

FAZIATHIN analysis report

Simone Valdre', Feb 3rd 2026

A bit of history

FAZIA... before FAZIA

To test the innovative features of FAZIA detector, up to 2014 we used the so called “**telescopini**” mounting: single telescopes with an attached PACI preamp, read through a VME DAQ system derived from GARFIELD acquisition



First ultra-thin Si detector test in 2012 with telescopini

Eur. Phys. J. A (2015) 51: 15
DOI 10.1140/epja/i2015-15015-2

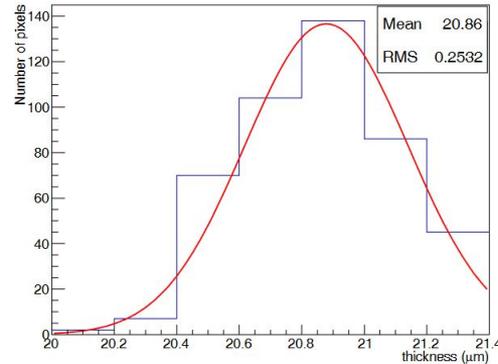
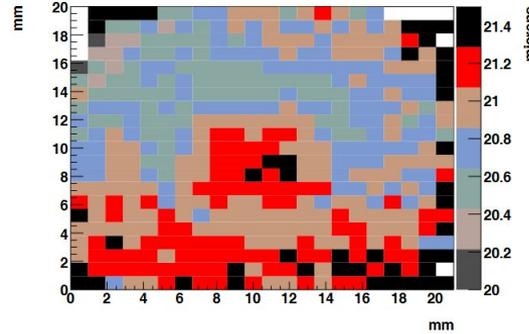
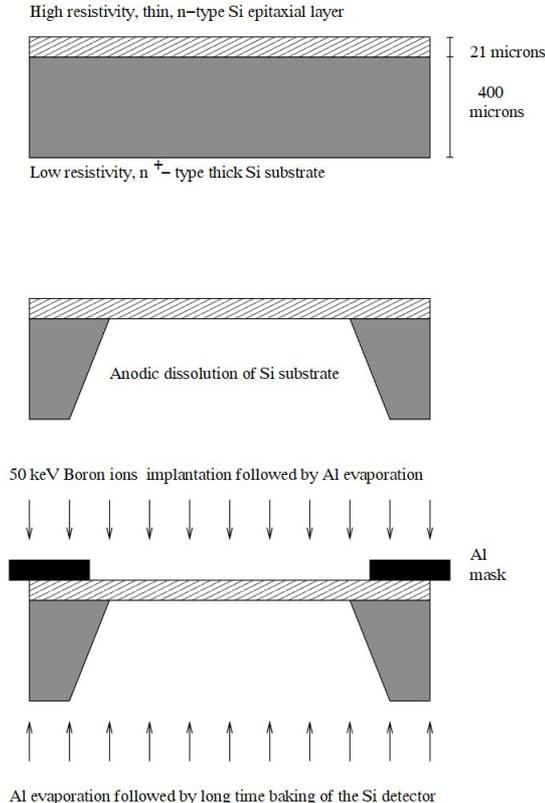
**THE EUROPEAN
PHYSICAL JOURNAL A**

Special Article – Tools for Experiment and Theory

Low-temperature technique of thin silicon ion implanted epitaxial detectors

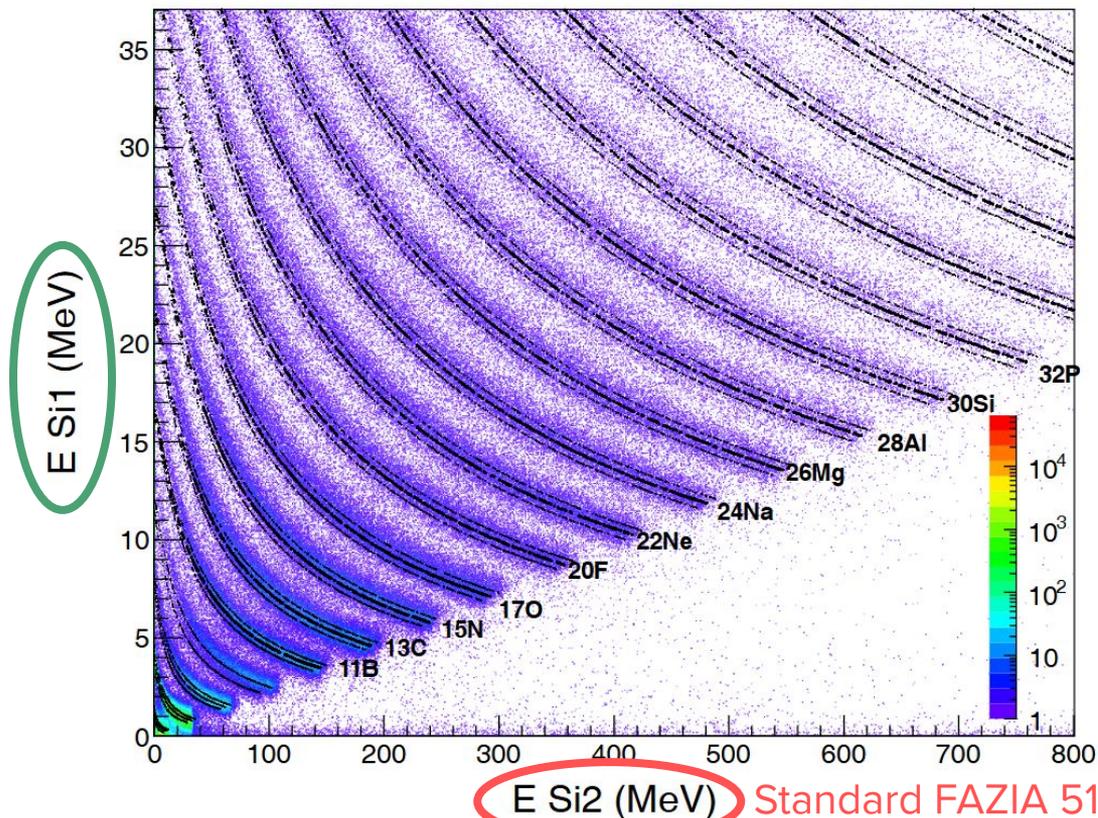
A.J. Kordyasz^{1,a}, N. Le Neindre², M. Parlog^{2,3}, G. Casini⁴, R. Bougault², G. Poggi⁴, A. Bednarek¹, M. Kowalczyk^{1,5}, O. Lopez², Y. Merrer², E. Vient², J.D. Frankland⁶, E. Bonnet⁶, A. Chbihi⁶, D. Gruyer⁶, B. Borderie⁷, G. Ademard⁷, P. Edelbruck⁷, M.F. Rivet⁷, F. Salomon⁷, M. Bini⁴, S. Valdré⁴, E. Scarlini⁴, G. Pasquali⁴, G. Pastore⁴, S. Piantelli⁴, A. Stefanini⁴, A. Olmi⁴, S. Barlini⁴, A. Boiano⁸, E. Rosato⁸, A. Meoli⁸, A. Ordine⁸, G. Spadaccini⁸, G. Tortone⁸, M. Vigilante⁸, E. Vanzanella⁸, M. Bruno⁹, S. Serra⁹, L. Morelli⁹, M. Guerzoni⁹, R. Alba¹⁰, D. Santonocito¹⁰, C. Maiolino¹⁰, M. Cinausero¹¹, F. Gramegna¹¹, T. Marchi¹¹, T. Kozik¹², P. Kulig¹², T. Twaróg¹², Z. Sosin¹², K. Gąsior¹³, A. Grzeszczuk¹³, W. Zipper¹³, J. Sarnecki¹⁴, D. Lipiński¹⁴, H. Wodzińska¹⁴, A. Brzozowski¹⁴, M. Teodorczyk¹⁴, M. Gajewski¹⁴, A. Zagojski¹⁴, K. Krzyżak¹⁴, K.J. Tarasiuk⁵, Z. Khabanova¹⁵, and Ł. Kordyasz¹⁶

The technology behind the 2012 sensor test



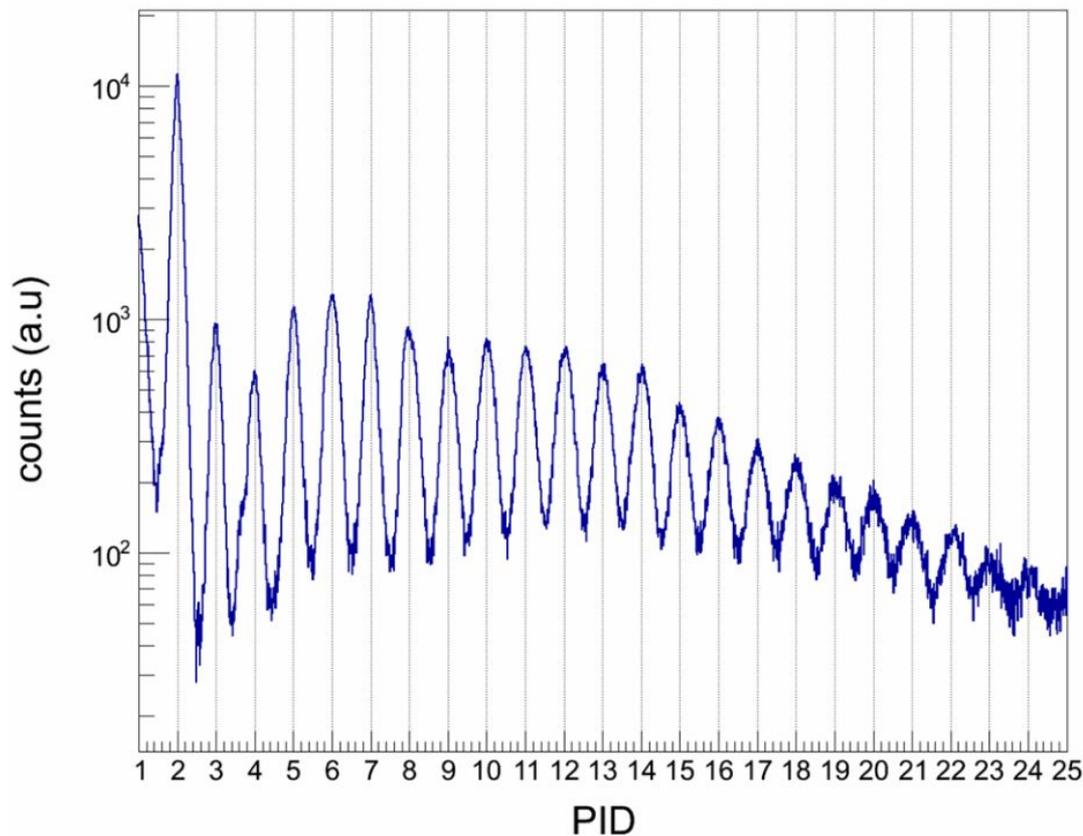
- Excellent thickness **homogeneity**
- Average thickness: 21 μm
- **Large** area (400 mm²)
- Compatible with FAZIA preamplifiers

The technology behind the 2012 sensor test



- Excellent thickness **homogeneity**
- Average thickness: 21 μm
- **Large** area (400 mm^2)
- Compatible with FAZIA preamplifiers
- Z identification up to ~25

The technology behind the 2012 sensor test



- Excellent thickness **homogeneity**
- Average thickness: 21 μm
- **Large** area (400 mm^2)
- Compatible with FAZIA preamplifiers
- Z identification up to ~25
- one of a kind...

