The FAZIA initiative:

towards a more powerful detector for future studies on nuclear reactions

Cracow, june 5th 2012 COPIGAL-COLLIGA MEETING
Giovanni Casini for the FAZIA collaboration

Outline:

- The FAZIA project: a brief history and the organization
- The FAZIA project: detectors and performances
- Towards the demonstrator phase
- Physics cases

A brief history of FAZIA

The basis ideas and the goals

- best exploiting of solid state detectors (Silicon, CsI)
- fully fast digital electronics for optimum pulse shape analysis and openness to future developments
- Lowering ion identification thresholds
- Also in view of exotic beams: main goal is investigation of isospin physics at intermediate energies and also interplay structure-dynamics for exotic species

See also the talk given yesterday by T.Kozik

A brief history of FAZIA

About 40 researchers, engeneers and technicians now involved in FAZIA

FAZIA steps from 2006:

2006 ideas, organization, preliminary basis
2007 first experiment in LNL, Legnaro
2009 2 test experiments in LNS, Catania
2009 participation to Spiral2 Eu preparatory phase
2010 test experiment in GANIL
2011 test experiment in LNS, Catania
2011 signature of a MoU
2012 proposal for first BLOCK commissioning (LNS)

A brief history of FAZIA

Publications

- Bardelli et al NIM A 572 2007 how to digitally synchronize different detectors
- Bardelli et al NIM A 605 2009 how channeling spoils PSA
- Bardelli et al NIM A 602 2009 laser method for lab Si doping control
- Barlini et al NIM A 600 2009 preliminary test with analogue electronics
- Napolitani et al PRC C81 2010 the Fazia perfomances via simulated reactions
- Parlog et al NIM A 613 2010 charge collection in reverse mounted Si
- Bardelli et al NIM A 654 2011 mass separation, full Fazia silicon recipe
- Carboni et al NIM A 664 2012 PSA, identification thresholds
- Barlini et al NIM A ready to submission radiation damage aspects
- Pasquali et al NIM A to be submitted Single chip telescope: sparing electronics preserving perfomances
- Bougault et al NIM A to be submitted PSA vs front and rear injection: a precise comparison

Letters of intent at RiB's facilities

- R. Lemmon et al. for Spiral2 beams coupling FAZIA and VAMOS
- G C et al. for Spiral2 beams on CN decay vs. isospin
- G C et al. for SPES beams on Dynamical Dipole Emission
- G C et al. for SPES beams on dissipative collisions and isospin

The present FAZIA organization

Spokesperson:
R.Bougault LPC Caen
Deputy-:
G.Poggi Uni and INFN Florence

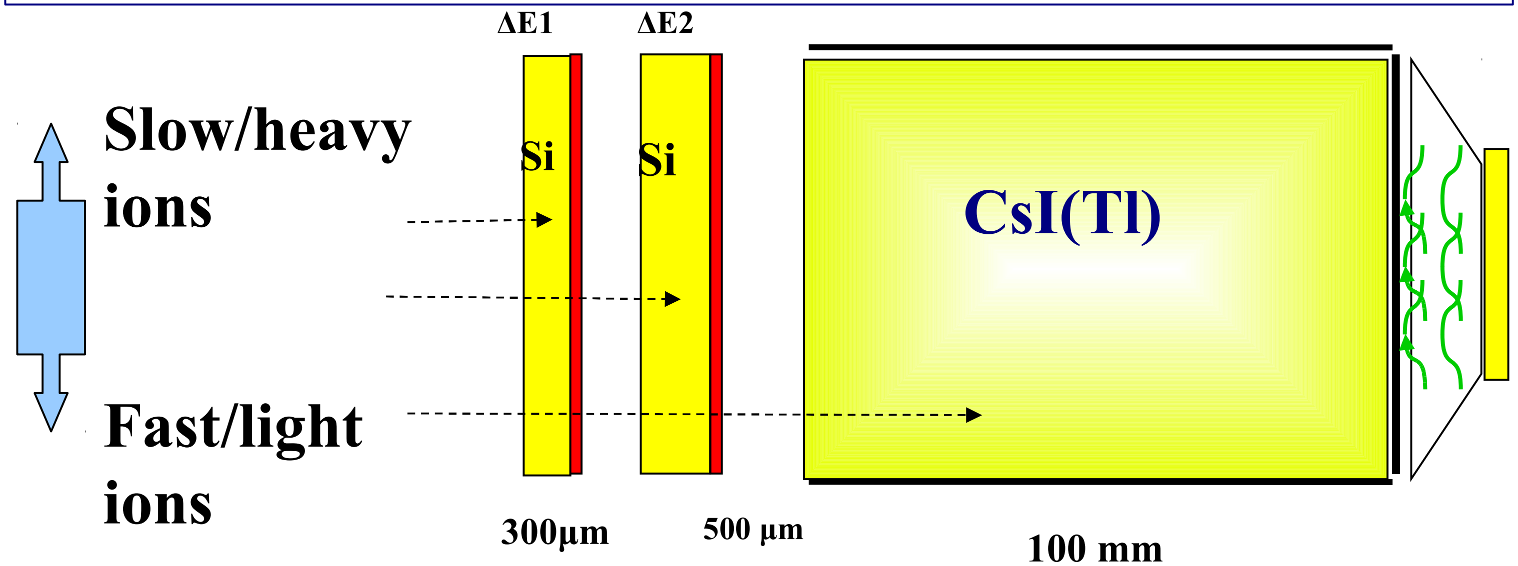
FPMB: Fazia project Management BOARD

TASK GROUPS for the Demonstrator PHASE

- TG1 Physics (G.C. INFN Fi)
- TG2 Data Analysis (N.LeNeindre, Caen)
- TG3 DAQ-FEE Trigger (P.Edelbruck, Orsay)
- TG4 Mechanics (M.Guerzoni INFN BO)
- TG5 Detectors (B.Borderie, Orsay)

November 2011: Memo. of Understandings signed by funding agencies of the five countries: it rules the activity **2012-2016** aimed at the construction and use of the Demonstrator

The Basis module



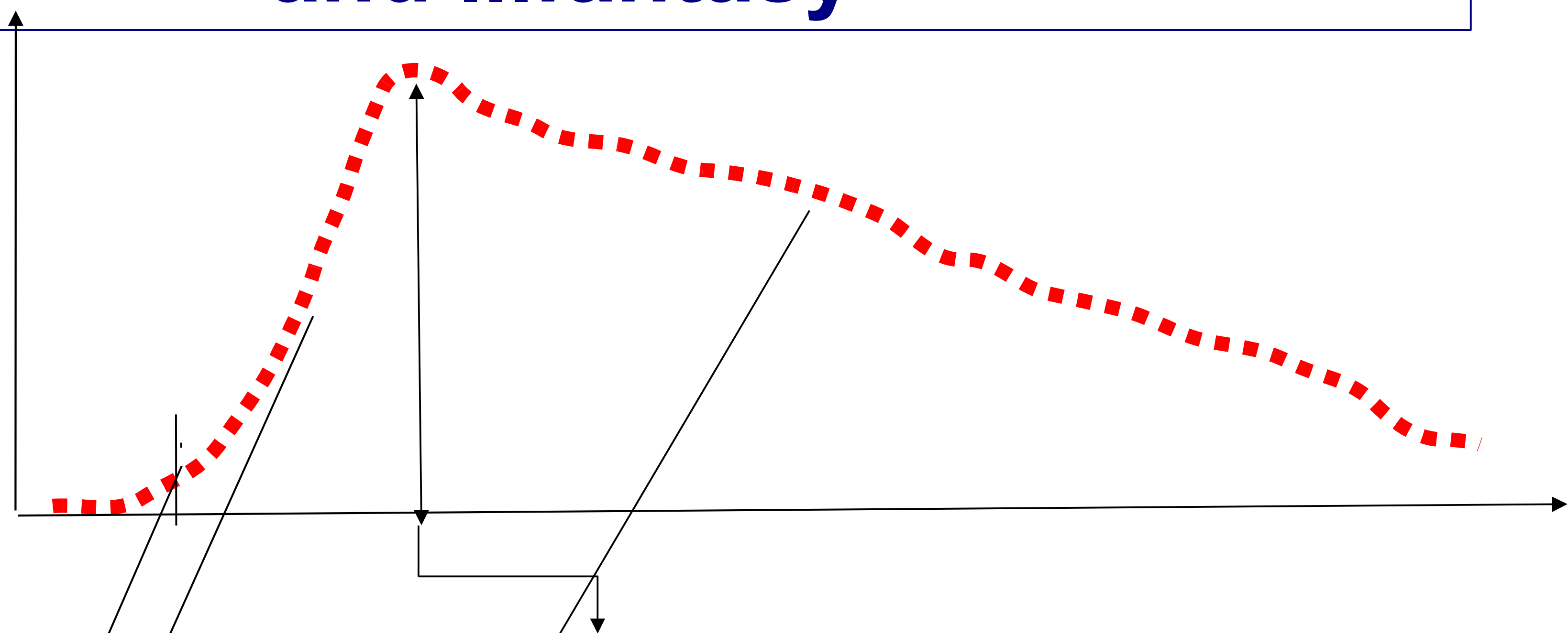
Rather conventional telescope but with special care to <u>detectors</u> and <u>electronics</u>.   NOTE: silicons are in **<u>reverse configuration</u>**

Specific Issues:

- How to best profit of digital electronics
- Aspects limiting PSA in Silicon (crystal structure and doping inhomogeneities)
- How to mantain good energy and timing performances (low E-field injection)
- Radiation Damage and PSA
- Strip detectors
- How to best exploit PSA with inorganic scintillators
- How to lower energy thresholds
- Single chip solution (second silicon stage also acts as a photosensor)
- Wide dynamical range (in ion size and energy)

Fast sampling, Pulse shape analysis (PSA) and ...fantasy

FAST sampling allows to deduce a rich information



Maximum (directly or after optimum filtering, ie. shaping) **ENERGY**

TIMING (time mark to be used as a difference with an other mark) **TOF**

RISETIME (algorithms to evaluate the leading edge duration) **PSA**

Skewness and others (algorithms to evaluate overall shape parameters) **PSA**

Ion identification in silicon detectors and its enemies

Structural effects

Crystalline nature of Silicon i.e. channeling
Doping inhomogeneities in Silicon bulk

Electrical, Electronics

Noise and sampling limits

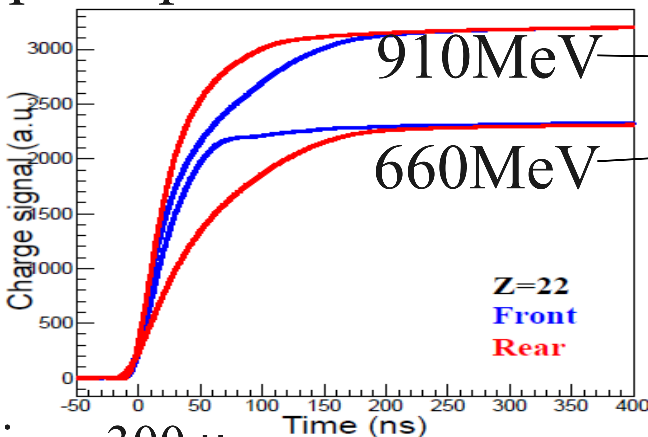
Dynamical effects

Radiation damage

PSA in Si detectors

Exp. shapes for Titanium ions

PSA is more effective in reverse mounting



910MeV → Range almost equal to det. thickness

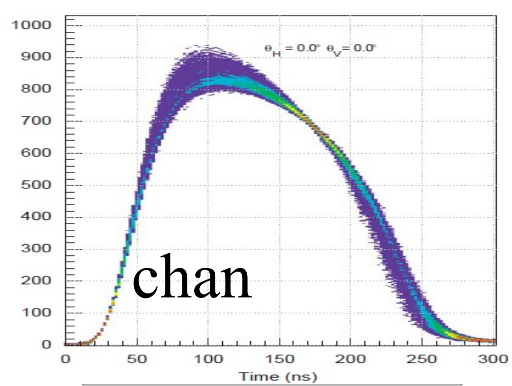
660MeV → Range around 2/3 of det. thickness

