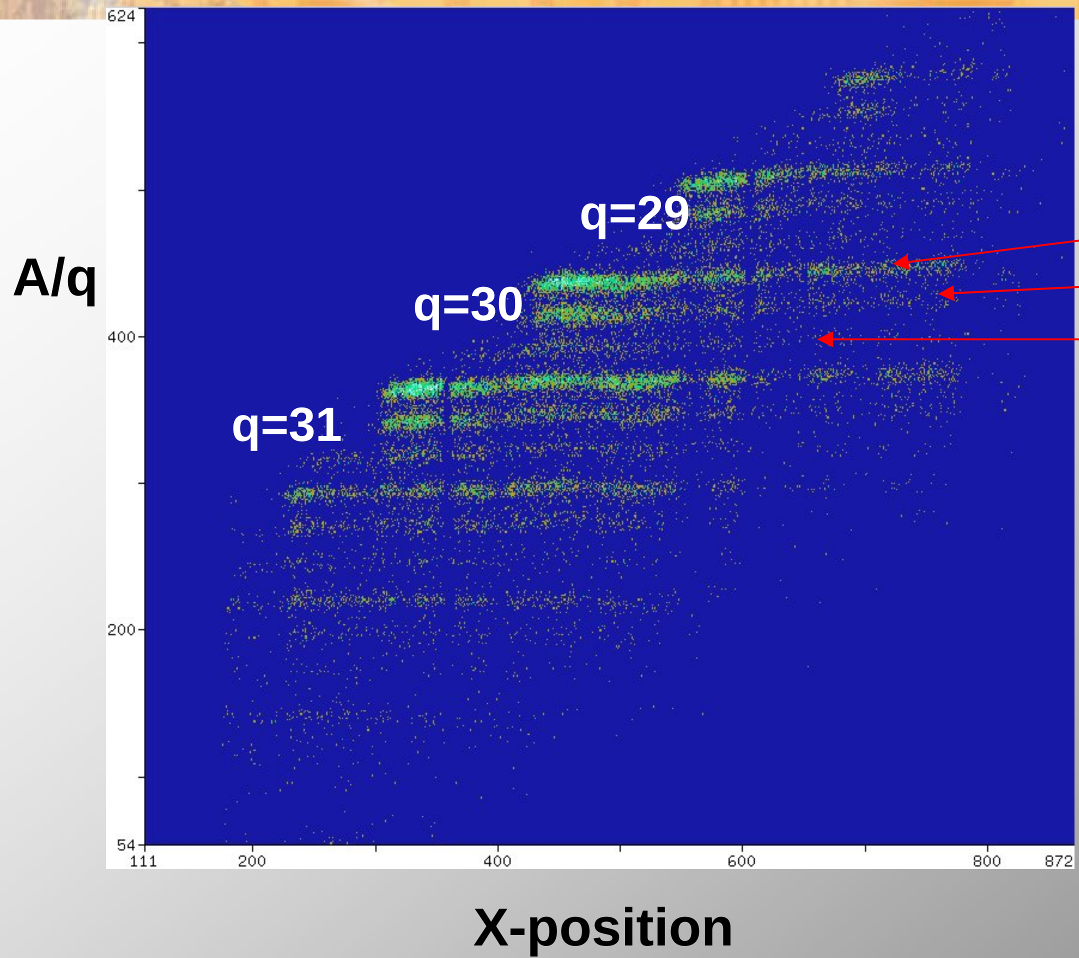


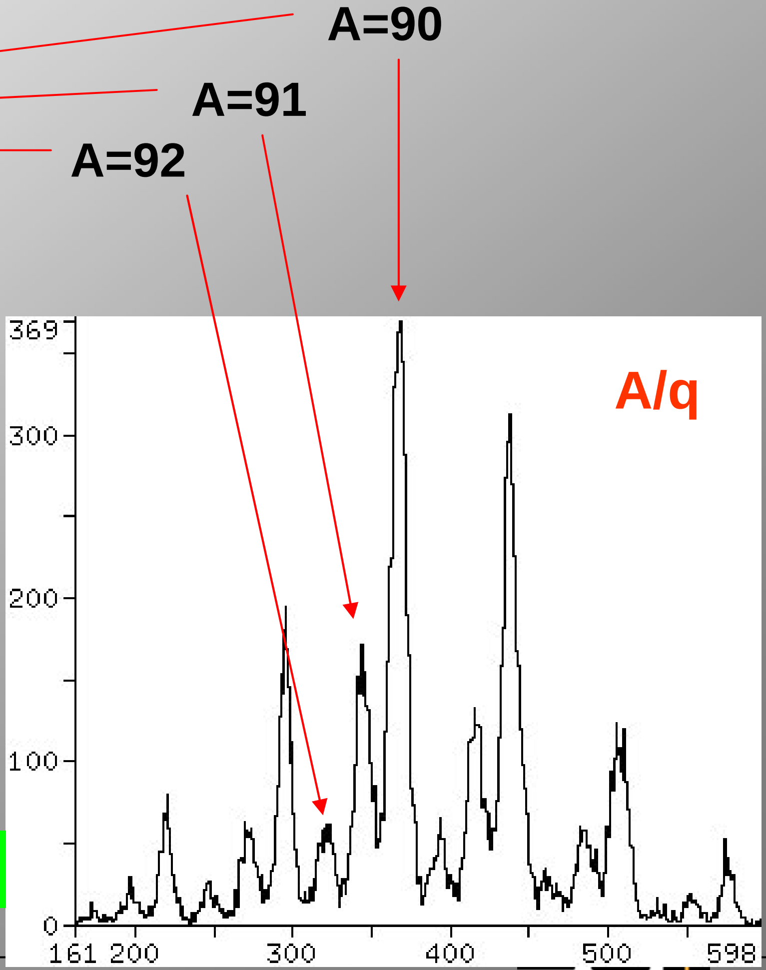
$^{90}Zr + ^{208}Pb$ E=560 MeV @ 62^o

Zr isotopes

LNL – APRIL 2004

1/100 of all statistics





LINEARIZED A/q SPECTRUM

Working Group

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Spectrometer/Separator
a task to be undertaken

- Tracking for particle identification of RIB beam and species to study
- High efficiency/transmission
- Sufficient mass resolution
- General problem: charge states
- low and intermediate energy range
- physics request