Possible applications

- @LNL ($E < 20$ AMeV)
 - stable and exotic beams

- @ RAON ($E \sim 10-20$ AMeV)
 - first operational phase

- @ FRIB (150-200 AMeV)



→ intermediate fragments from QP
→ fusion compound



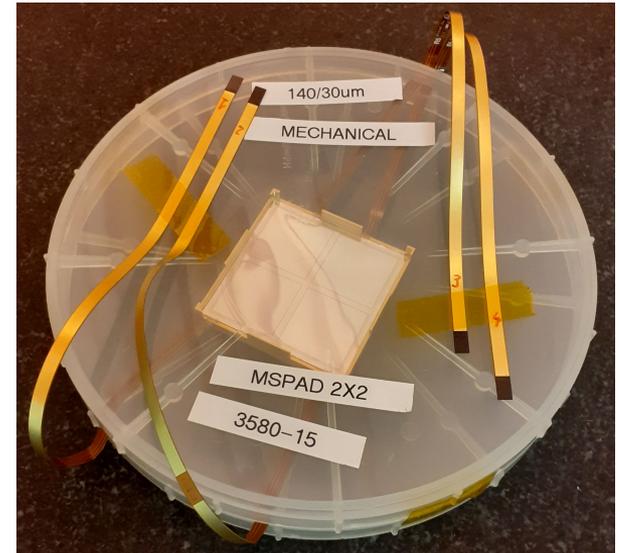
→ complex fragments from target spectator
at intermediate energies

Looking for large-scale production

In view of using FAZIA blocks with low energy beams we started to explore how to produce a large quantity of 20-30 μm thick sensors.

2022 → first prototypes from **Micron Semiconductor Ltd** were tested with source

2023 → first production of sensors for 1 FAZIA block



Looking for large-scale production

In view of using FAZIA blocks with low energy beams we started to explore how to produce a large quantity of 20-30 μm thick sensors.

2022 → first prototypes from **Micron Semiconductor Ltd** were tested with source

2023 → first production of sensors for 1 FAZIA block

2024 → LNL PAC approved the beam test in GARFIELD scattering chamber

Looking for large-scale production

In view of using FAZIA blocks with low energy beams we started to explore how to produce a large quantity of 20-30 μm thick sensors.

2022 → first prototypes from **Micron Semiconductor Ltd** were tested with source

2023 → first production of sensors for 1 FAZIA block

2024 → LNL PAC approved the beam test in ~~GARFIELD~~ scattering chamber

Access to LNL “Sala 3” has been denied

2025 → 2 days of measurement (Nov 9 - Nov 11) in PISOLO scattering chamber

(Many, many thanks to G. Montagnoli, A. Stefanini, and LNL staff)

The FAZIATHIN experiment

The proposal (PAC contribution, July 2024)

Detection of charged particles produced in reaction with Tandem beams,
in particular we selected:



with new FAZIA telescopes featuring customized ultrathin ΔE silicon stage
for low-energy ion spectroscopy
to test their performances

The proposal (PAC contribution, July 2024)

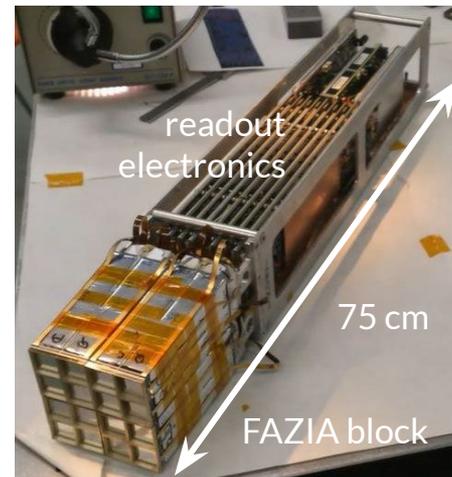
Before a more massive production and before possible physics experiments, we propose to irradiate the demonstrator FAZIA block with fragments produced in the QP phase space, whose **Z identification should be achievable** with a thin Si as ΔE stage.

- Setup:
 - inside the scattering chamber of the GARFIELD-RCo apparatus
 - new FAZIA block mounted to cover the proximity of the grazing angles
- Possible chance 1: 2 BLKS standard+thin for direct comparison
- Possible chance 2: coupling DAQ of GARFIELD with FAZIA

Scattering Chamber in Exp. Hall III



(we are aware of the TAC radioprotection note)



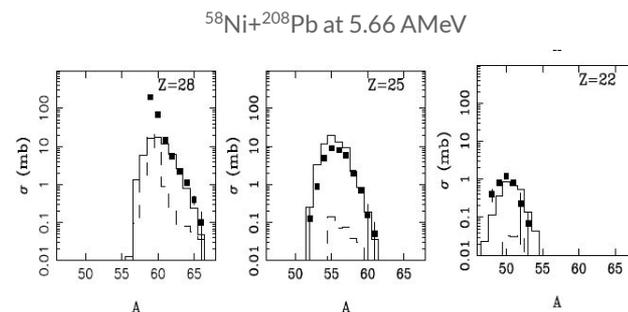
The proposal (PAC contribution, July 2024)

Considering the limitations due to beam energy and size, ease of the beam production and available currents, we have chosen the ^{32}S beam at the maximum Tandem energy of 5.8 AMeV and a ^{48}Ti target.

$^{32}\text{S} + ^{48}\text{Ti}$ @ 5.8 AMeV:

- fragments with charge and energy of interest mainly produced via multinucleon transfer
 - MNT fragments emitted with cross sections that decrease with decreasing charge (see for instance the PRISMA studies at LNL)
 - cross section peaks around the grazing angles (typically below 10 mbarn/sr)
- fusion channel not of interest (about 50% of cross section but evaporation residues too heavy and slow to be identified)

Tandem beam	E/A [MeV/A] max	I_{target} [pA]
^{28}Si	6.3	2.4
^{32}S	5.8	4.7
^{35}Cl	5.6	2.7
^{40}Ca	3.8	2.3
^{48}Ti	4.1	2.1
^{52}Cr	3.0	2.3



M. Veselsky and G. Souliotis, Nuclear Physics A 872, 1 (2011).

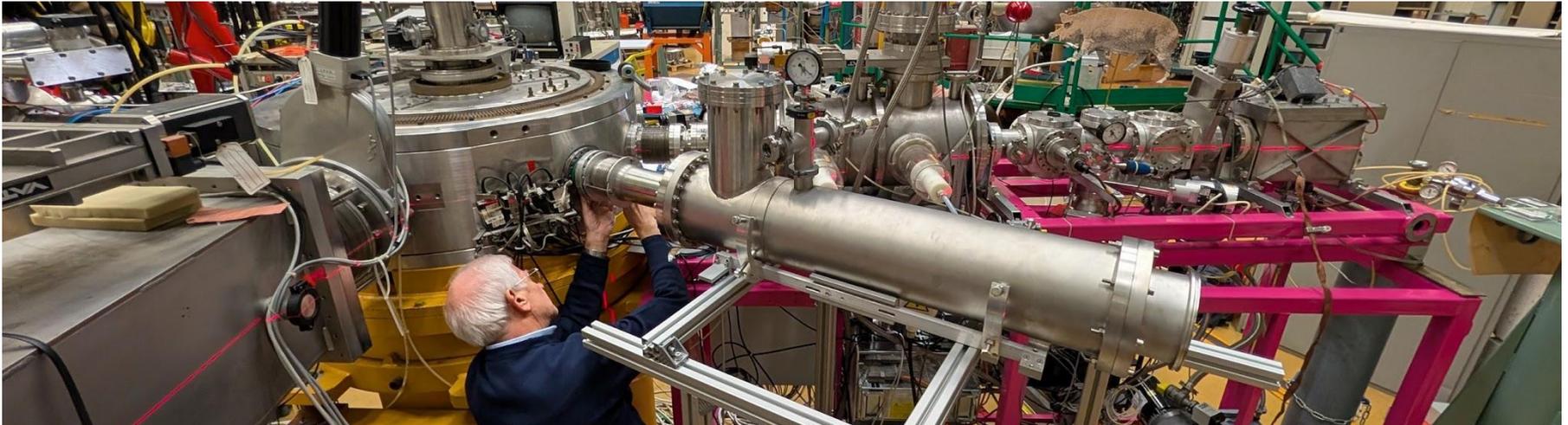
The PISOLO scattering chamber...

- ~1 m diameter cylindrical scattering chamber
 - too small to host a FAZIA block!



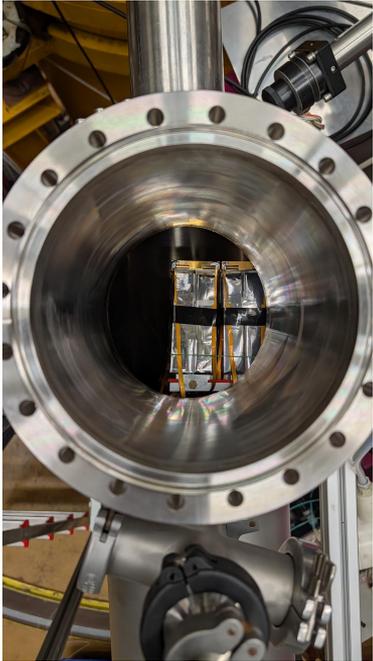
The PISOLO scattering chamber... upgraded

- ~1 m diameter cylindrical scattering chamber
 - too small to host a FAZIA block!
- A “long nose” hosting FAZIA was added



Block alignment

A very precise alignment was performed, but due to some re-opening of the flanges and short water pipes, optic fibers and 48V wires, the block moved a bit.

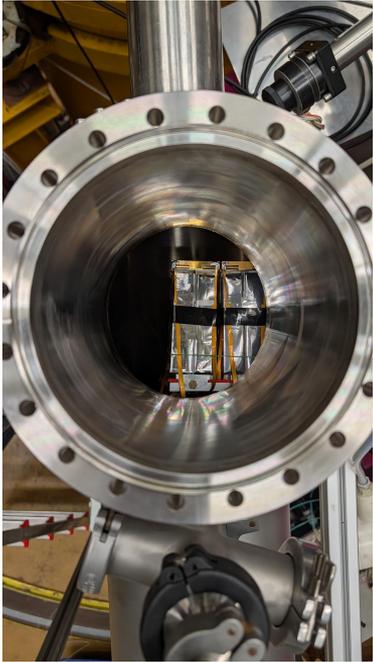


Mid-shift opening from above:
the block was misaligned
(4 telescope were completely shadowed)

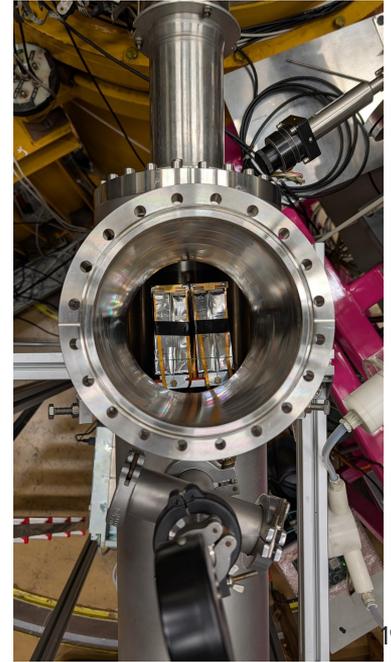


Block alignment

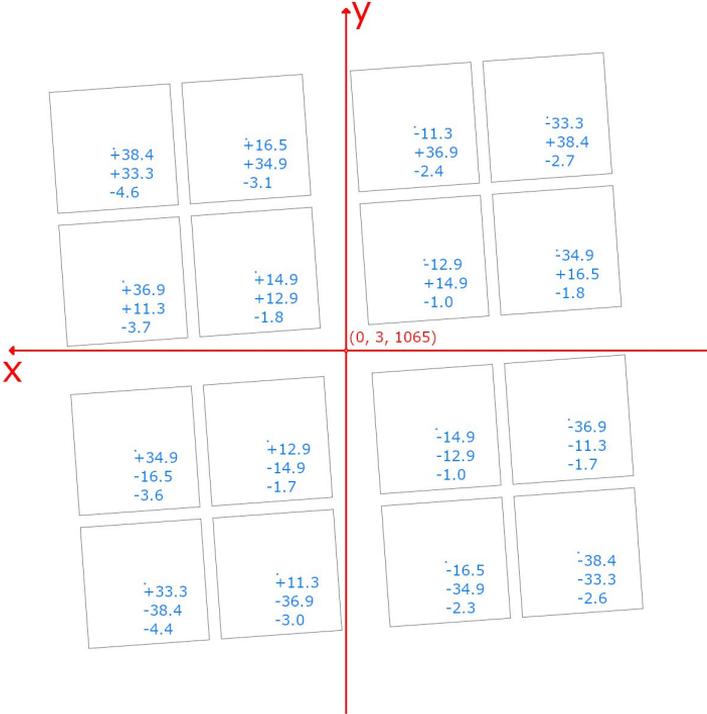
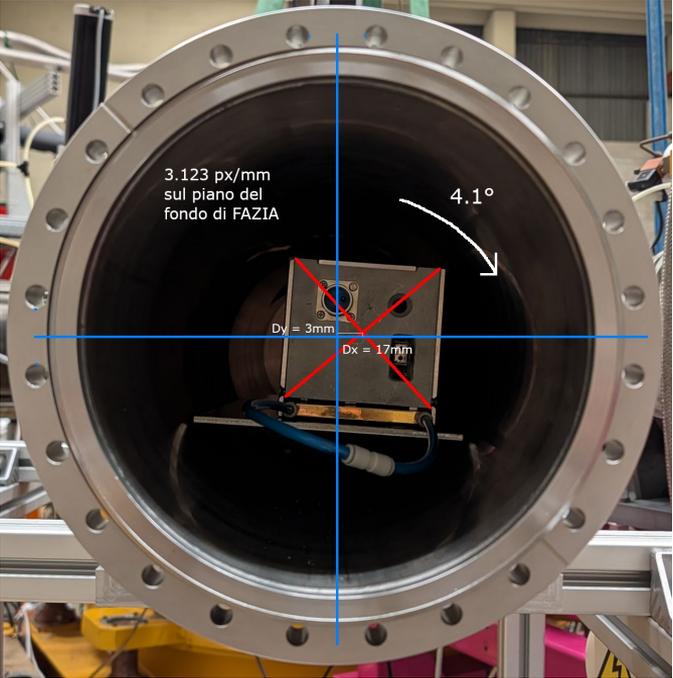
A very precise alignment was performed, but due to some re-opening of the flanges and short water pipes, optic fibers and 48V wires, the block moved a bit.