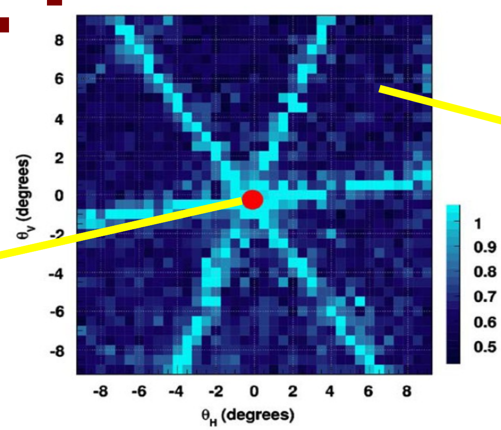
Silicon 300 µm

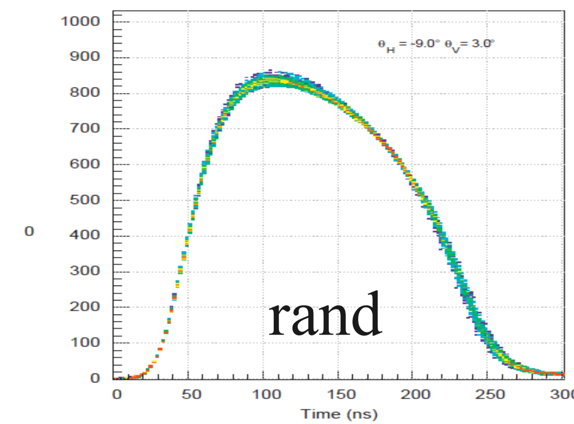
R.Bougault et al. In preparation

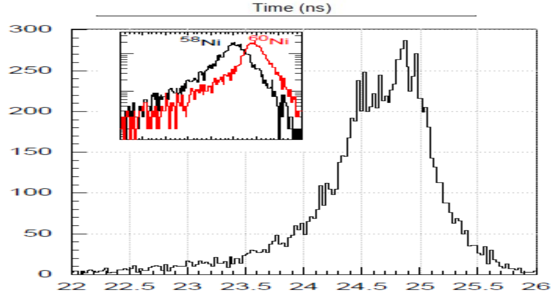
CHANNELING EFFECTS

Bardelli et al NIM A 605 2009







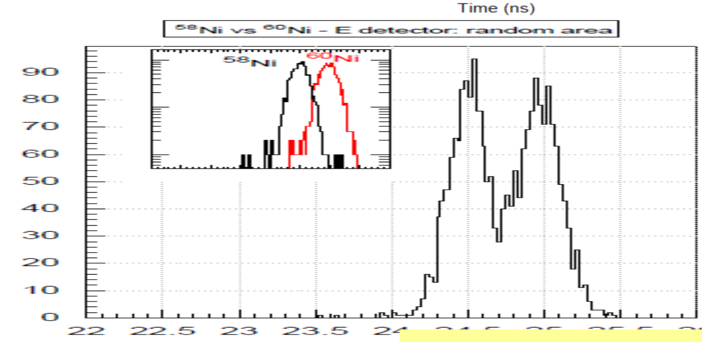


Current risetime

STOPPED IONS

^{58}Ni ^{60}Ni

703MeV

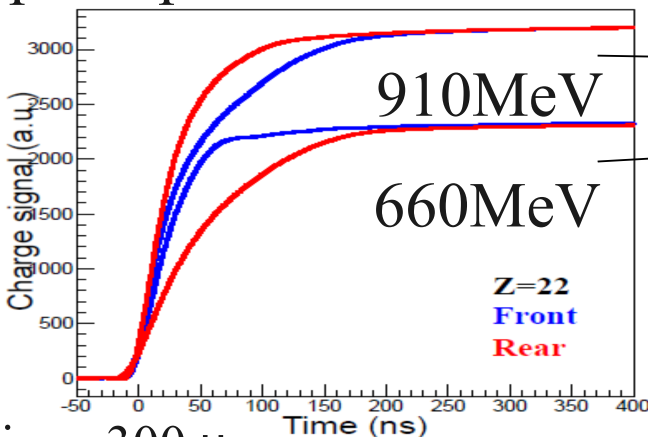


Current risetime

PSA in Si detectors

Exp. shapes for Titanium ions

PSA is more effective in reverse mounting



→ Range almost equal to det. thickness

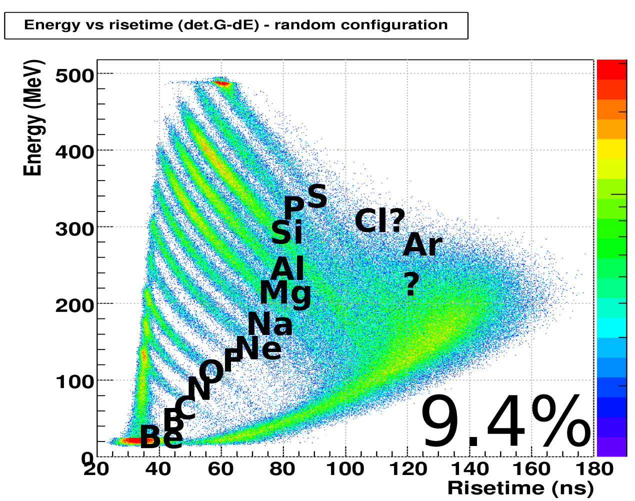
→ Range around 2/3 of det. thickness

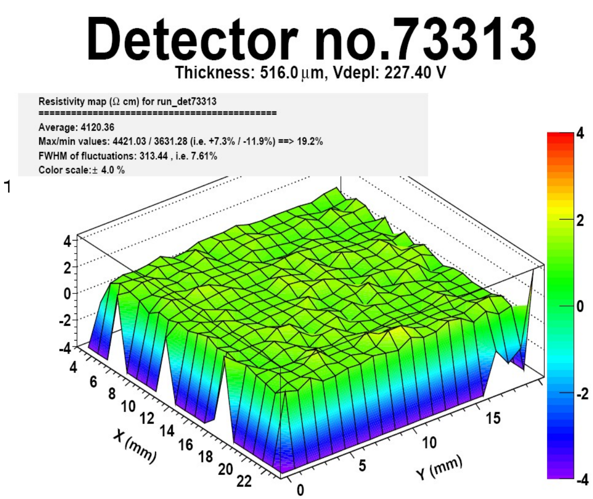
Silicon 300 µm

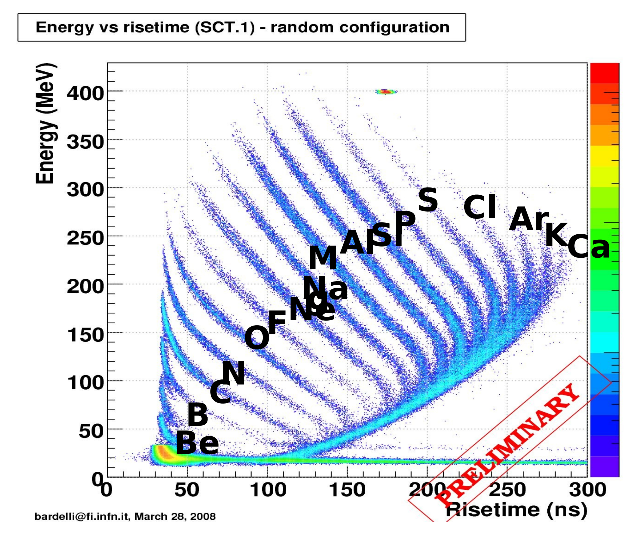
R.Bougault et al. In preparation

DOPING INHOMOGENEITY

Bardelli et al NIM A 654 2011







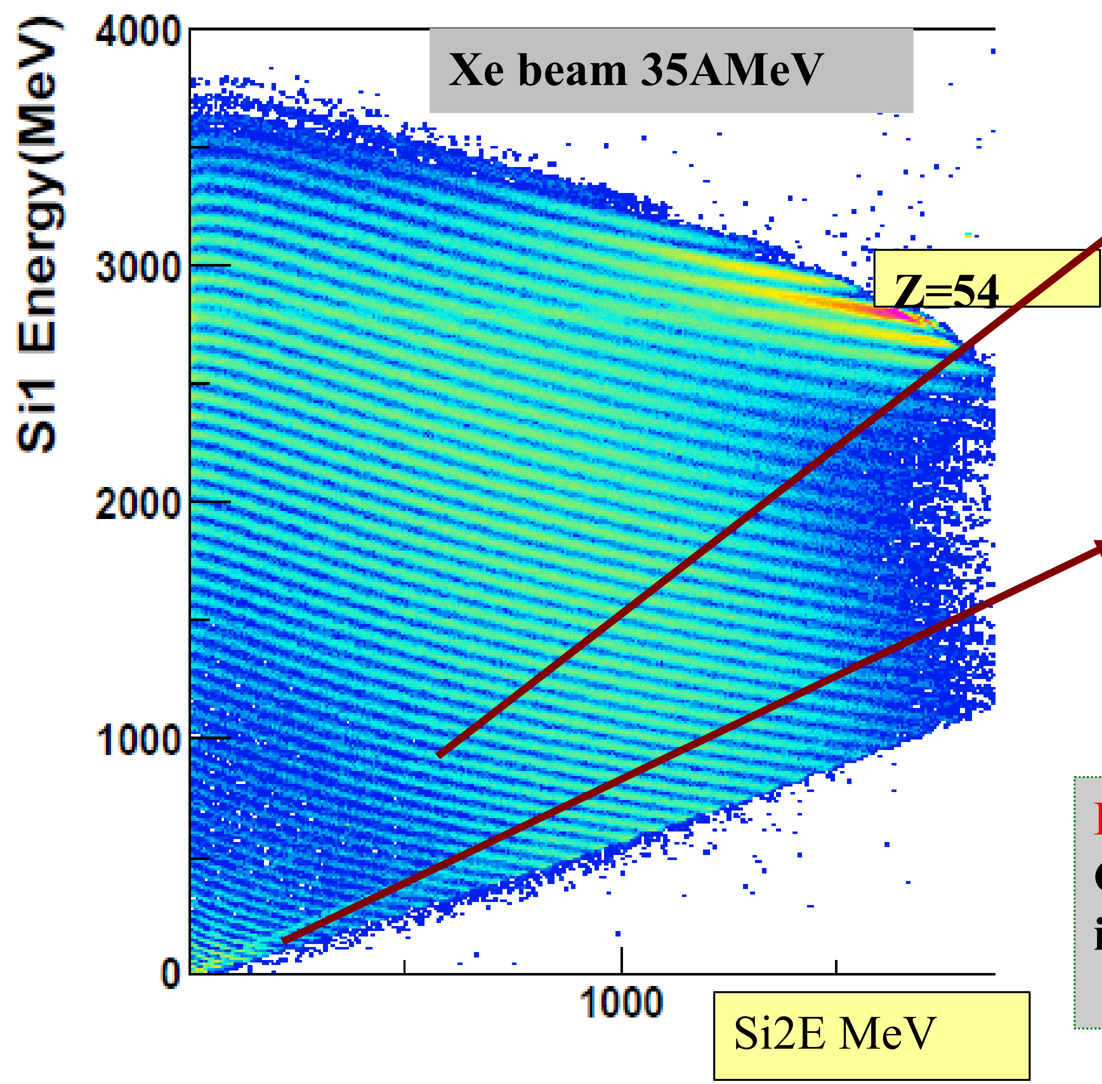
1%

IN THE END

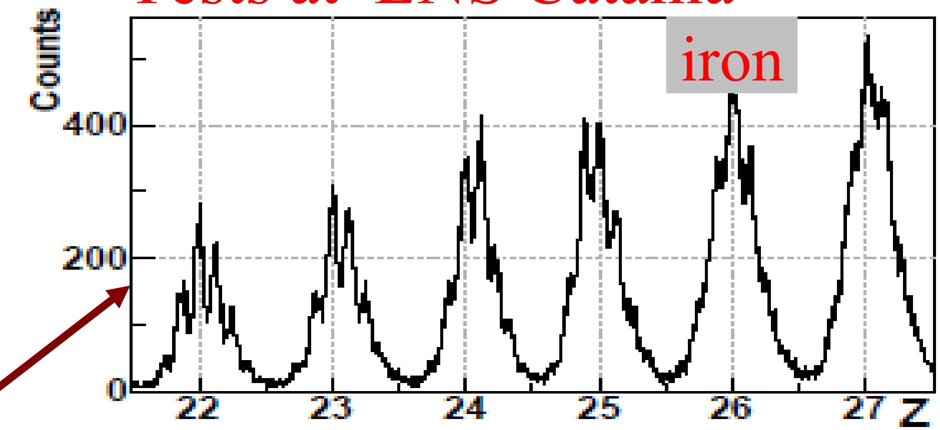
Keep under control channeling effects
Reduce as possible doping inhomogeneities (nTD silicon ingots)

Performances for fast ions

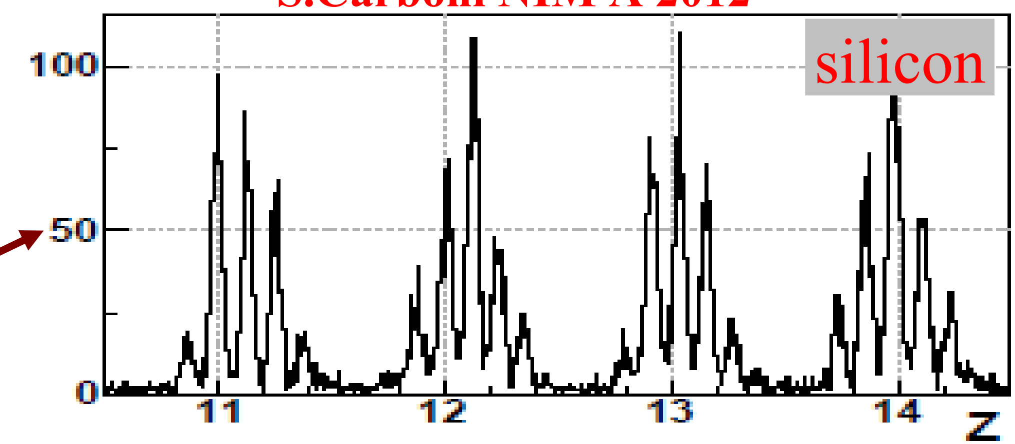
**ΔE-E technique
for ions passing-throu the first
300micron Si-layer**



Tests at LNS Catania



S.Carboni NIM A 2012



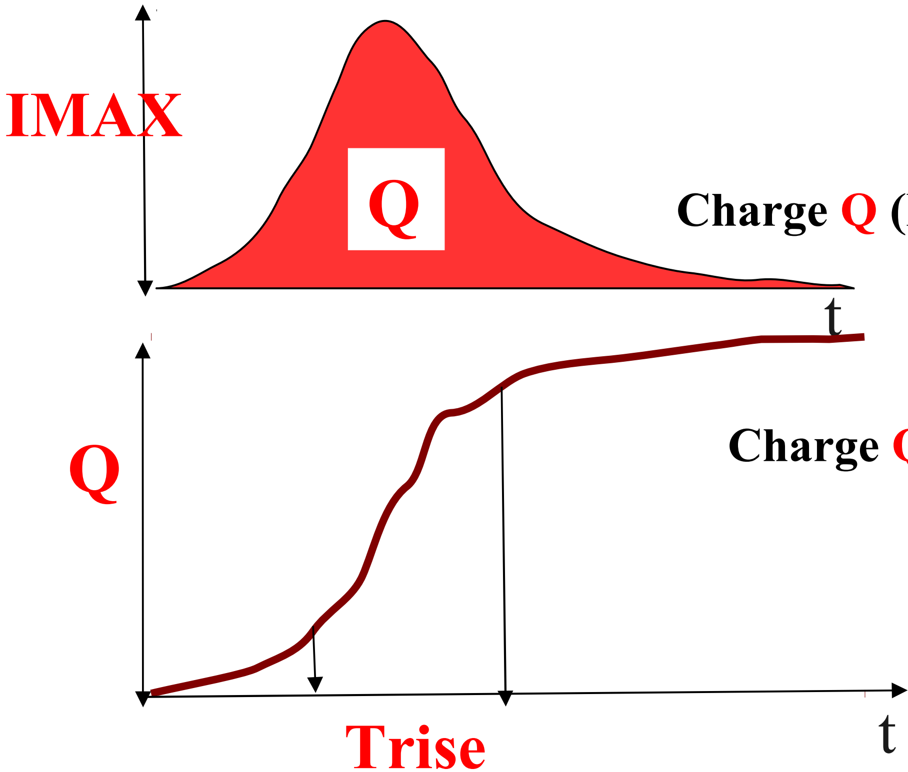
Powerful for Intermediate energy experiments!
Ca-Ni quasi-projectiles: (almost) fully A,Z identified at intermediate energies

Performances for slower ions

The big challenge of identifying ions stopped in one Silicon stage

FAZIA developed special electronics: PACI preamplifier (IPN ORSAY) with two outputs

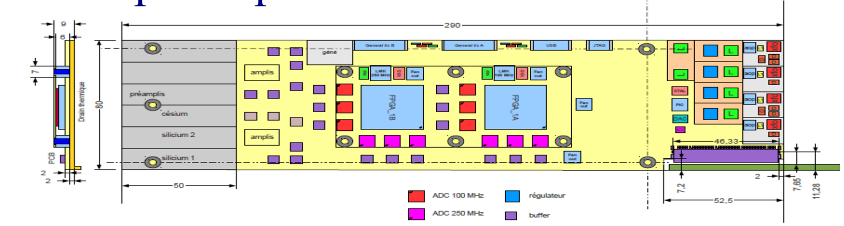
Current output
Charge output (Miller integr.)