Mid-shift re-alignment:
only one beam day with
all 16 telescopes irradiated



Block alignment and geometry



Chosen targets

Many targets in order to have many elastic peaks for energy calibration:

- $^{\text{nat}}\text{Au}$ 200 $\mu\text{g}/\text{cm}^2$
- ^{65}Cu 500 $\mu\text{g}/\text{cm}^2$ (not used after the final block re-alignment)
- ^{64}Zn 510 $\mu\text{g}/\text{cm}^2$
- ^{62}Ni 500 $\mu\text{g}/\text{cm}^2$ (not used after the final block re-alignment)
- **^{48}Ti 600 $\mu\text{g}/\text{cm}^2$ (main measurement target)**
 - Very thick (good to have more reactions to populate correlations)
 - Light (good to suppress elastic scattering)

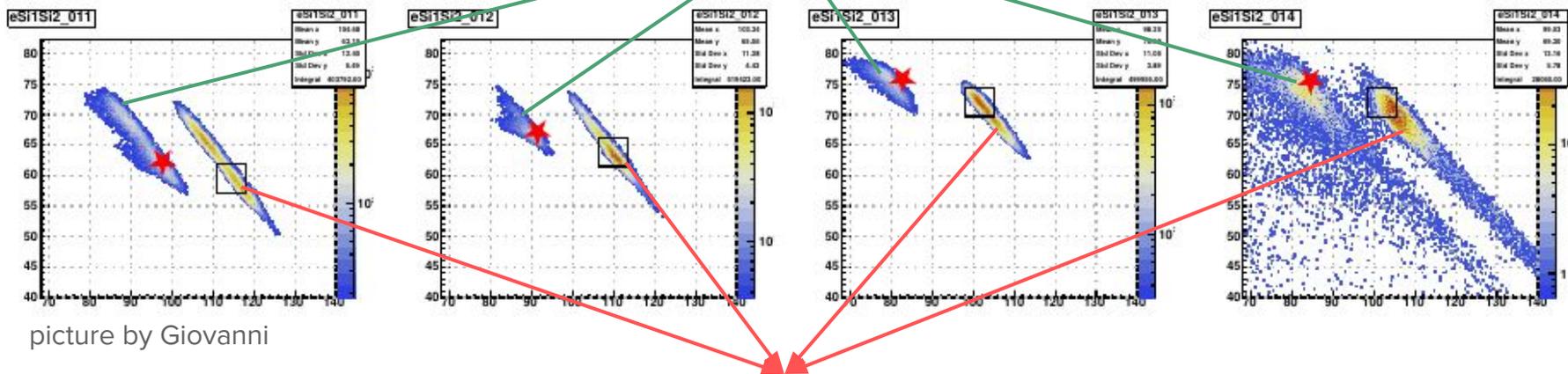
Except Au target, the others were old targets found in a GARFIELD cabinet

The Ti target showed some surprises!

Double elastic peak observed



48Ti

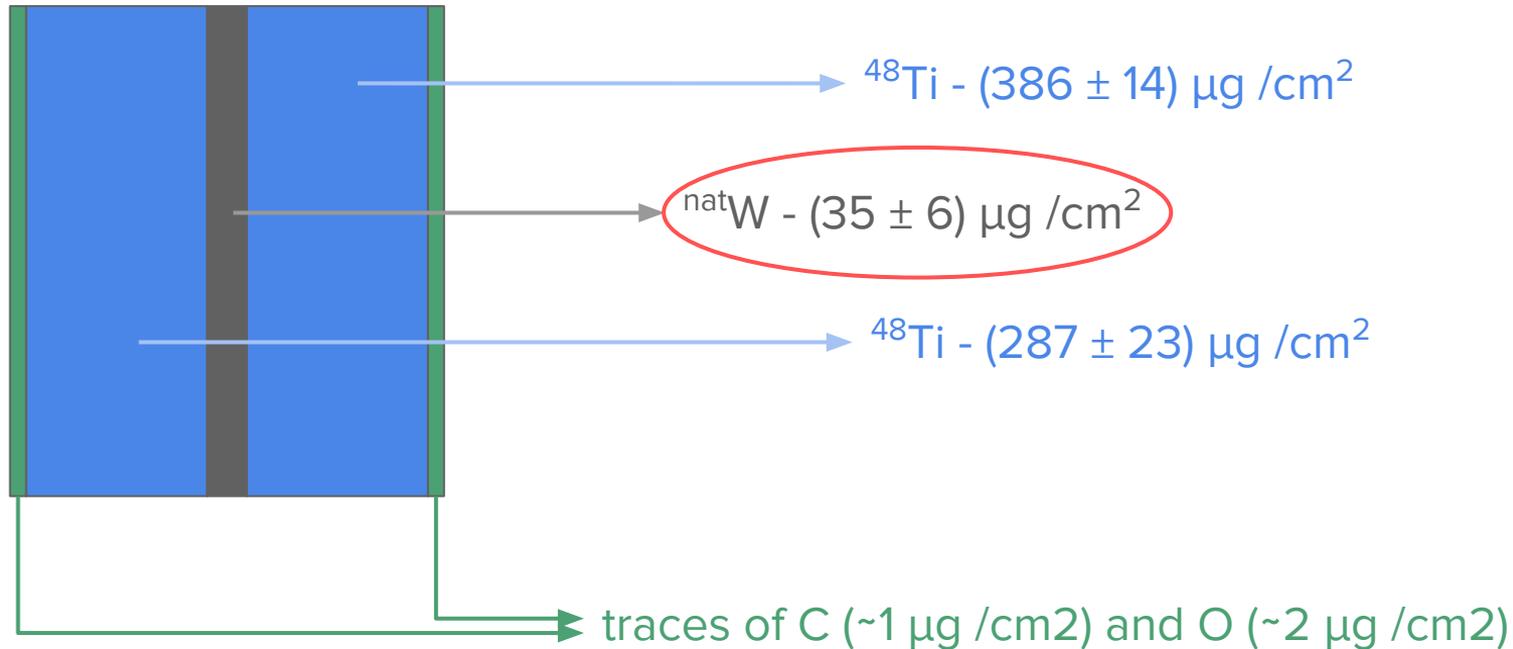


picture by Giovanni

? (something heavy)

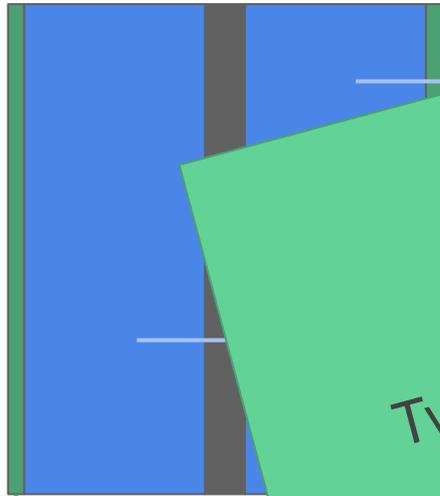
Ti target real structure

M. Chiari from LABEC performed a complete PIXE and RBS analysis on the target



Ti target real structure

M. Chiari from LABEC performed a complete PIXE analysis of the target



Good news!
Two calibration points with one target!

traces of C ($\sim 1 \mu\text{g} / \text{cm}^2$) and O ($\sim 2 \mu\text{g} / \text{cm}^2$)

The main analysis

Analysis main goals

Give a characterization of Micron's thin silicon sensors:

- Determine Z identification FoM (figure of merit) for each telescope
- Estimate thickness homogeneity
- Evaluate the high capacity effect on preamplifier chain (gain, linearity, etc..)

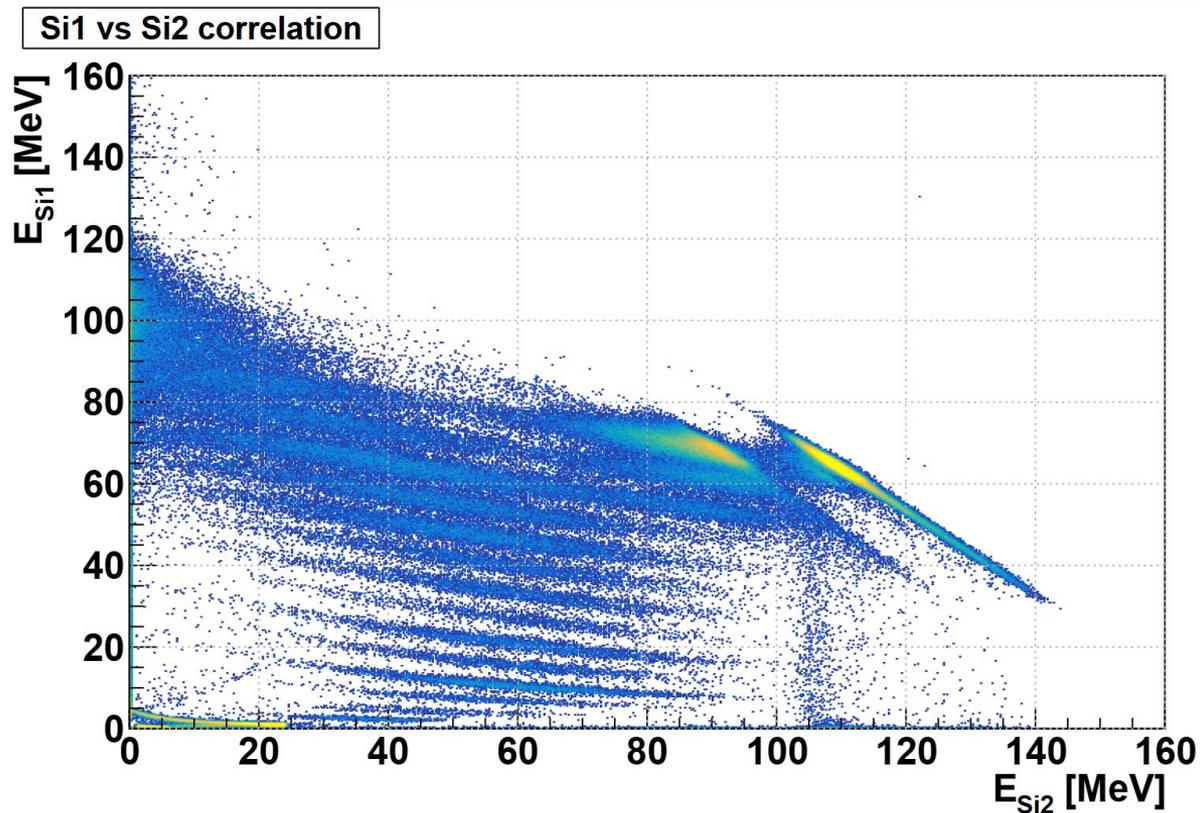
Validate the design for future production

Produce a technological paper

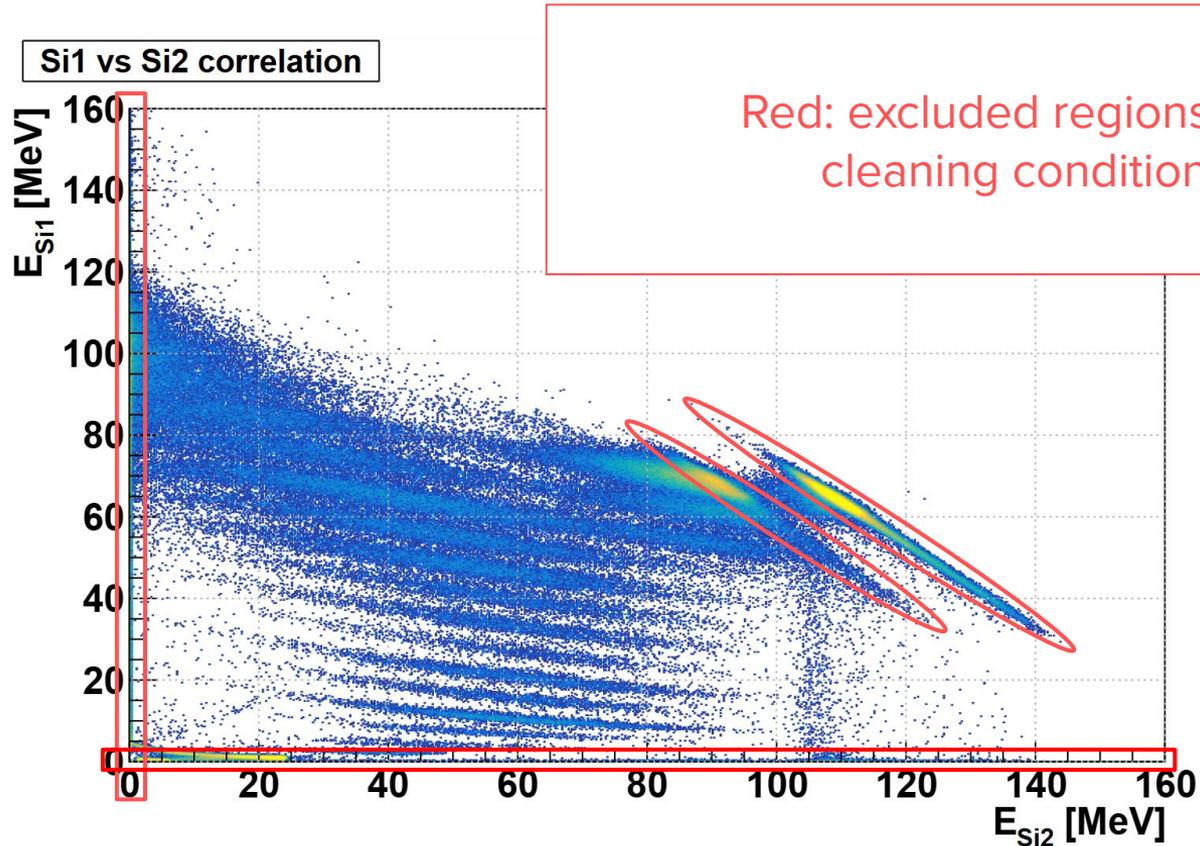
Analysis is still in progress!

(Giovanni and me are covering different topics)

PID: long story short

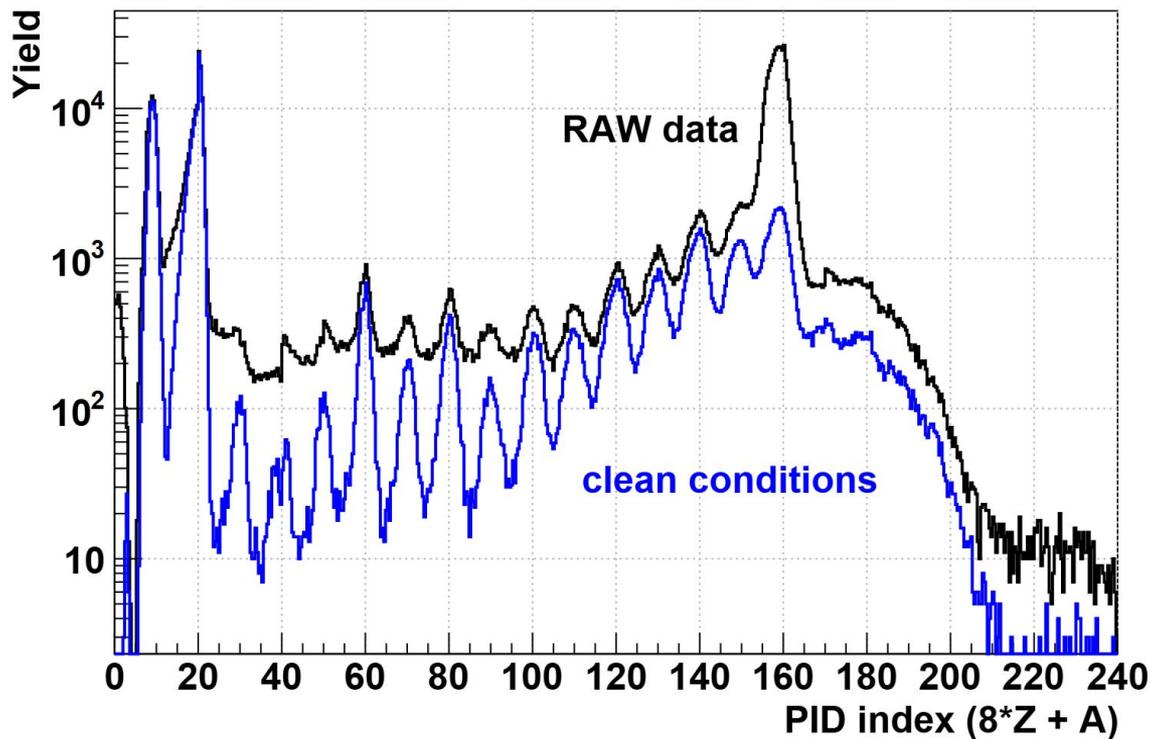


PID: long story short



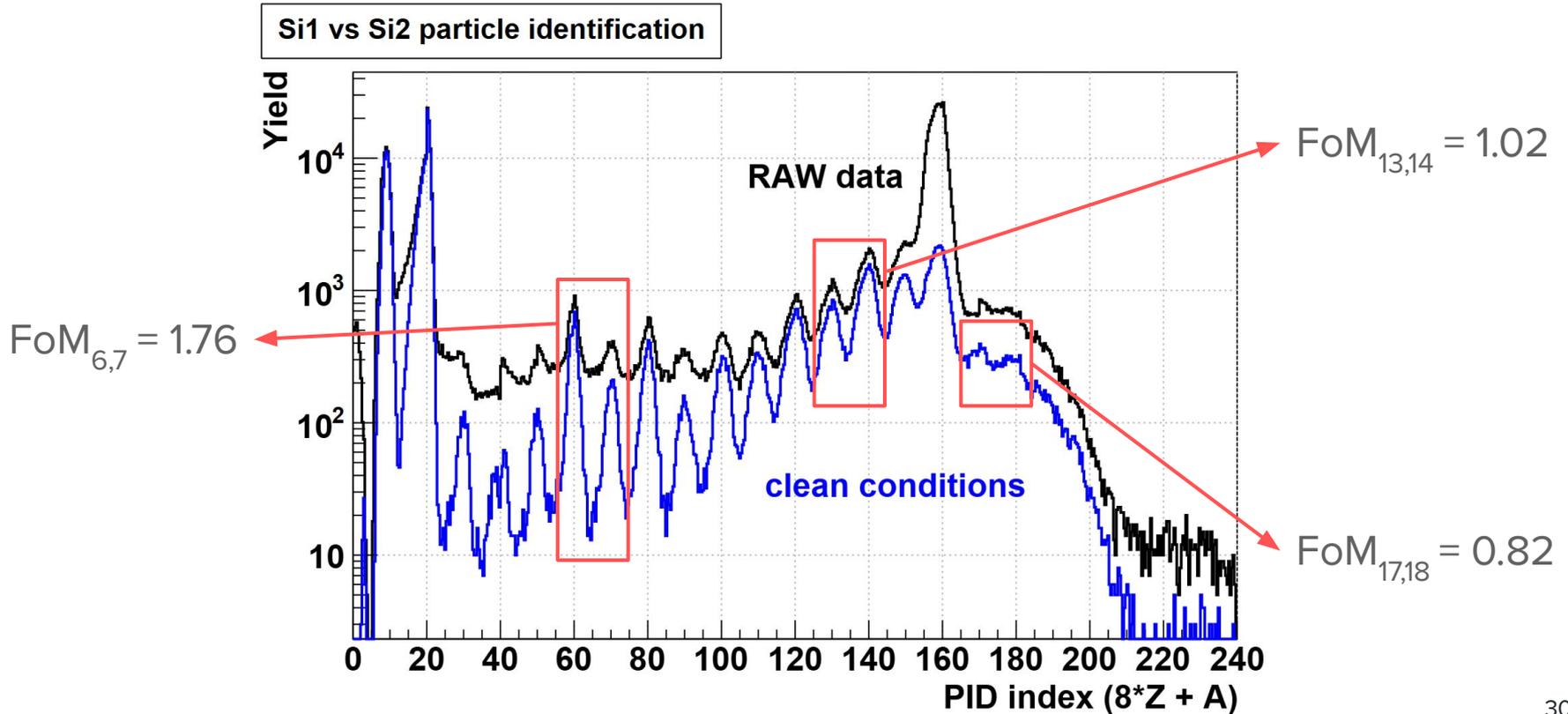
PID: long story short

Si1 vs Si2 particle identification



$$\text{FoM}_{Z_1, Z_2} = (\text{PID}_{Z_2} - \text{PID}_{Z_1}) / (\text{FWHM}_{Z_1} + \text{FWHM}_{Z_2})$$

PID: long story short



That's all folks!

DE-E and PID spectrum analysis shows that:

- in some telescopes we achieve Z identification up to $Z \sim 18$
- channeling is clearly visible (Giovanni estimated it as around 5%)
- thickness dishomogeneity is larger than expected
 - still to be investigated
- overall detector quality worse than 2012 Andrzej's sensor
 - but we are now able to produce thin sensors on a large scale

That's all folks! (or maybe not)

DE-E and PID spectrum analysis shows that:

- in some telescopes we achieve Z identification up to Z~18
- channeling is clearly visible (Giovanni estimated it **around 5%**)
- thickness dishomogeneity is larger than expected
 - still to be investigated
- overall detector quality worse than 2012 Andrzej's sensor
 - but we are now able to produce thin sensors on a large scale

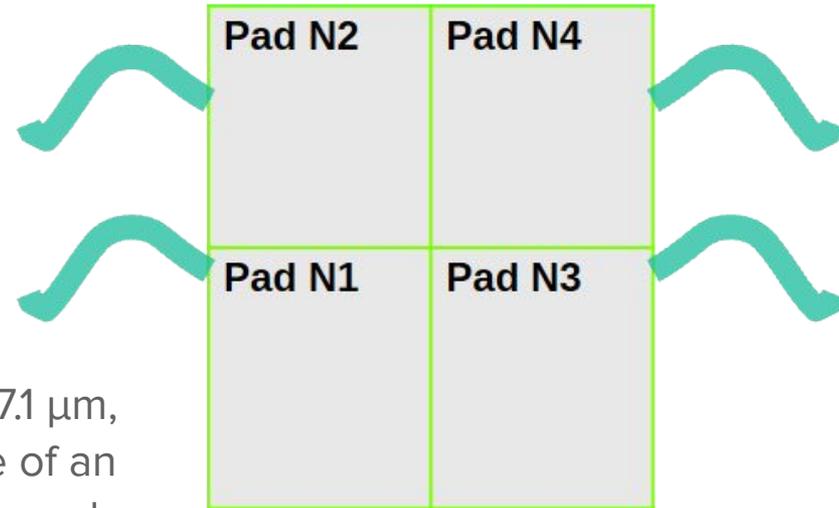
Many other aspects need to be investigated

Thickness estimation with α -source (by Giovanni)