Charge Q (E) vs. Current max IMAX

Charge Q (E) vs. Q risetime Trise

PACI preamplifier board SIX CHANNELS



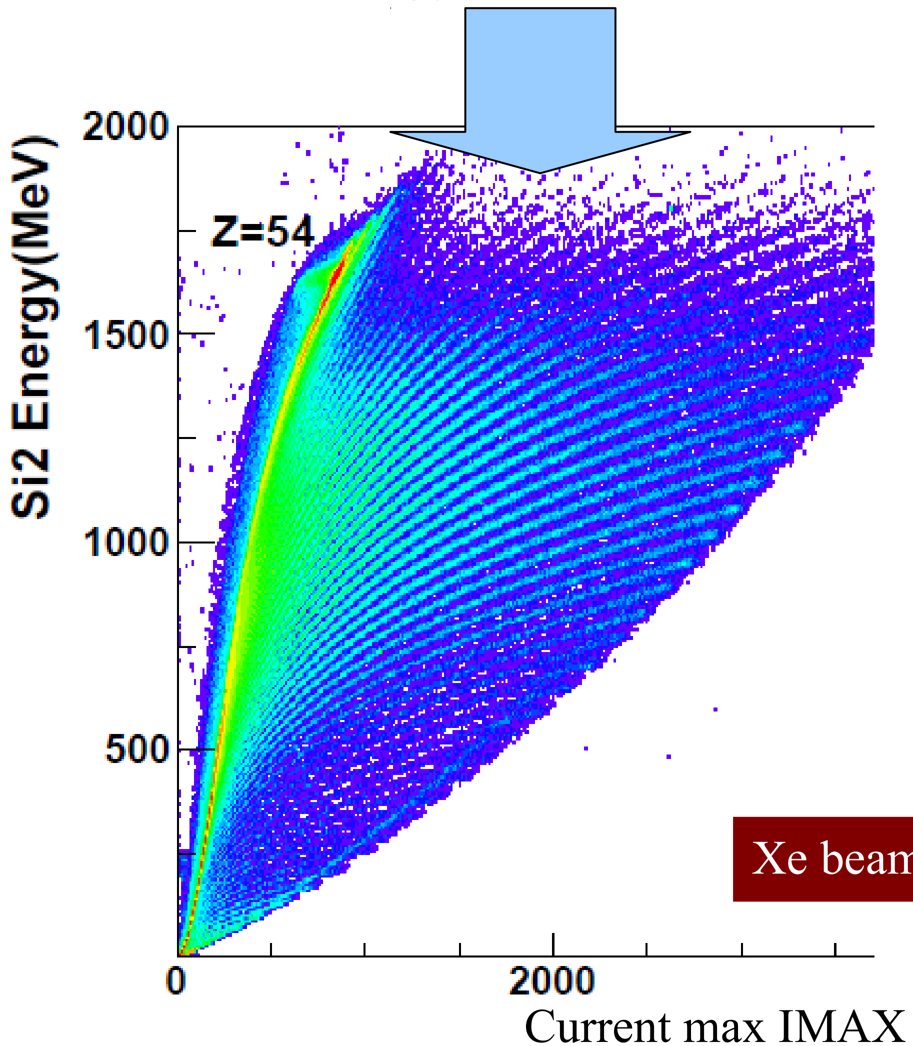
Used in the past tests:

Digitizer (bit/rate)	14 bit/100 MHz
Digitizer ENOB	11.2
Actual full range	Between 2 and 4 GeV (Q output)

Performances for slower ions: Z

CURRENT SIGNAL

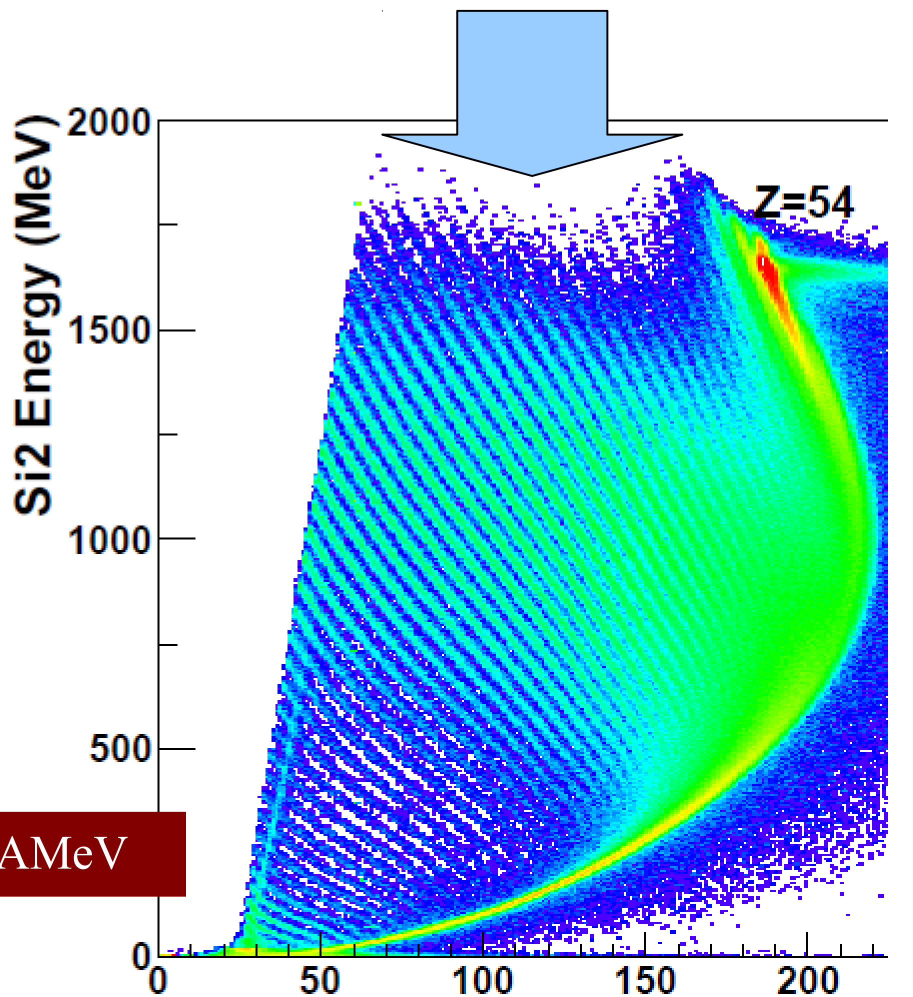
Energy vs IMAX



Xe beam 35AMeV

CHARGE SIGNAL

Energy vs Qrisetime



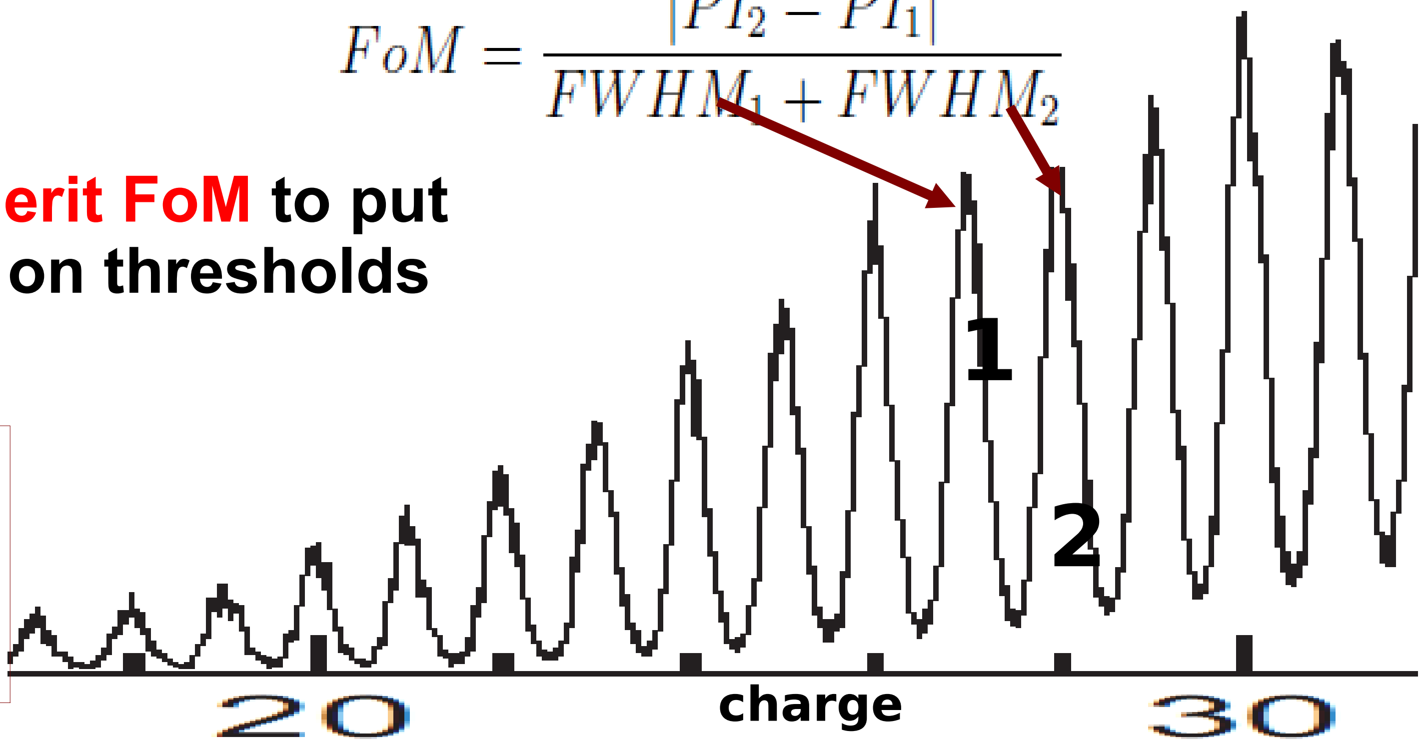
Si+Si 300+300 micron for test @LNS

S.Carboni et al, NIM A 664 2012

Comparison of identification methods

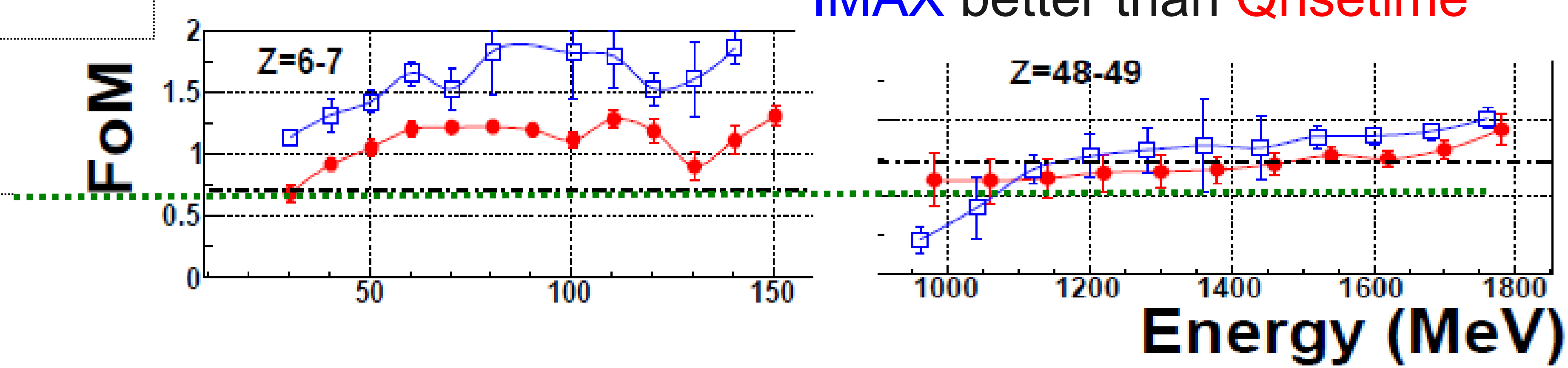
$$FoM = \frac{|\overline{PI_2} - \overline{PI_1}|}{FWHM_1 + FWHM_2}$$

Use of Figure of Merit FoM to put quantitative limits on thresholds



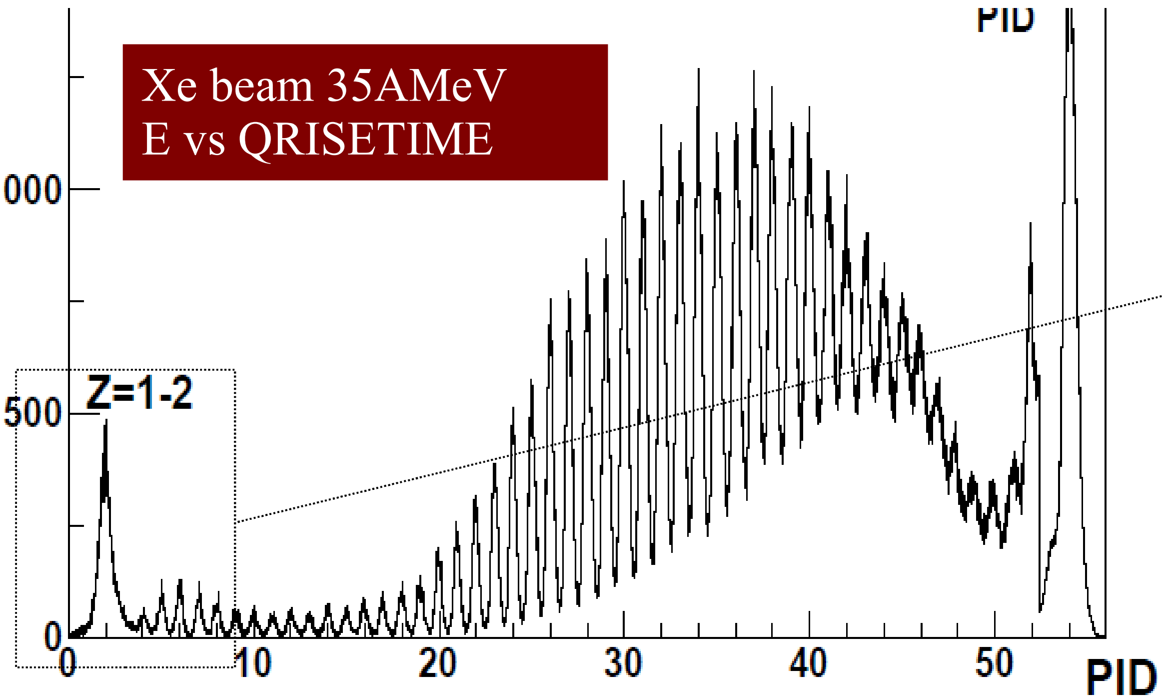
Arbitrary limit 0.7 chosen for good identification