- The 4 Si-2x2-thin pad matrices have been tested with ^{241}Am α -source to get an estimation of every pad thickness
- 4 matrices available, labeled: 20,21,22,23
- Manufacturer: Micron Semic. Ltd. UK
- Irradiation from ohmic side (FAZIA-standard)
- V_{depl} : 3-10Volt

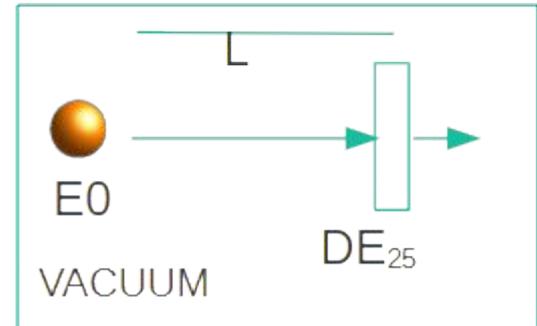
WARNING: the range in Si for 5.48 MeV alpha is 27.1 μm , thus at the limit for a Si layer around 25 μm in case of an ancillary E-stop detector placed after the FAZIA thin pad. The residual energy after 25 μm is 530keV

Sensor matrices: N=20,21,22,23



Thickness estimation with α -source (by Giovanni)

- Run at pressure P to surely stop alphas in SiThin. Various pressure values used. Find the peak position in ch CERES₂₅
- Pulser used to correct for possible scale non-linearities (very small) > ch to ch
- From geometry and pressure find DE_a (MeV) in air from Range-E Tables and find $ERES_{25}$ (MeV) in SiThin from CERES₂₅ and DE_a
- Namely calibration for SiThin is $f=(E_0-DE_a)/CERES_{25}$ (keV/ch)
- Go to run in vacuum: detector gives DE_{25} in channels, CDE_{25}
- From Range – energy table (or functional) deduce thickness TH; I adopted form (literature) $R=p_1 \cdot E^{p_2} + p_3$
- $TH=R(E_0)-R(E_0-DE_{25})$
- **The DE_{25} spectra for the various pads are broad, they often present structures and are not single 'gaussian'.** This fact has been confirmed during the LNL experiment where structures have been evidenced signing a not flat thickness map
- From the width of DEC distribution (not easy, broad distros), estimate the thickness spread (associated to FWHM or 2.35σ in case of not fittable distro)



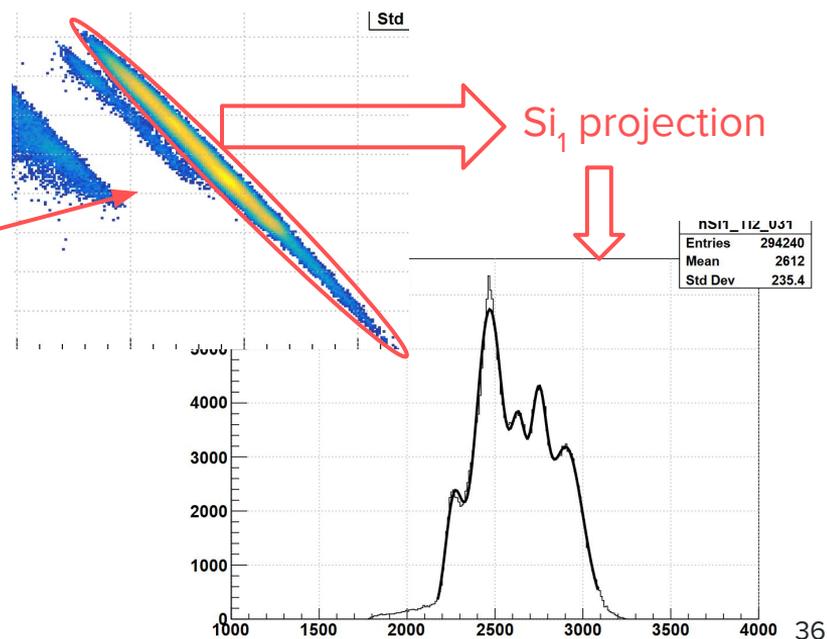
Thickness estimation with α -source (by Giovanni)

21.3	22.7	21.4	22.4
Q1		Q2	
25.3	25.3	<u>broken</u>	22.9
21.7	22.7	21.1	20.7
Q4		Q3	
21	21.8	24.3	23.3

Thickness estimation with α -source (by Giovanni)



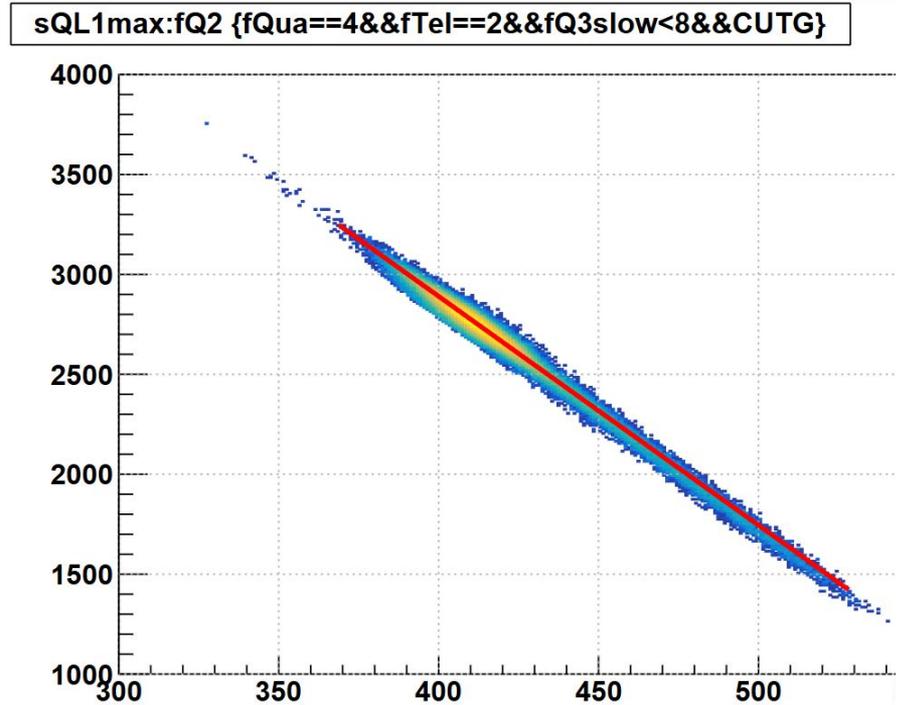
WARNING: these are average values!



Energy calibration

Standard method:

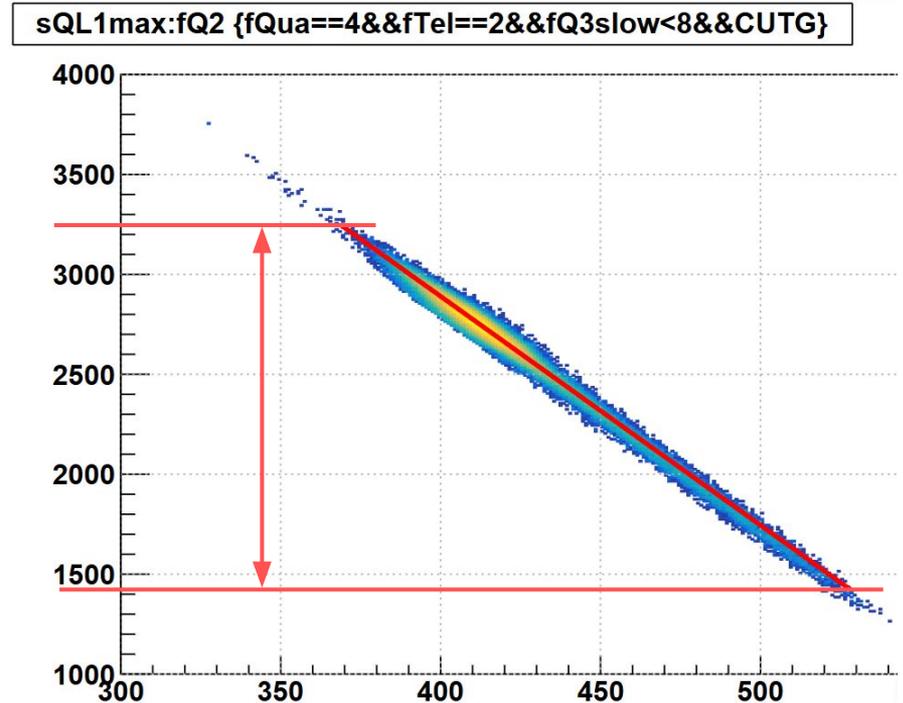
- Assume thickness from α -source measurement
- Take the average of the elastic peak energy distribution in channels
- Calibrate using calculated energy loss in Si_1 from elastic scattering



Energy calibration

Standard method:

- Assume thickness from α -source measurement
- Take the average of the elastic peak energy distribution in channels
 - Our distribution is extremely broad!
- Calibrate using calculated energy loss in Si_1 from elastic scattering
 - Calibration depends on energy loss tables



Energy calibration

Alternative method exploiting channeling and dishomogeneity!

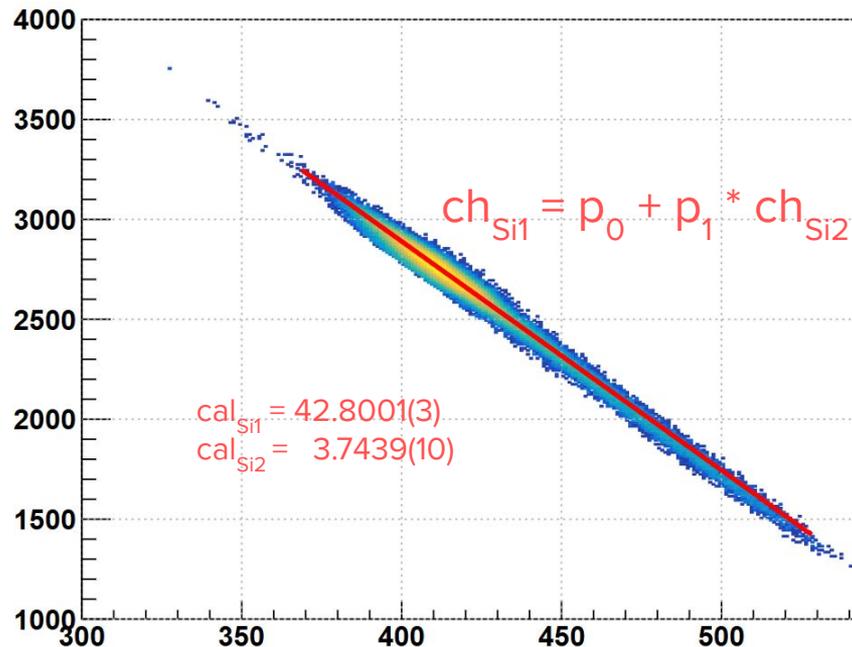
From:

- $E_{Si1} = ch_{Si1} / cal_{Si1}$
- $E_{Si2} = ch_{Si2} / cal_{Si2}$
- $E_{elas} = E_{Si1} + E_{Si2}$

We get:

$$ch_{Si1} = \underbrace{cal_{Si1}}_{p_0} * E_{elas} - \underbrace{(cal_{Si1} / cal_{Si2})}_{p_1} * ch_{Si2}$$

sQL1max:fQ2 {fQua==4&&fTel==2&&fQ3slow<8&&CUTG}



Energy calibration

Alternative method exploiting channeling and dishomogeneity!

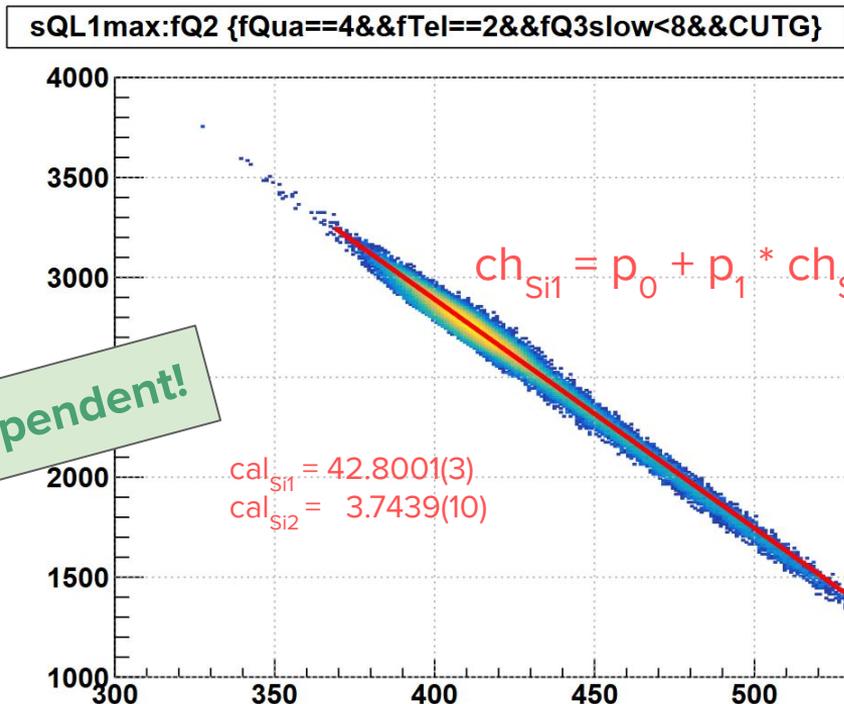
From:

- $E_{Si1} = ch_{Si1} / cal_{Si1}$
- $E_{Si2} = ch_{Si2} / cal_{Si2}$
- $E_{elas} = E_{Si1} + E_{Si2}$

We get:

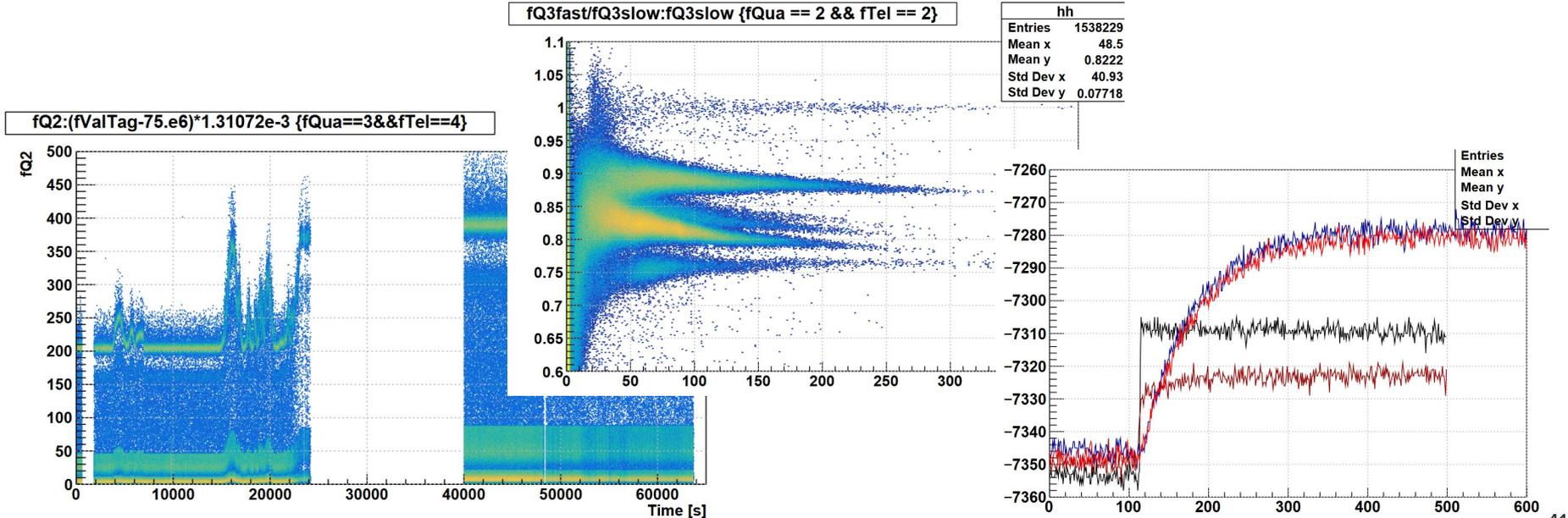
$$ch_{Si1} = \underbrace{cal_{Si1}}_{p_0} * E_{elas} - \underbrace{(cal_{Si1} / cal_{Si2})}_{p_1} * ch_{Si2}$$

Completely model independent!

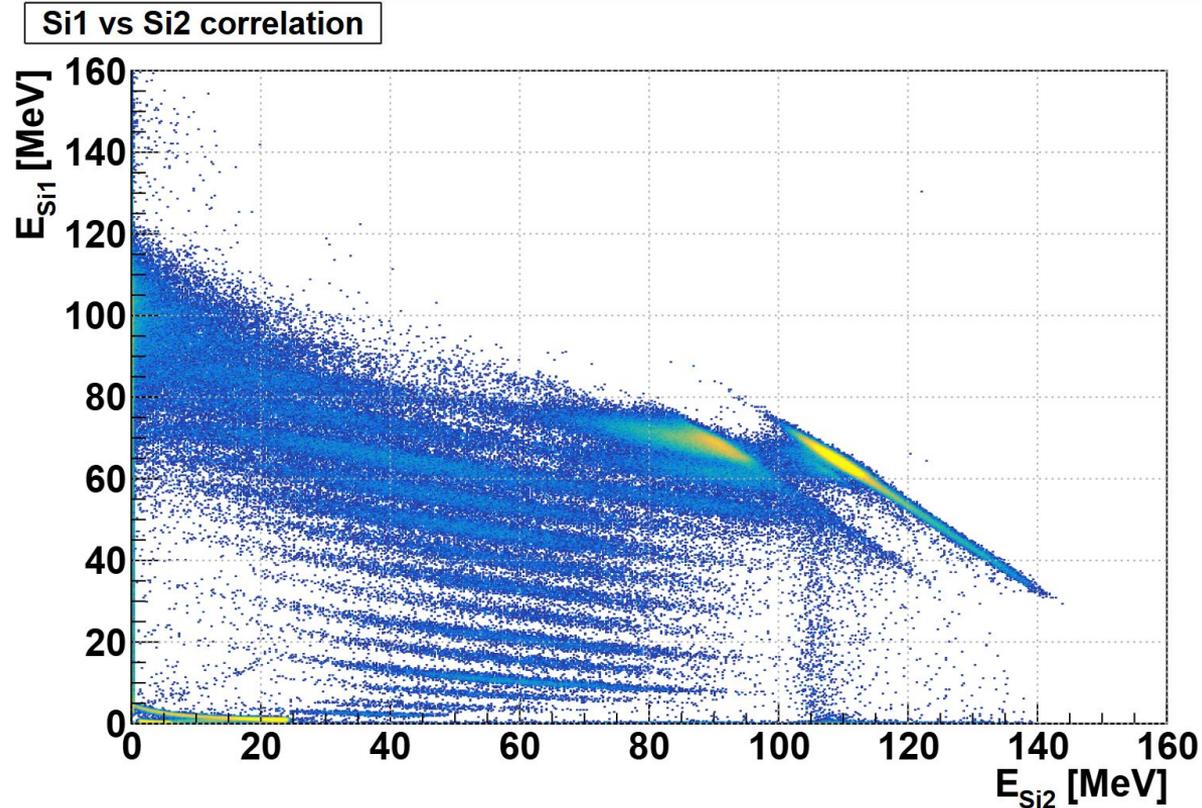


Other stuff

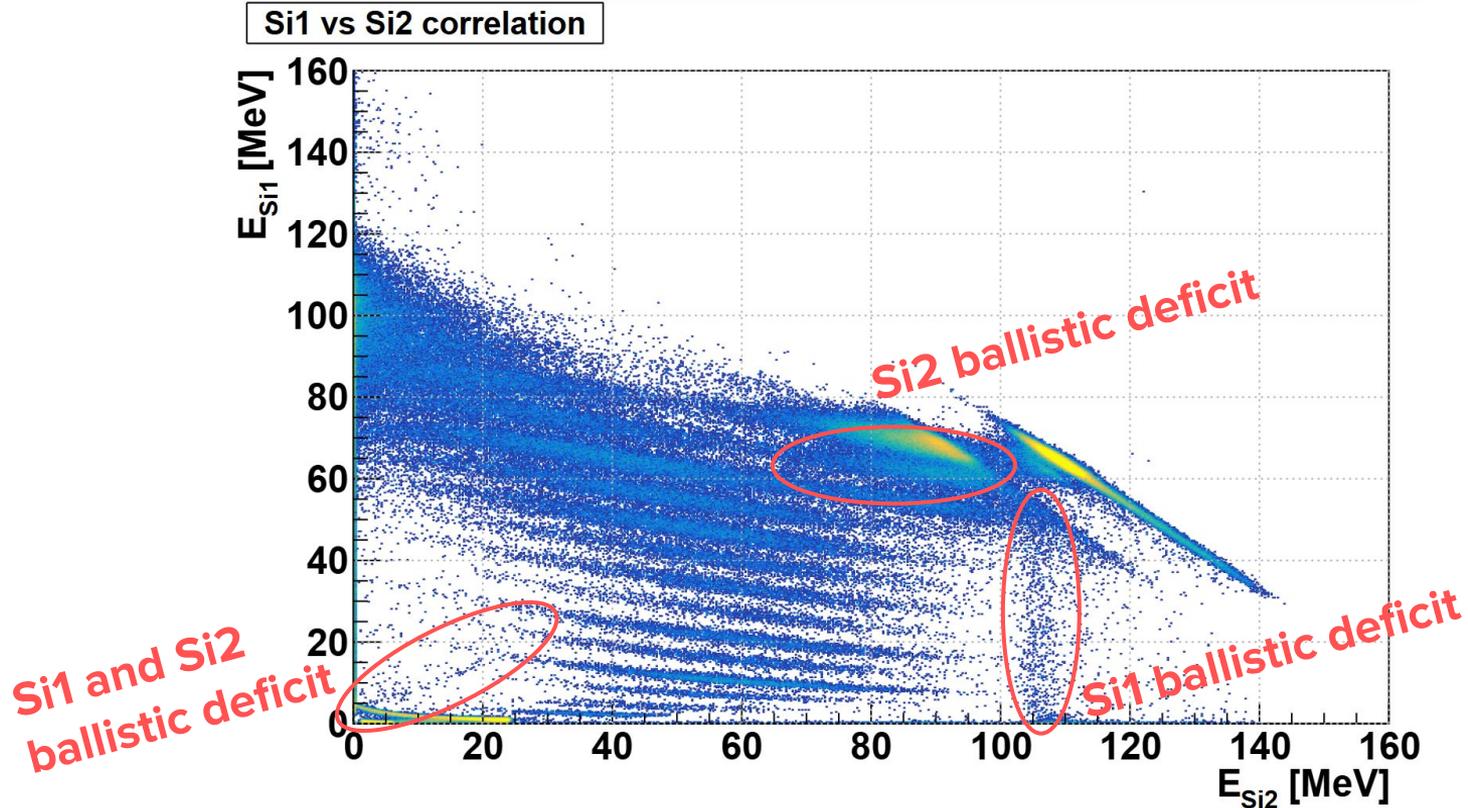
Meanwhile we are also looking at gain instabilities, border effects, strange spots on Csl fast-slow correlations, but they are not the main topic of this analysis...