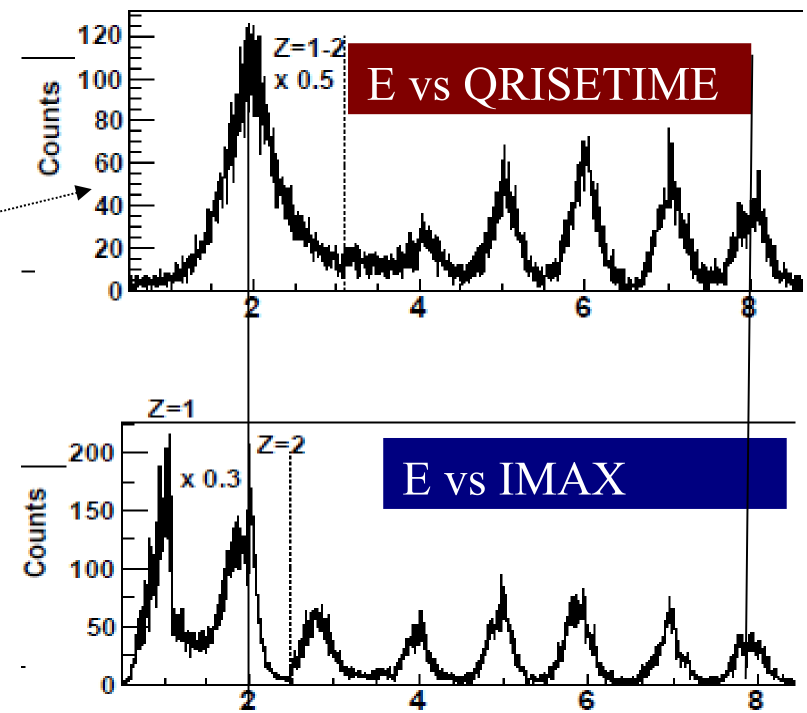
IMAX better than Qrisetime



S.Carboni et al, NIM A 664 2012

Performances for slower ions: Z





Heavy ions well Z-separated up to over Z=54
with both current and charge estimators

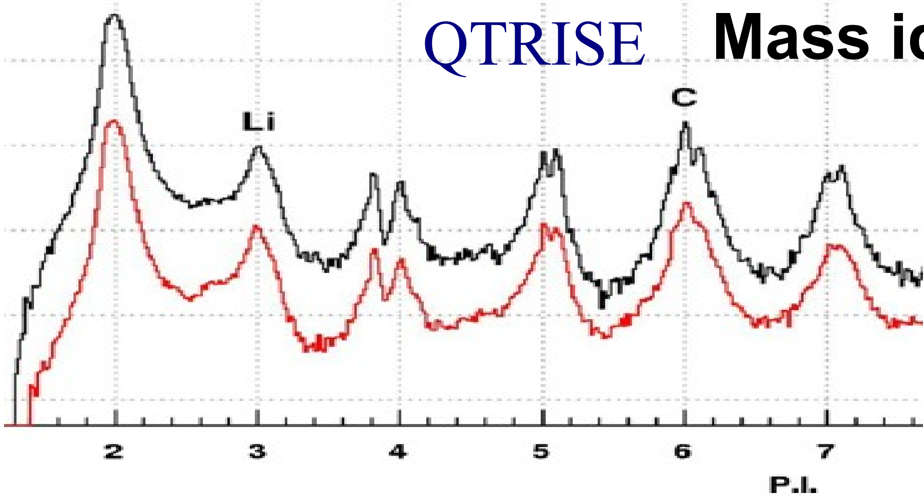
PSA through current signals looks better for light ions

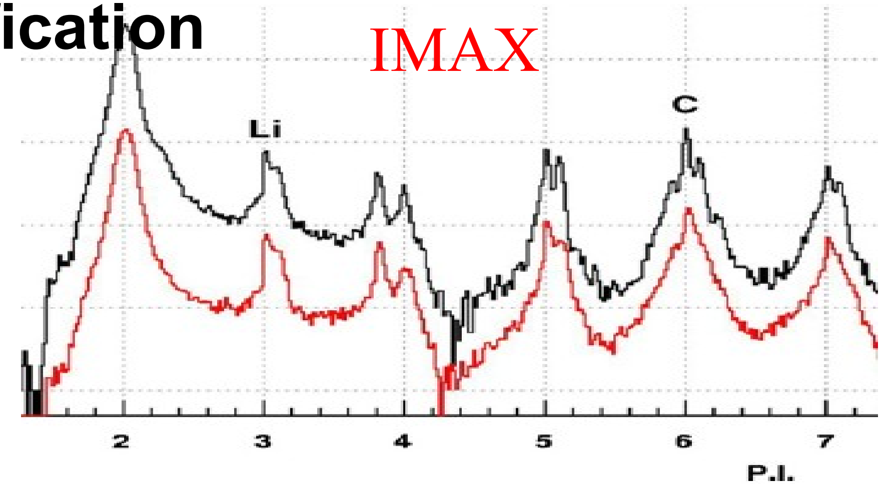
Z=1,2 separated even with a full dynamics of 2-4GeV !

What about mass separation for slow ions (from PSA)?

Performances from D-PSA: mass and thresholds

QTRISE **Mass identification** IMAX





Isotopes till Z=7-12 above roughly 5-9AMeV, but this demands:

-High PREAMP gains (we have indeed double gain on Si1)
-Very high doping homogeneity
-radiation damage?

Fore sure delicate subjects!

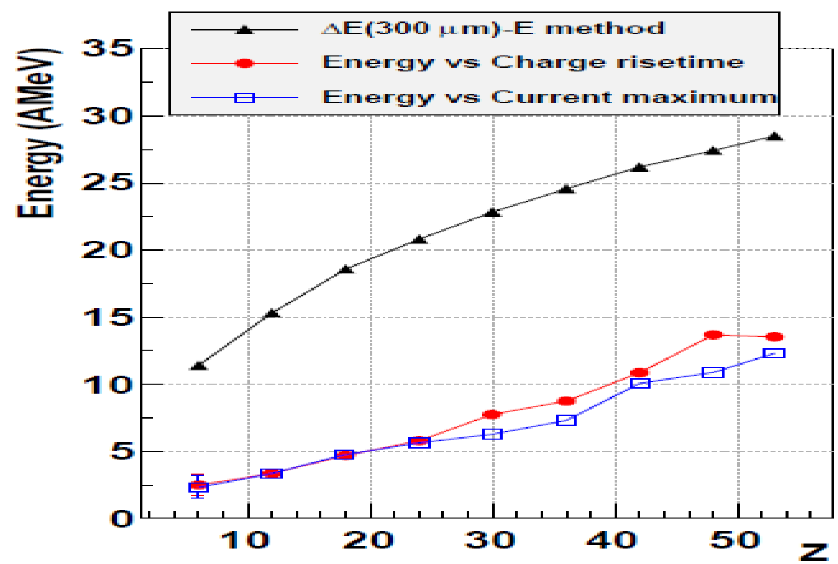
Bardelli NIM A 2009 Carboni NIM A 2012

	FoM $^{12}C-^{13}C$ @ 100 MeV	Threshold C–N Z	Threshold $^{12}C-^{13}C$ A	
Fig. 3(a): PSA chan.	0.7	33MeV (2.5AMeV)	110MeV (8.5AMeV)	
Fig. 3(b): PSA rand.	1.0	32MeV (2.5AMeV)	64MeV (4.9AMeV)	RND
Fig. 4(a): PSA chan.	0.7	36MeV (2.8AMeV)	108MeV (8.3AMeV)	
Fig. 4(b): PSA rand.	1.1	35MeV (2.7AMeV)	65MeV (5.0AMeV)	RND

FoM for Isotope separ. for 100MeV Carbon ions

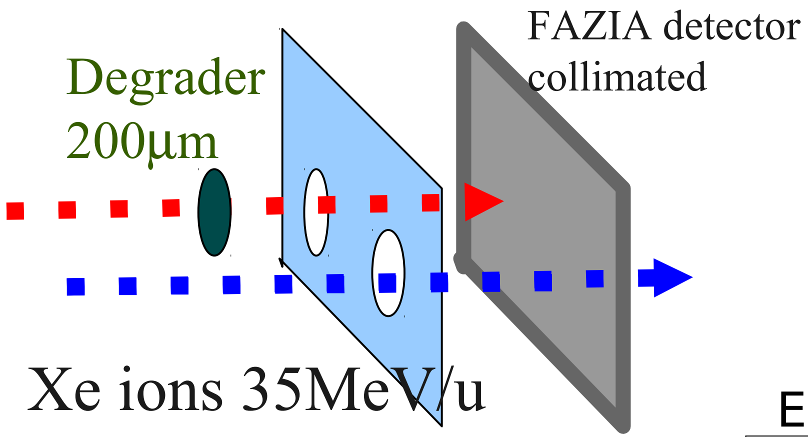
sep.thresholds

E thresholds for Z-identification

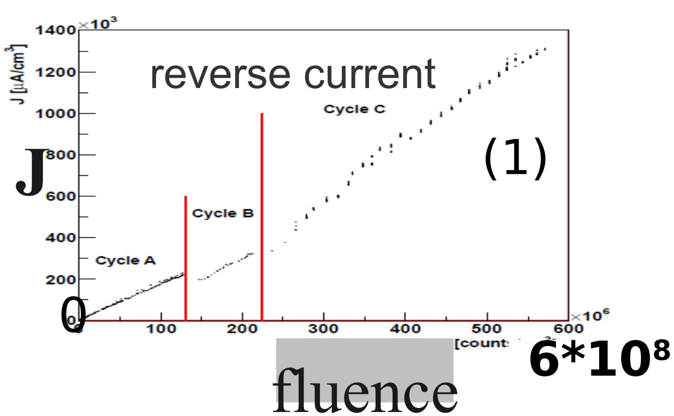


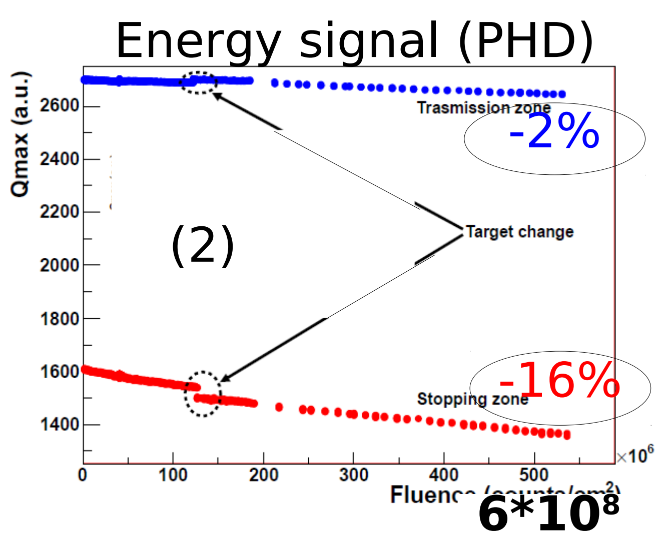
Performances from D-PSA: radiation hardness

Stability of shapes with ion fluence is relevant: PSA vs. Radiation Damage studied with specific under-beam experiment

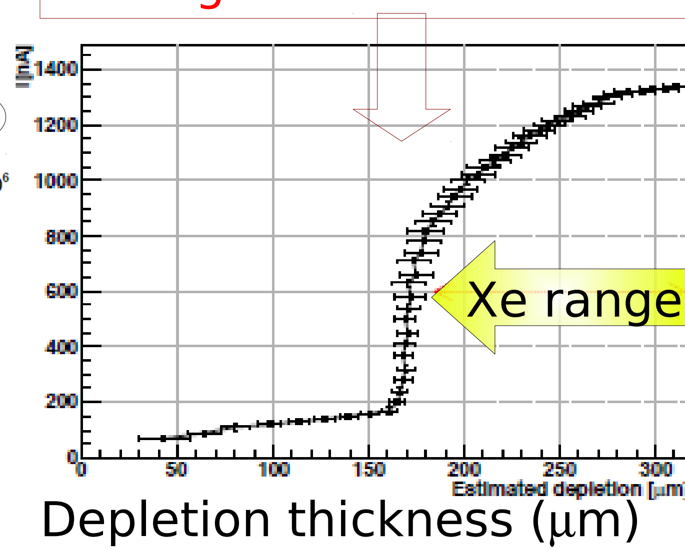


- Reverse current increase (1)
- increase of PHD (loss of carriers) (2)
- slight influence for transmitted ions
- big effect for stopped heavy ions





...two years later a steep jump in i-V characteristic was found in lab: the Xe-damaged wall



NOTE: the Silicon Voltage is mantained at a fixed value by correcting for the reverse current growth!

S.Barlini et al,
Eurorib2012 poster and
Paper ready to submission

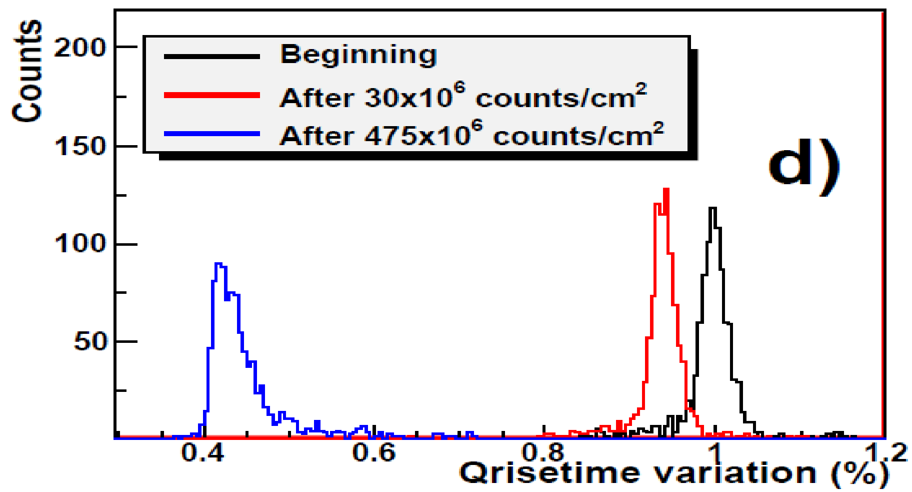
Performances from D-PSA: radiation hardness

New finding:

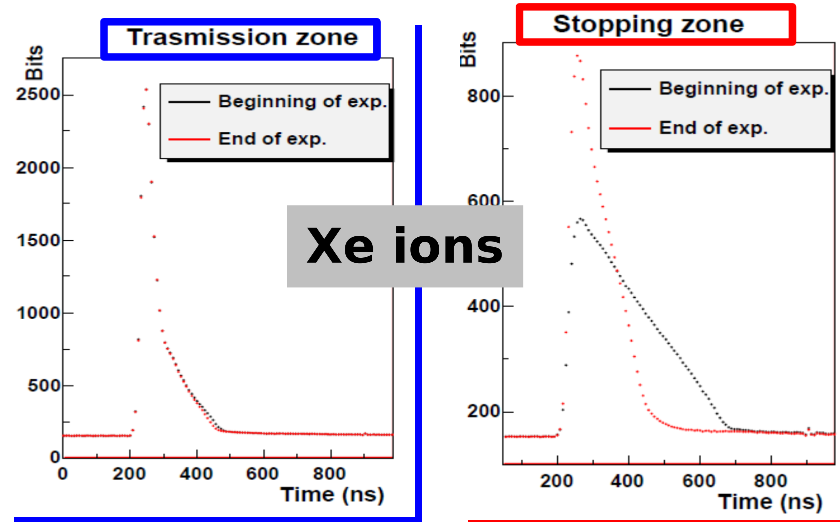
Shortening of the collection times

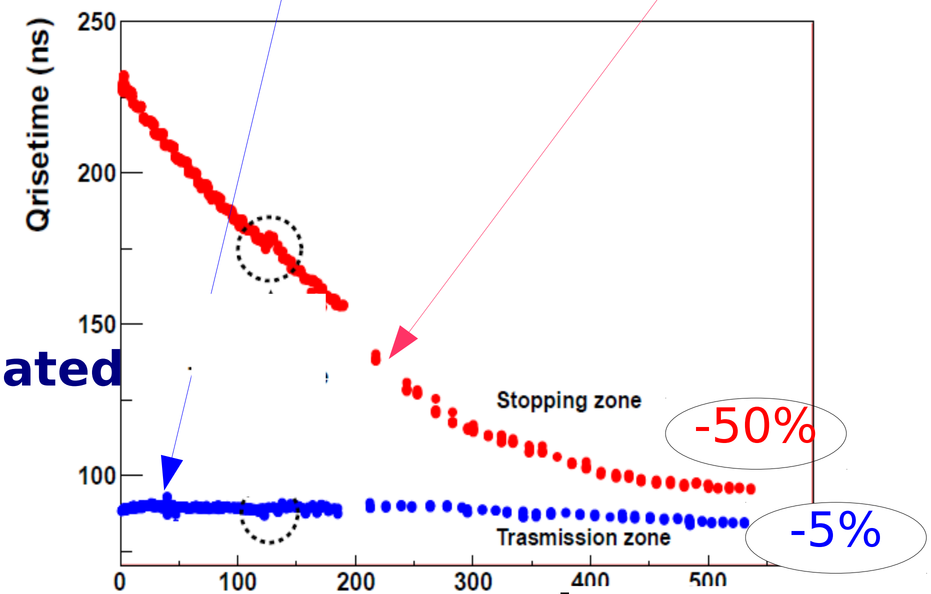
-big effect for stopped heavy ions

-slight influence for transmitted ions



Here is the evolution with Fluence





Fluence up to $600 \cdot 10^6$ ion/cm²

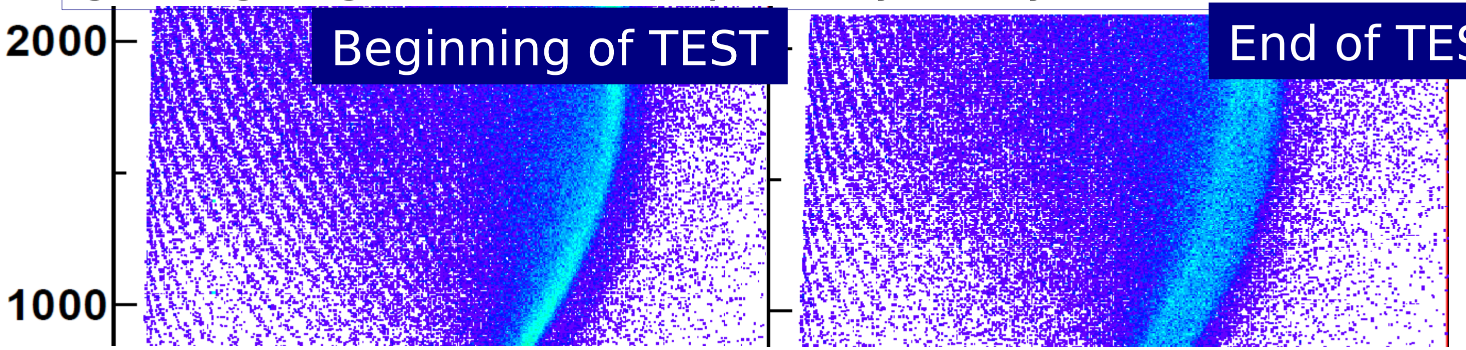
New result, it should be further investigated

Signal time profile is given by
e-h collection time and plasma delay.

*Does **PLASMA DELAY** decrease due to recombination (trap centers) at the track end?*

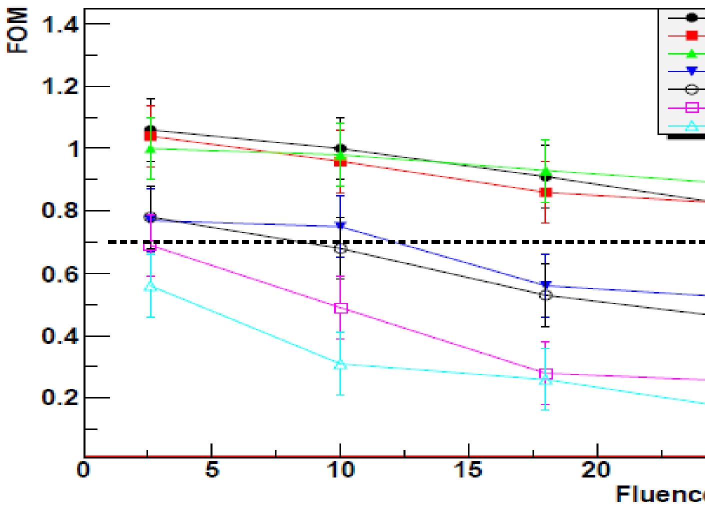
Performances from D-PSA: a real-life silicon detector

PSA from a 'real-life' Silicon Detector (20x20mm^2 not collimated), close to the grazing angle (2.35°) and partially hit by scattered Xe ions



FoM decreases continuously

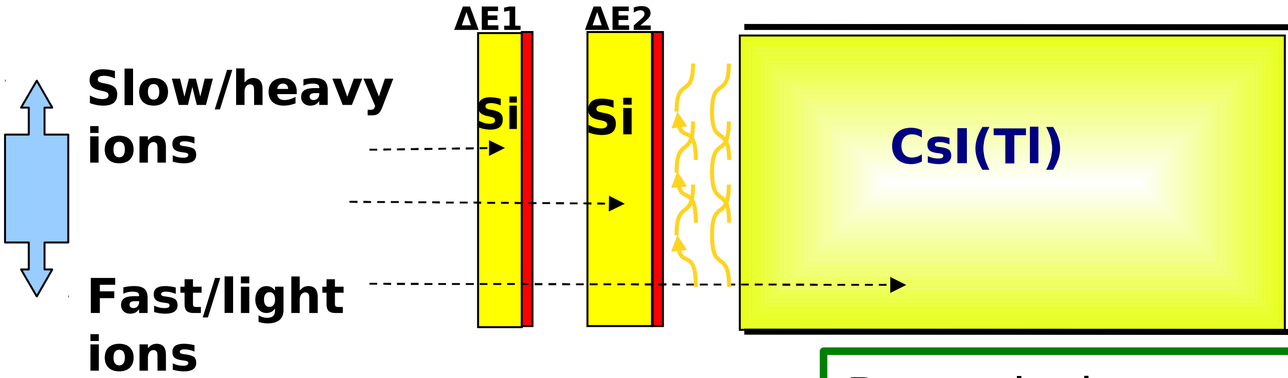
S.Barlini et al,
ready to submission



estimated SAFE LIMITS (for damage by **Xe**):
300 million ion/cm2
in TRANSMISSION
10 million ion/cm2
in ABSORPTION

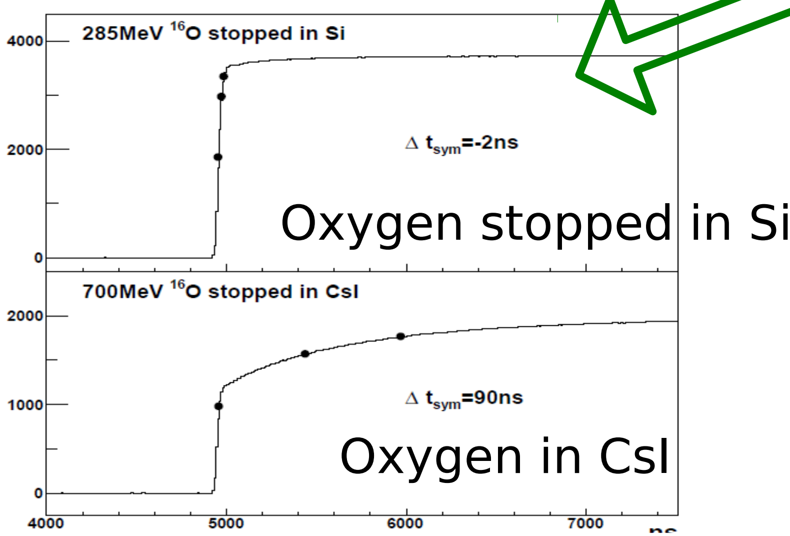
- Only few detectors will be below 2-3deg.
- The damage should go as Z^2
- PSA is used for first layer (less damage risk)
- self-annealing?

Single Chip mode



A rather aged idea (G.Pasquali et al NIM A 1991) fully renewed thanks to Digital Electronics

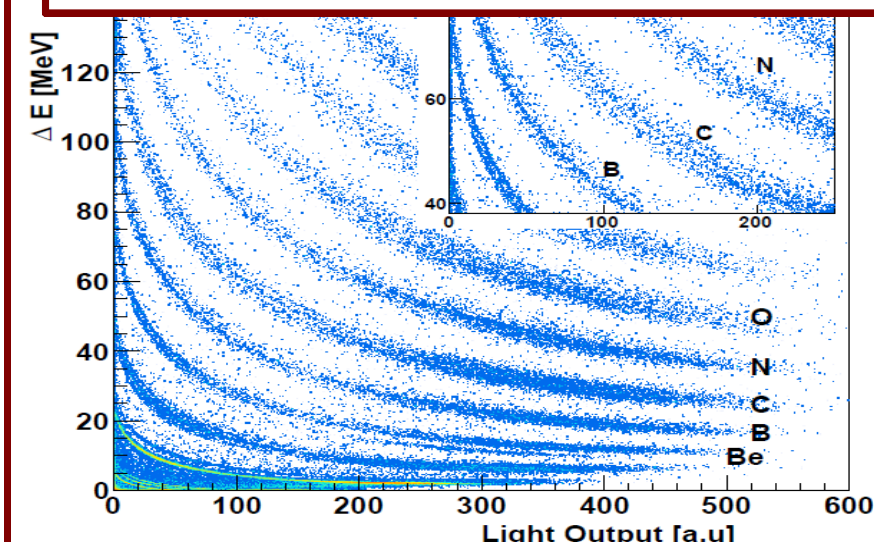
By analyzing sampled shapes (leading edge) one can disentangle the different cases



Time ns

Two **shaping filters** method: **short** T_s=700ns and **long** T_L=8000ns

Ions stopped in silicon vetoed



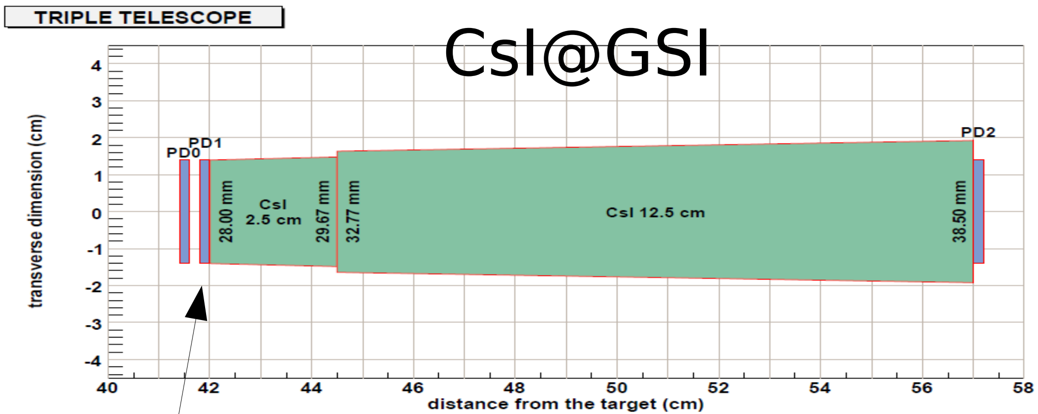
Pasquali et al. ready for submission

GOOD PERFOMANCES almost equivalent to standard read-out for light-charged particles. Worse resolution for IMF (DE info spoiled by Eres (light) in CsI).

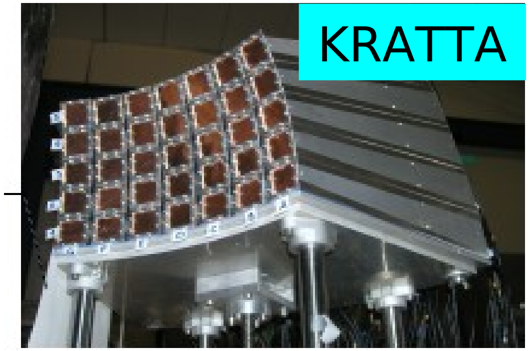
Single Chip mode

A fruitful Poland-Italy 'long-range' cooperation!

CsI@GSI

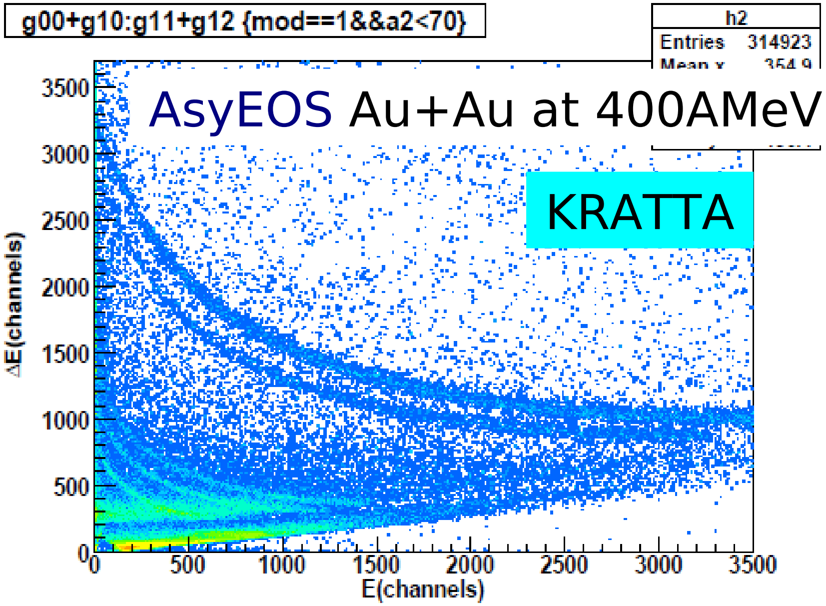


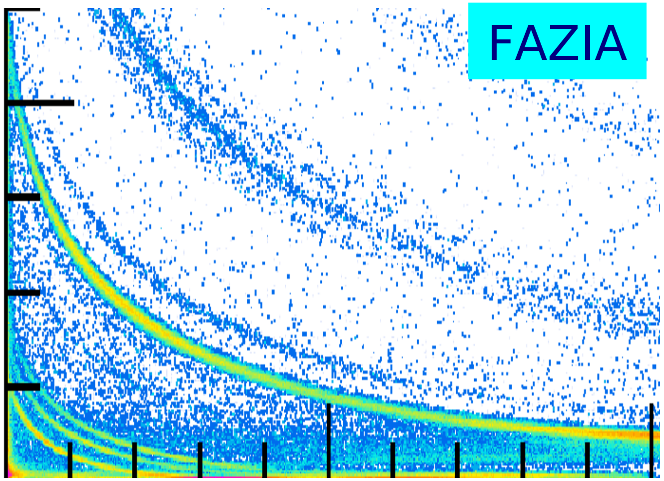
Single chip mounting scheme: the PD Hamamatsu S5277 acts also a ionization detectors (DE)



J.Lukasik et al.2008

KRAKOW ARRAY
36 triple PHOSWICH detectors from cracovian group of the **ASY-EOS** collaboration at GSI

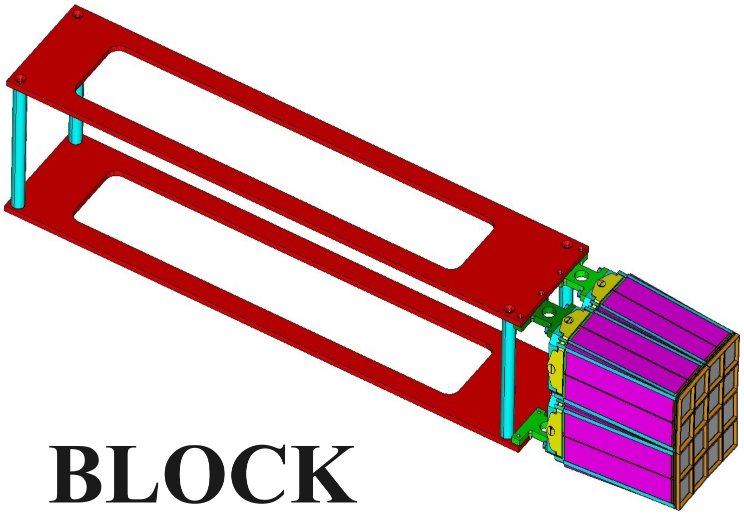




LNS Xe+Sn at 35AMeV

Towards the demonstrator

Silicons: 20x20 mm2; Thickness: 300 and 500 micron; special productions steps for homogeneity and orientation
CsI(Tl): 20.5x20.5x100mm3 slightly tapered; Thallium-doping 1500-2000ppm; wrapping with innovative reflecting film (Vikuiti 3M). Readout: specially developed FBK Photodiodes
Electronics: fully digital treatment of PREAMPout signals (current and/or charge)



BLOCK

FrontEnd: PRE-ADC-FPGA under vacuum with special solutions for mechanics, cooling and data-trigger I/O already discussed and approved
Unit-Module (block): 4x4 telescope matrix, about 88x88mm2 front face package

Towards the demonstrator

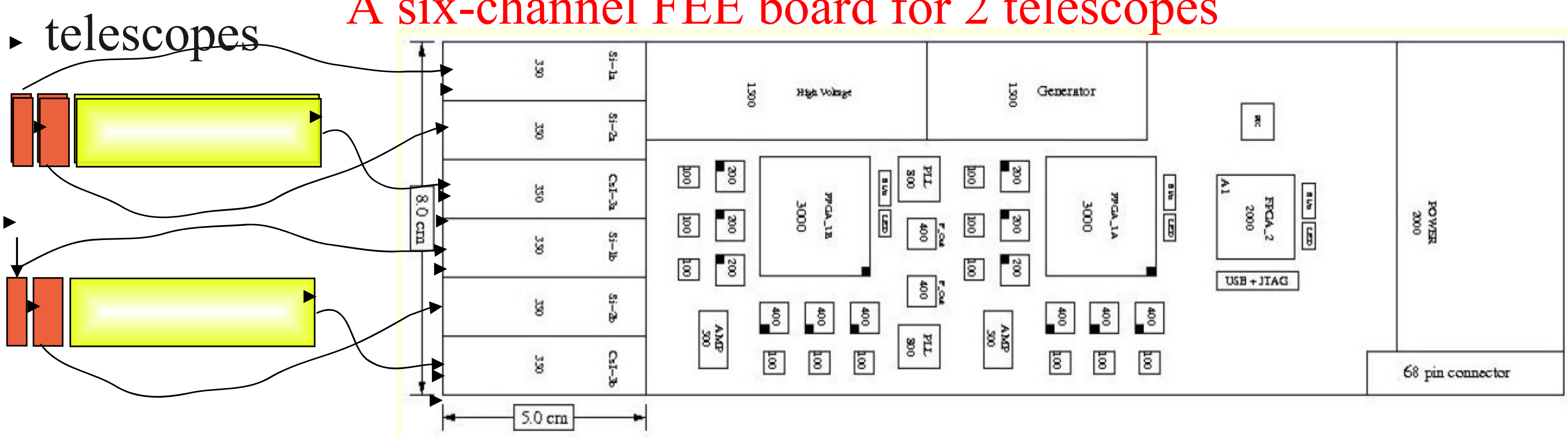
- Stage 1 (silicon 300 μm)
  - Charge 250 MeV full scale 250 Ms/s 14 bit
  - Charge 4 GeV full scale 100 Ms/s 14 bit
  - Current 250 Ms/s 14 bit
- Stage 2 (silicon 500 μm)
  - Charge 4 GeV full scale 100 Ms/s 14 bit
  - Current 250 Ms/s 14 bit
- Stage 3 (CsI + photodiode)
  - Charge 4 GeV full scale 100 Ms/s 14 bit

Services to the detectors

- Single low voltage power supply 48 V
- High voltage bias production/monitoring
  - 30_000 individually monitored voltages
- Temperature monitoring
- Pulser and other calibration facilities
- In-situ, in-vivo configuration of the FPGAs
- Software dowload (slow control, calibration)

Everything under VACUUM

A six-channel FEE board for 2 telescopes

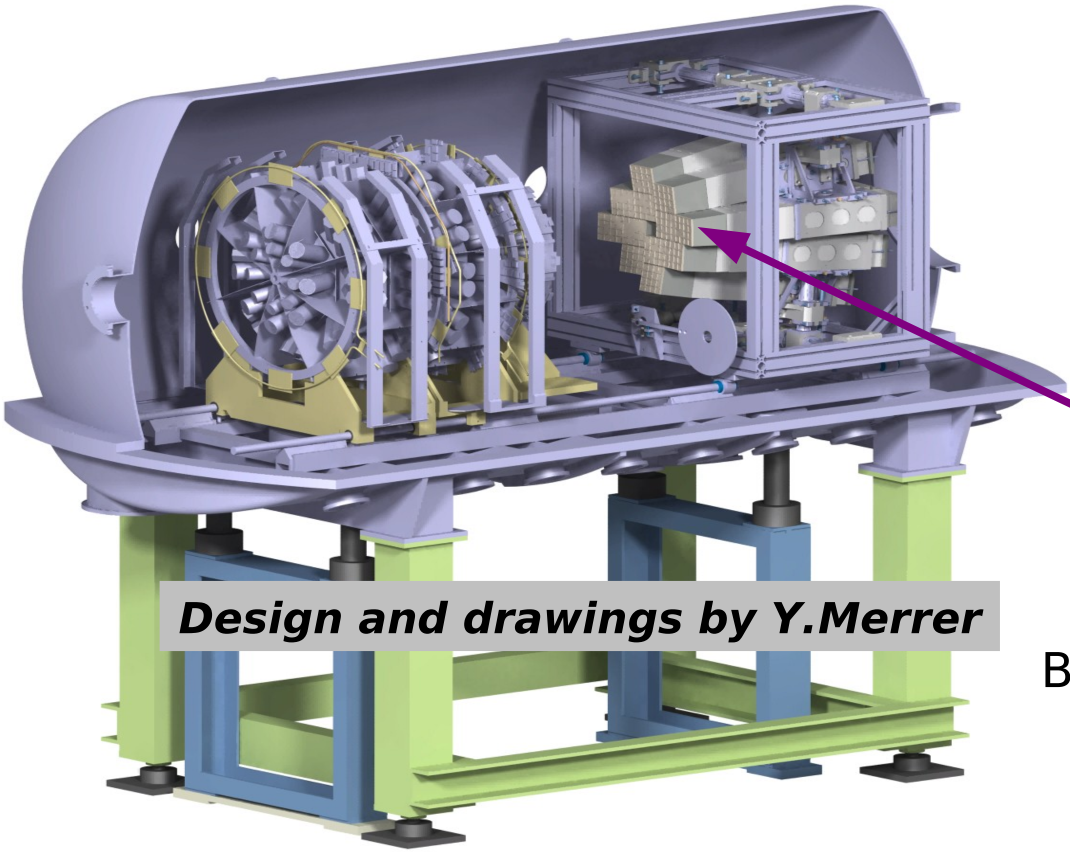


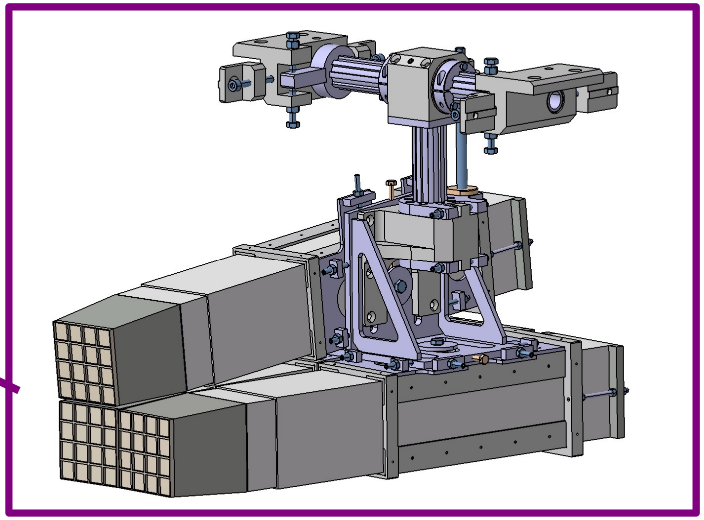
25W /board: **cooling** is an issue (Naples, Bologna UNI+INFN Sections)

Towards the demonstrator

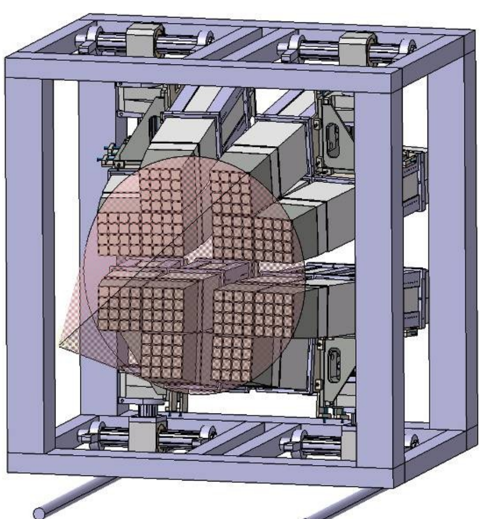
Demonstrator together with **INDRA at GANIL**