Just a couple of slides on new cleaning conditions



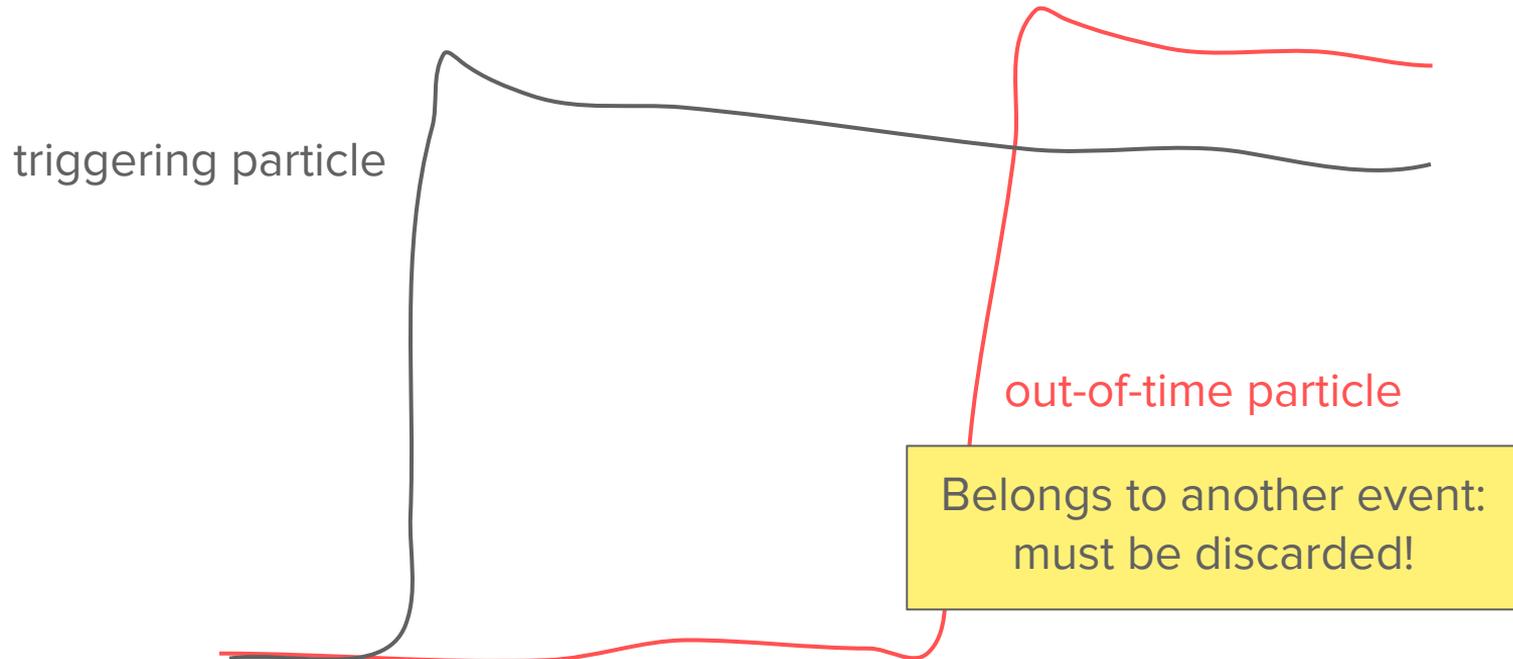
Just a couple of slides on new cleaning conditions



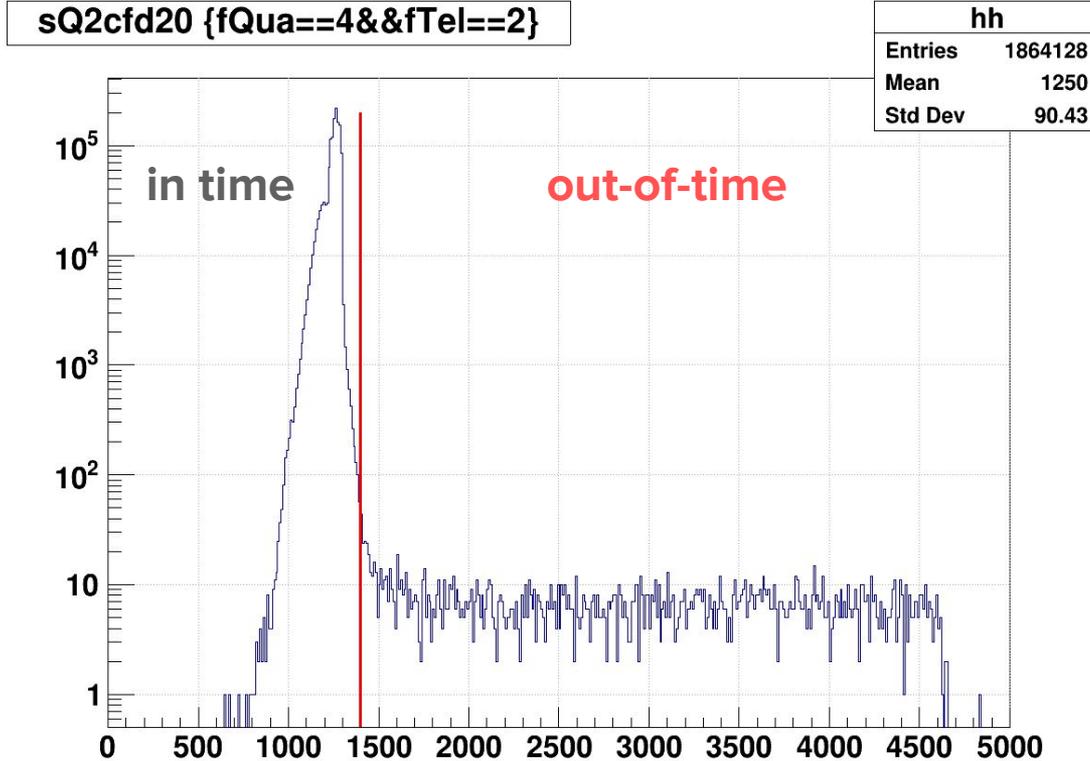
Online vs offline shaping

- We don't observe ballistic deficit with online shaping
 - continuous shaping is not limited by waveform sent size
- **In any case spurious particles must be discarded even if their energy is well calculated!**
- Strange behaviour observed with online shaping to be investigated
 - some values which should be 0 go to $\sim 10^6$
 - in NOTICE card only, it seems related to some underflow/overflow issue
 - zero control on parameters after acquisition
- for this analysis I chose to use **offline** calculated variables only
 - We did not sent QH1 waveform, so it cannot be manipulated offline
 - We don't need QH1 signals because our energy deposition in Si1 is always in the QL1 range!

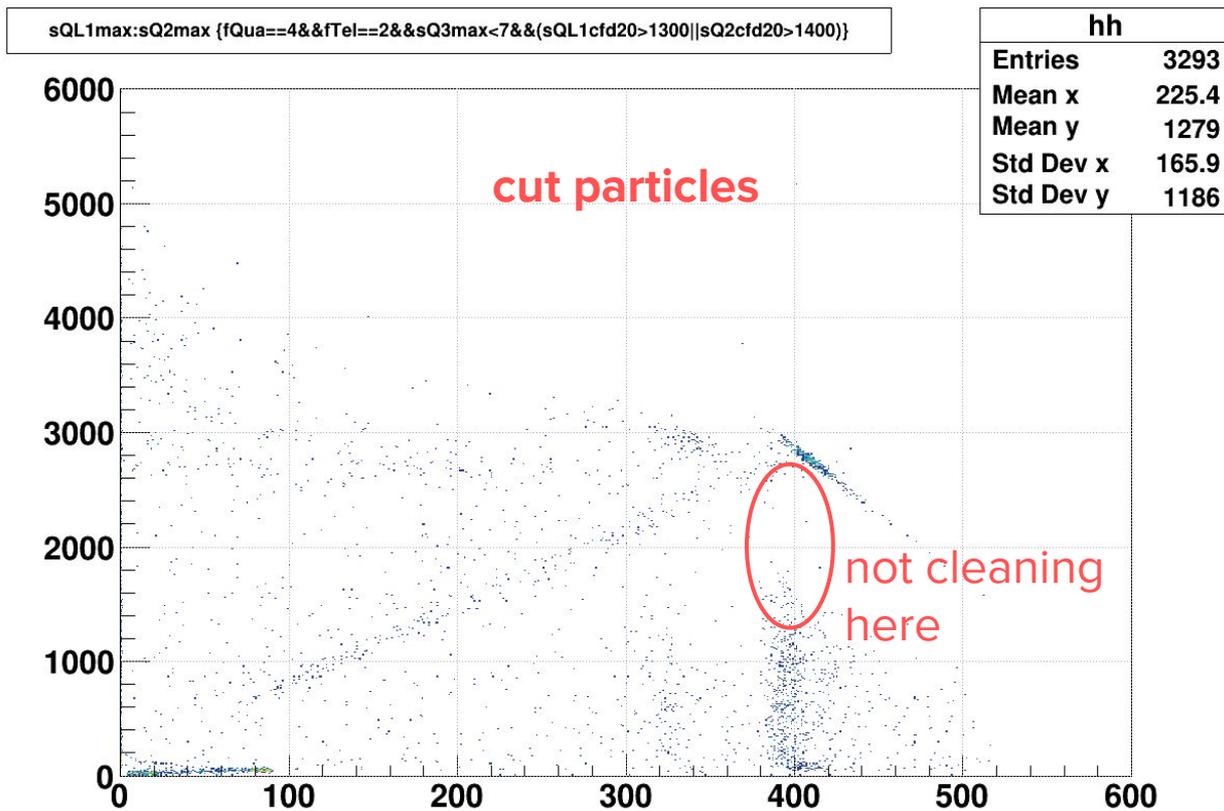
CFD conditions (obvious, but not sufficient)



CFD conditions (obvious, but not sufficient)

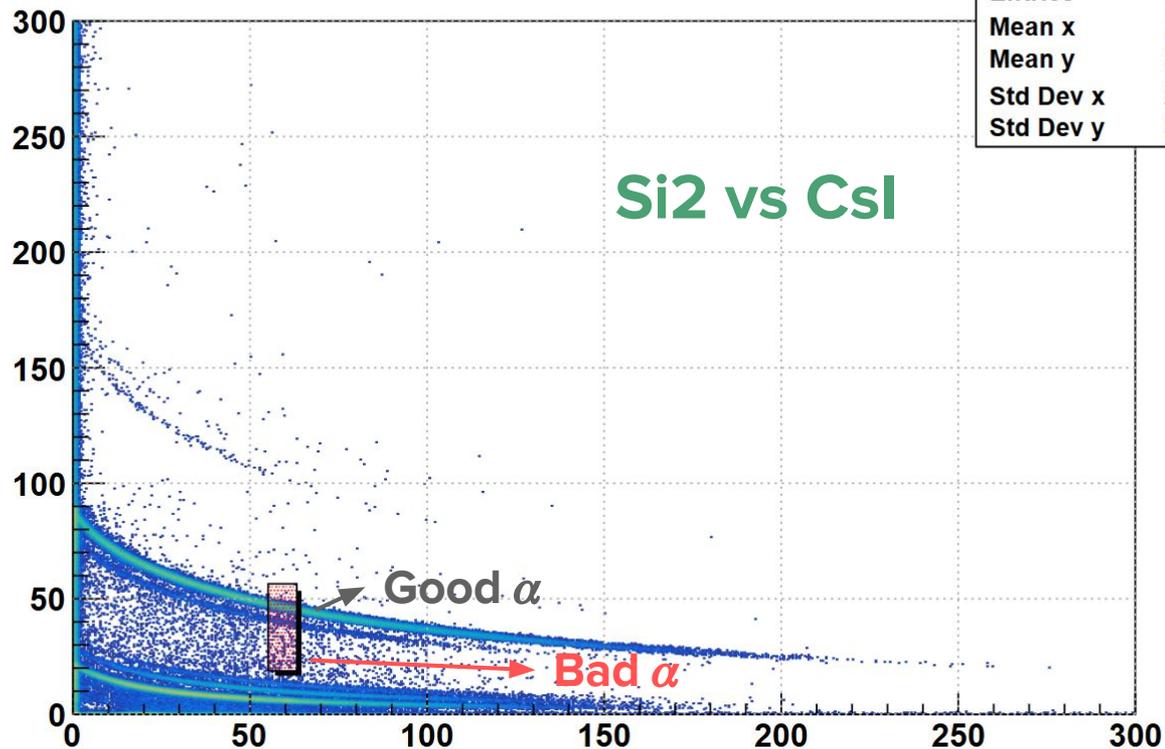


CFD conditions (obvious, but not sufficient)



Border effects?