Schedule: **fall 2013-2015**



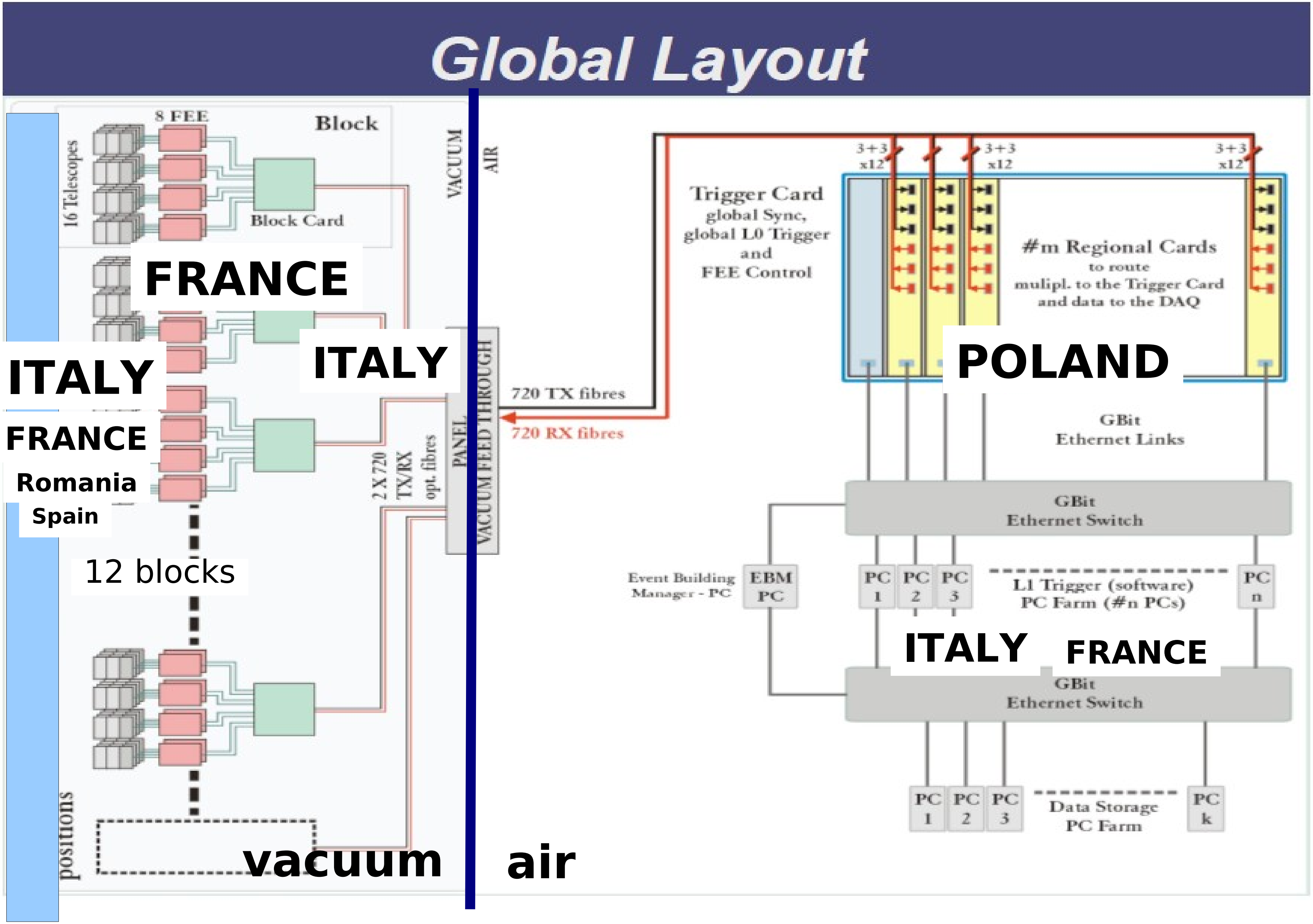


Block held by supports in group of three



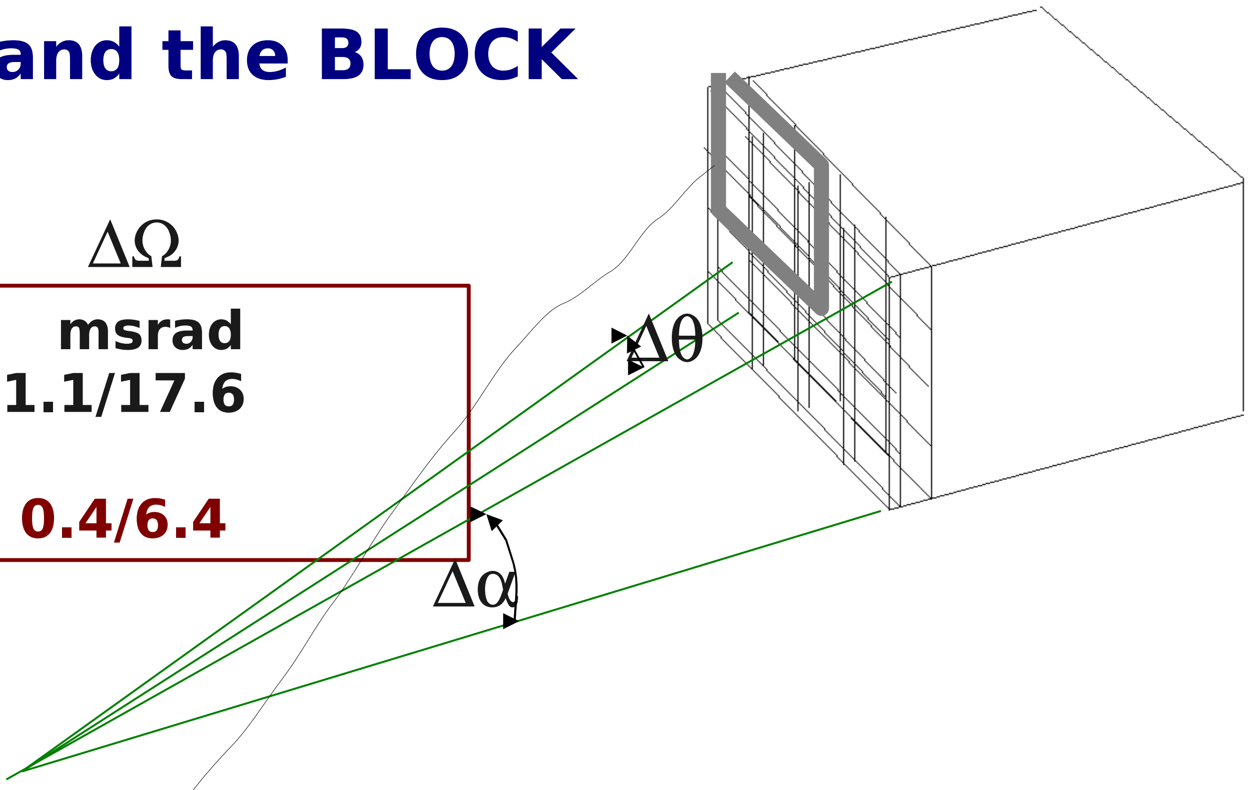
- **192 telescopes organized in 12 blocks, mounted at 100cm from target**

Towards the demonstrator

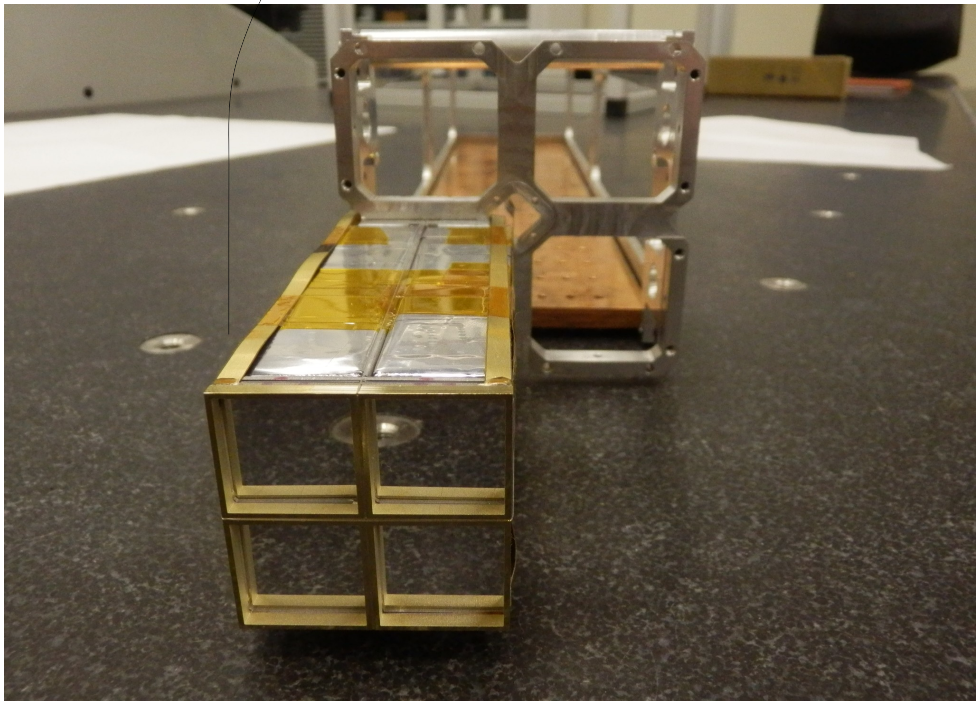


The Quartets and the BLOCK

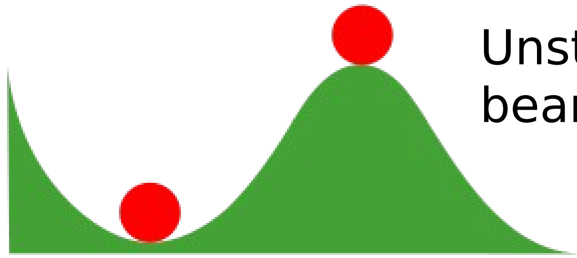
distance from target	$\Delta\alpha$	$\Delta\theta$	$\Delta\Omega$
mm	**deg**	**deg**	**msrad**
600	**8.4**	**1.9**	**1.1/17.6**
1000	**5.0**	**1.1**	**0.4/6.4**



Mounting tests in FLORENCE
March to May 2012



Physics themes for FAZIA



Recent interests with strong italian-french-poland overlap

Deformation in nuclei:

- Dynamical shape transitions: Jacobi, Poincare'
- Particle emission from scissioning systems
- Collective phenomena: GDR, DDR

Collective and Stastical models

Clustering:

- Presence and/or Emission of pre-formed clusters
- Behavior of clustering with N/Z

Isospin dynamics in the Fermi Energy regime (and below)

Isospin drift (due to density inhomogeneity)

Isospin diffusion (due to isospin asymmetry)

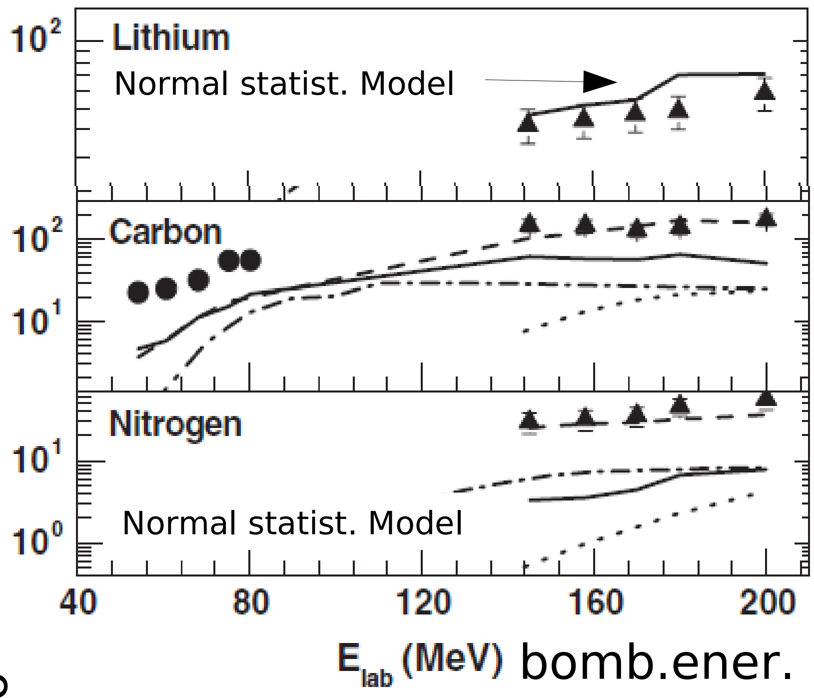
Role of the periphery in nucleon exchange dissipation

Transport models

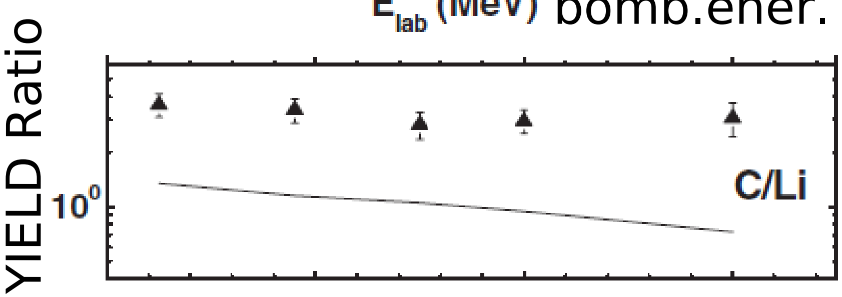
Fragments and particles from scissioning "light" systems

^{20}Ne(7–10 MeV/nucleon)+^{12}C

Aparajita Day et al., C **74**, 044605 (2006)
C **76**, 034608 (2007)



bomb.ener.

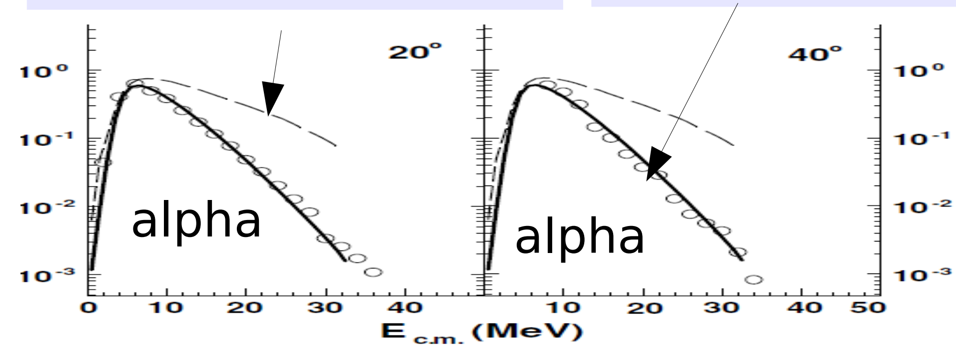


RELEVANT ALSO FOR **SHE**!

From CN to a Di-nuclear system (quasi-fission)

Without deformation

With deformation



ERs emitted at $\theta_{lab} = 10°$ in the ^{20}Ne +C 158MeV

Need of strong deformations in the models to explain alpha spectra

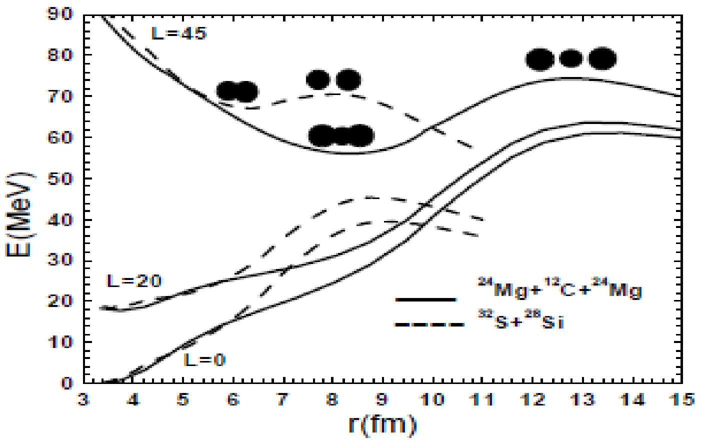
Strong impact of deformation on particle and IMF production: favoured by HIGH SPINS

Specific models including collective and discrete states and coulping with dynamics

Baiocco PhD Thesis 2012
Raj Kumar PRC 79 2009
Ademard PRC 2011
Kalandarov et al. PRC 83 2011
Mazurek et al PRC 84 2011

Particle emission and clustering

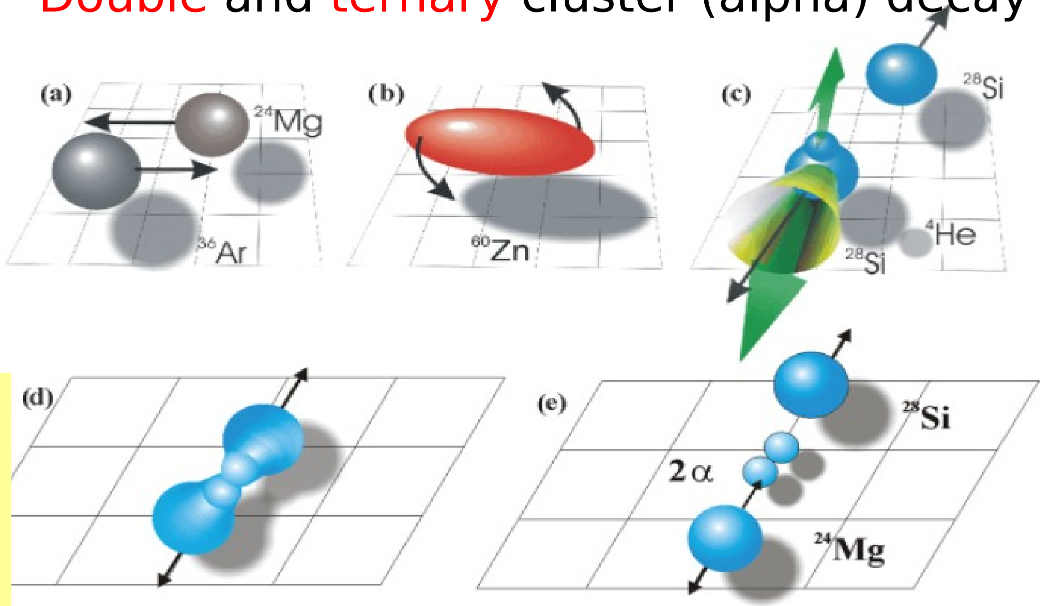
Nuclear structure studies by charged particle spectrometry?



Von Oertzen et al PRC 78 2008

36Ar+24Mg=60Zn system **LOW ENERGY**

Double and ternary cluster (alpha) decay



An alpha-neck emission can be energetically favoured

Physics of an undersaturated region (neck): is there room at low energies for N/Z effects predicted by transport models?
M.Colonna and C.Rizzo NUFRA2009, PRC 2010

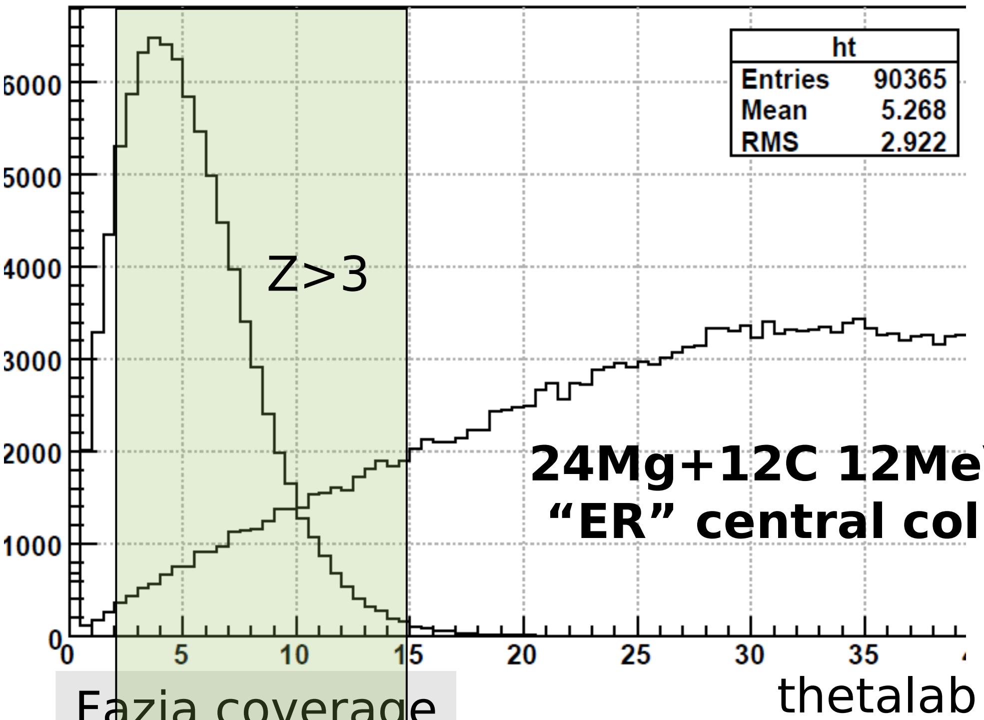
Hyperdeformed medium-mass nuclei N=Z

Ternary fission predicted for hyperdef. Nuclei A<100

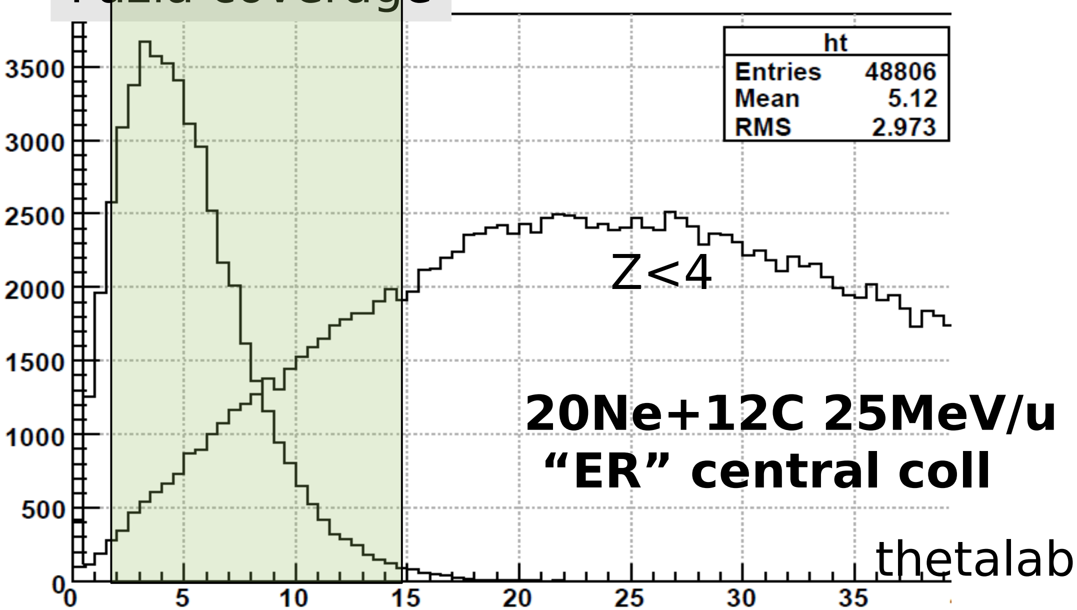
For high spin see also **Langevin calculations+RLDM** Mazurek et al. PRC 84 2011

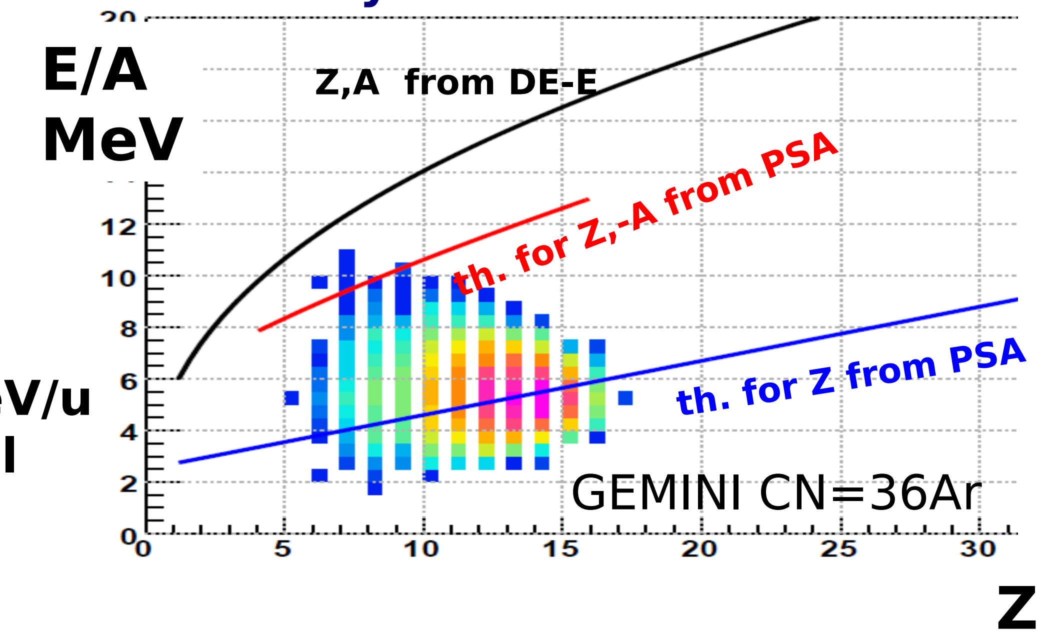
Preliminary calculations: where FAZIA can a good job....

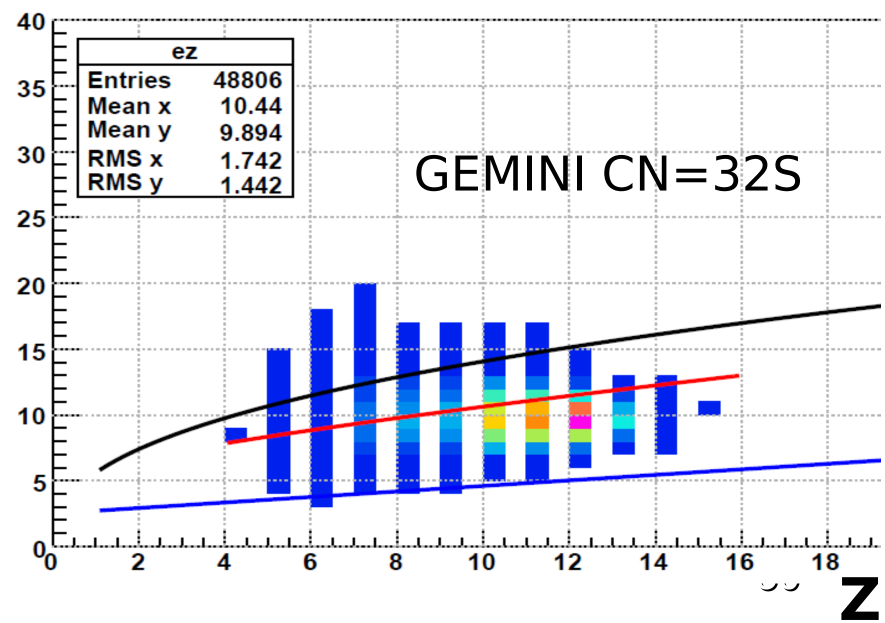
ER detection of light systems

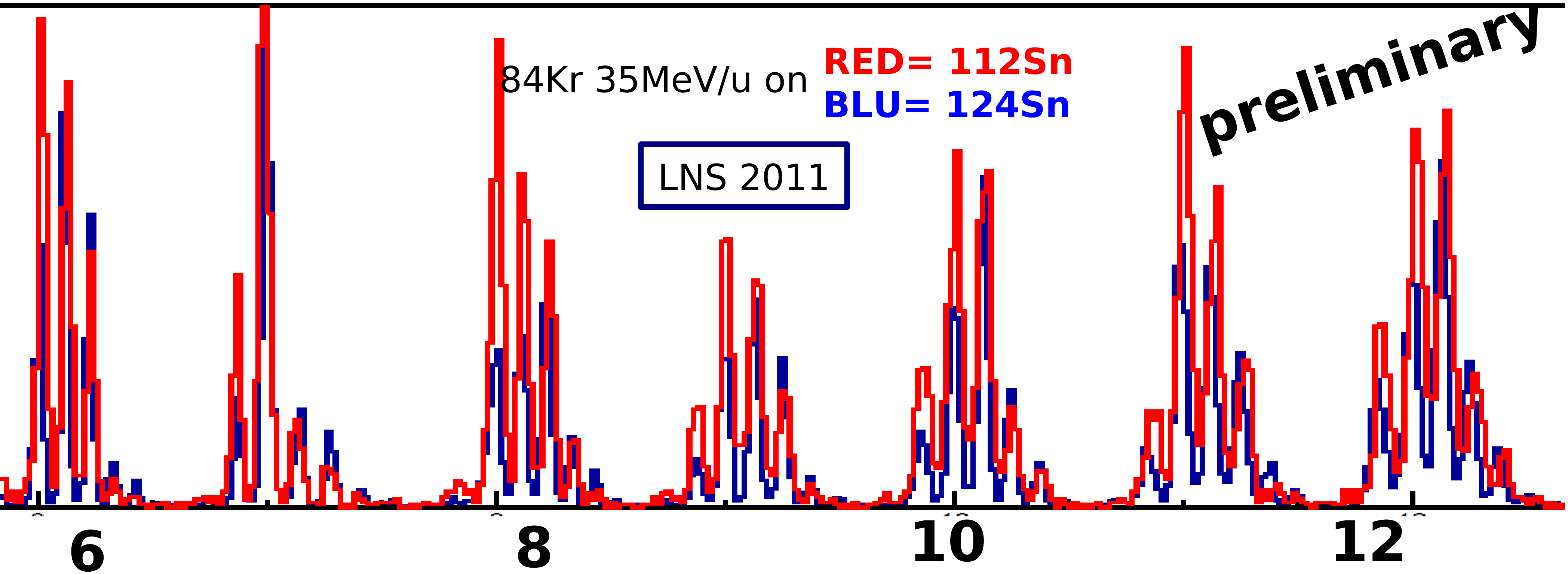


Fazia coverage



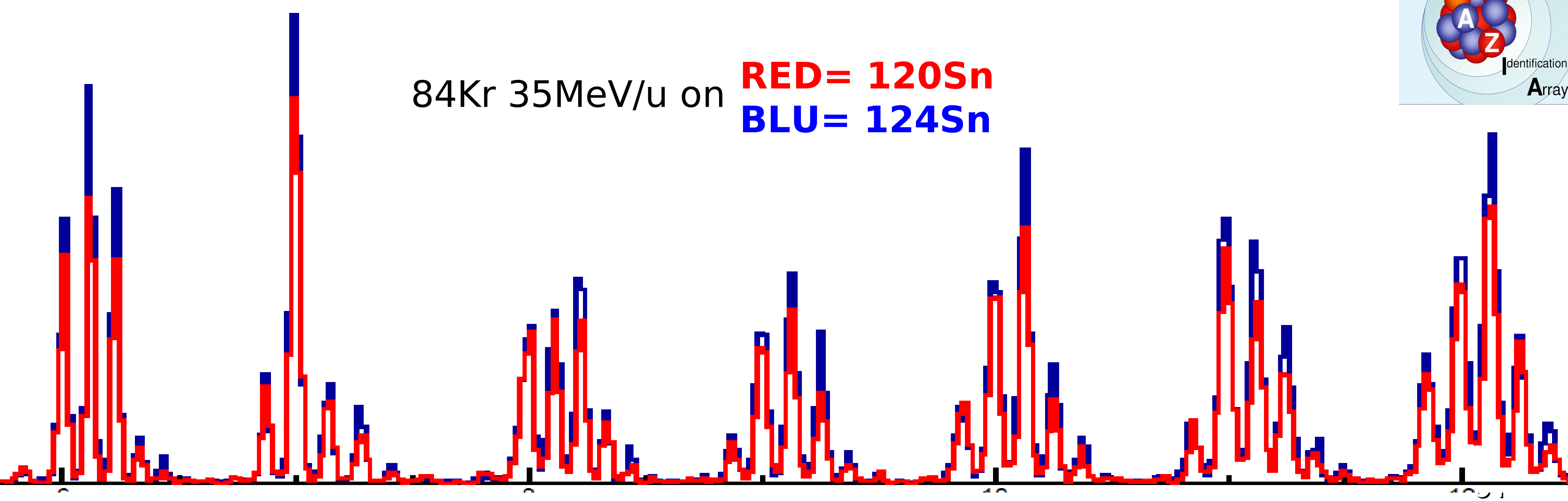


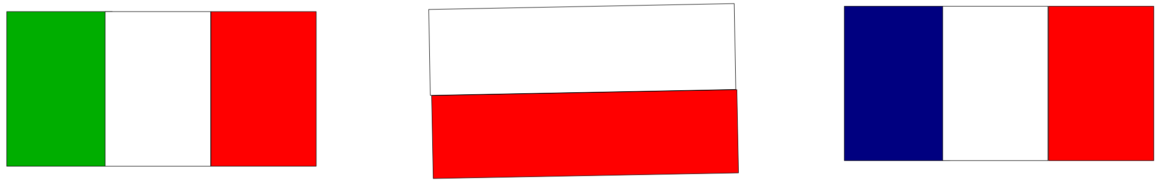




IMF Yields normalized at the QP Z=34 yield

Four-π A Z Identification Array





Conclusions

Fazia is one of the good environments where building and developping collaborations for next heavy-ion studies at an european level

With stable beams at intermediate energies, Fazia is expected to get high-quality data useful to stringent test of transport models, as far as isospin physics is concerned

At lower energies and with next RIB facilities we think FAZIA can helpfully contribute together with other specific arrays (spectrometers and/or particle-correlators)

Fazia is open to discuss possible use of detectors in experiments devoted to nuclear structure

THANK YOU