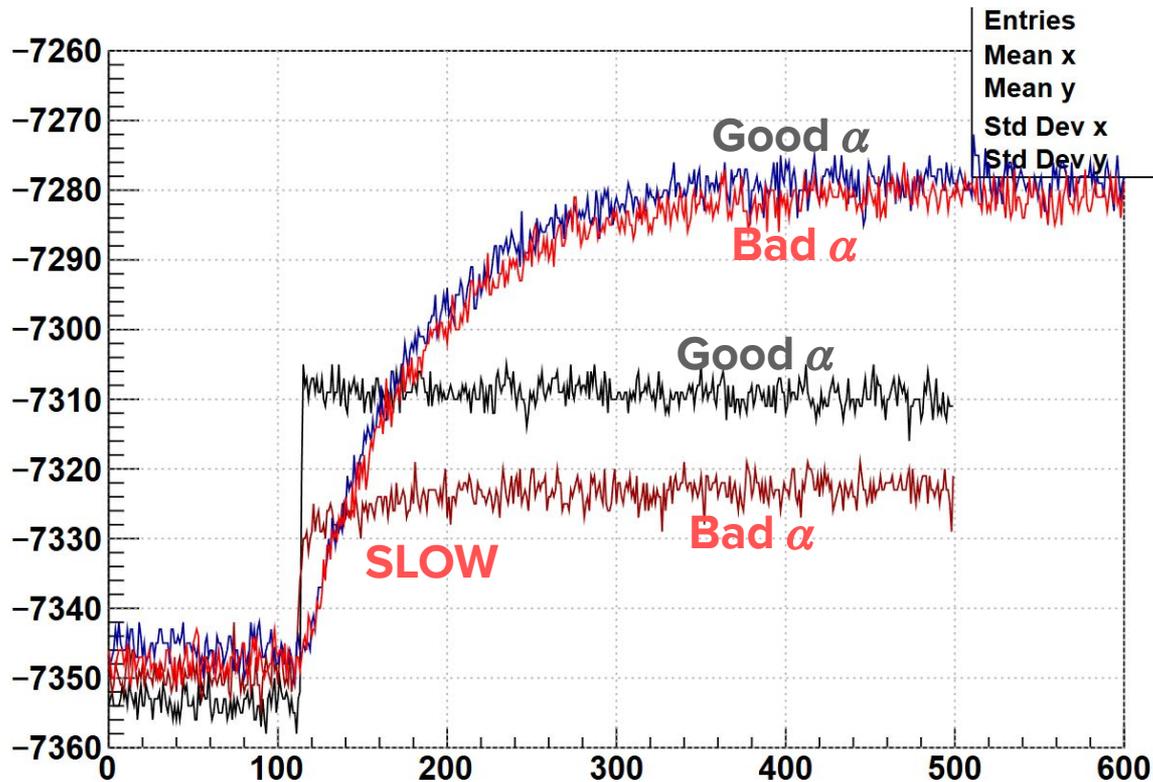
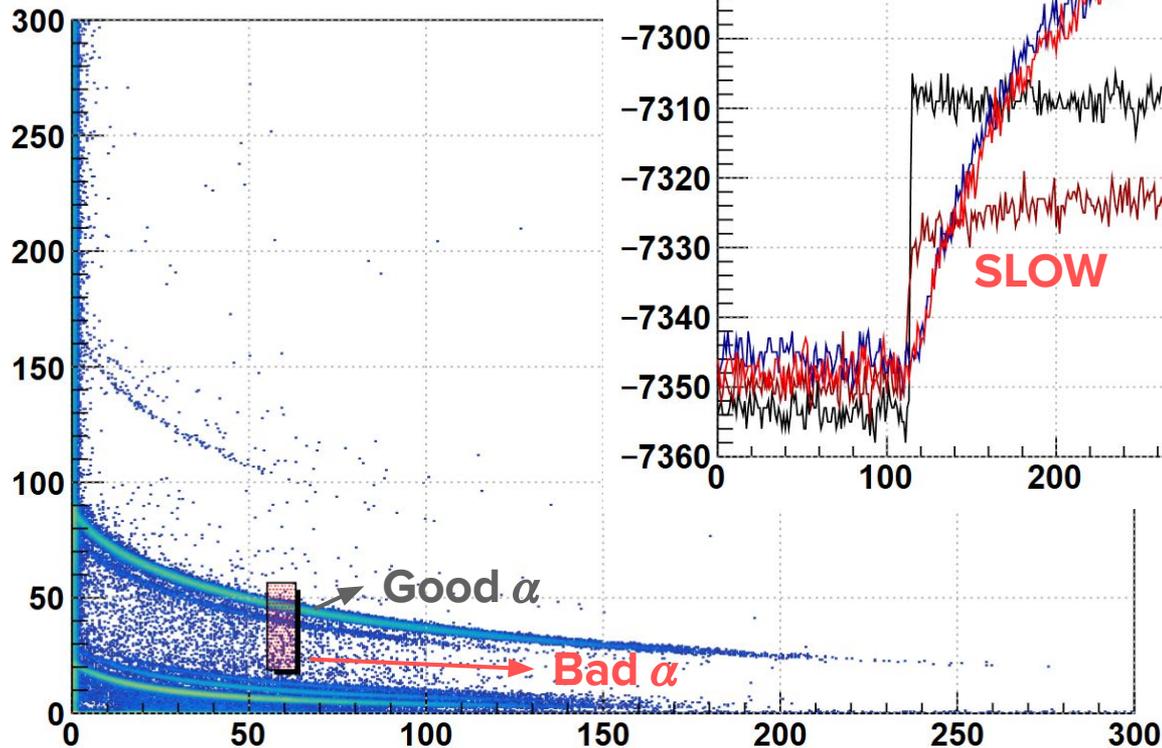
sQ2max:sQ3max {fQua==3 && fTel==1}



hh	
Entries	1653738
Mean x	24.51
Mean y	35.32
Std Dev x	27.57
Std Dev y	50.36

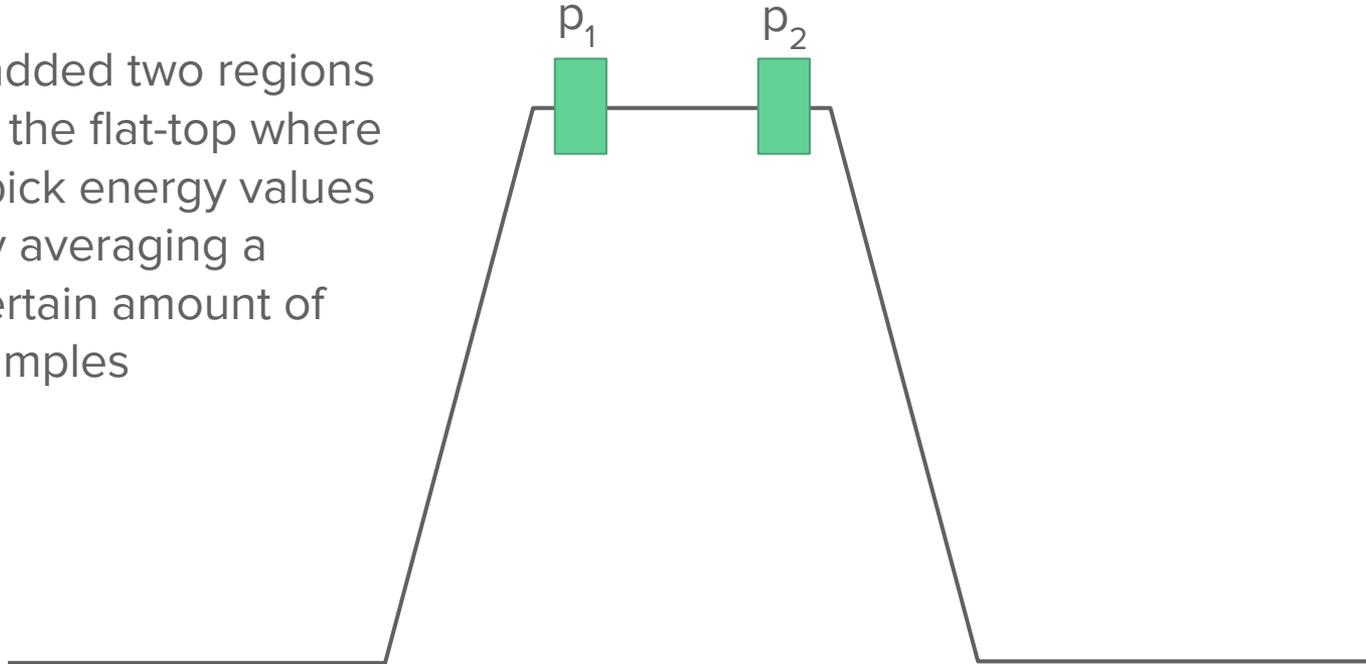
Border effects?

sQ2max:sQ3max {fQua==3 &&



New implementation in my tree extractor*

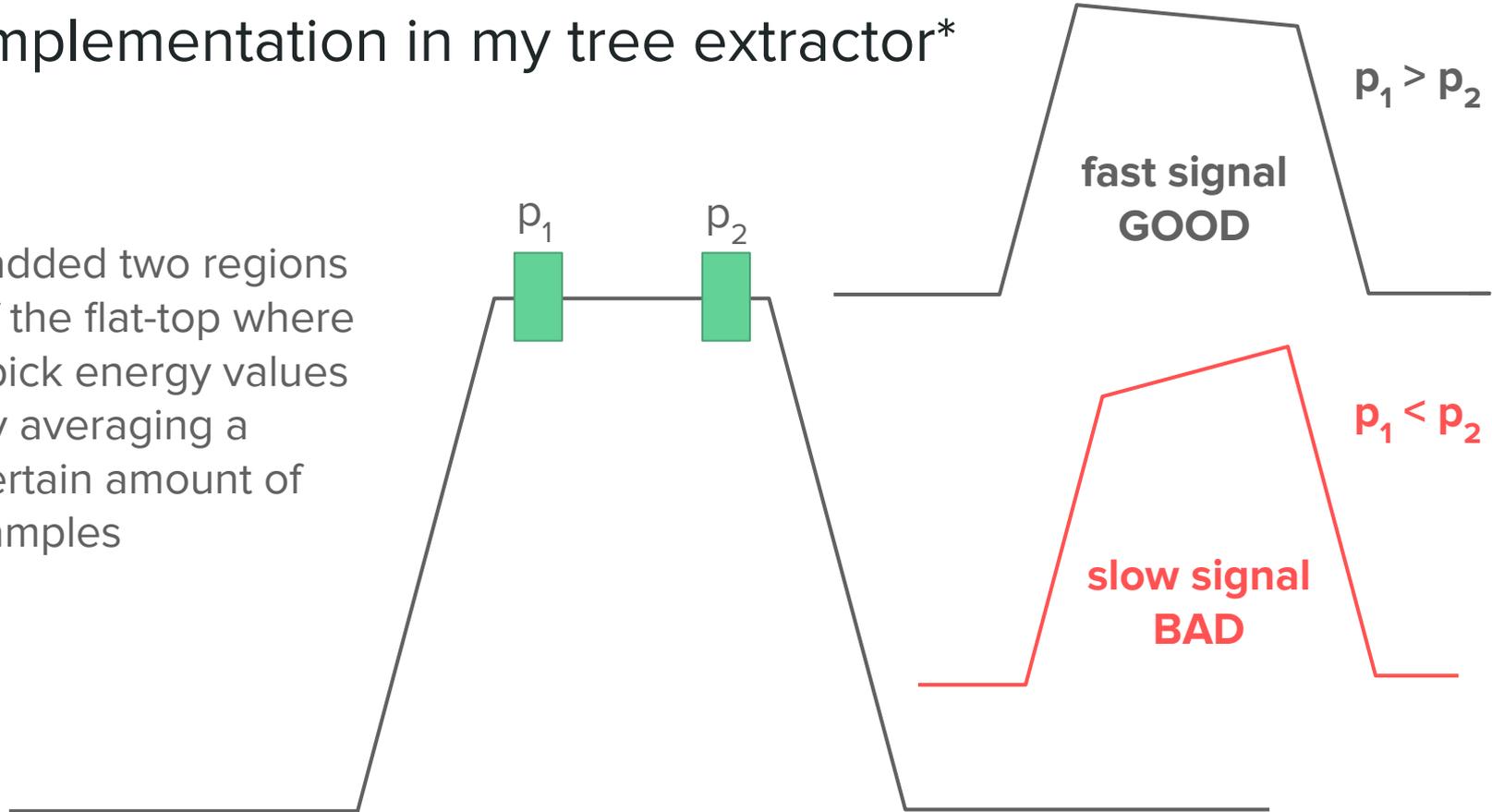
I added two regions of the flat-top where I pick energy values by averaging a certain amount of samples



*fz-tree from "<https://baltig.infn.it/valdre/fz-utils>"

New implementation in my tree extractor*

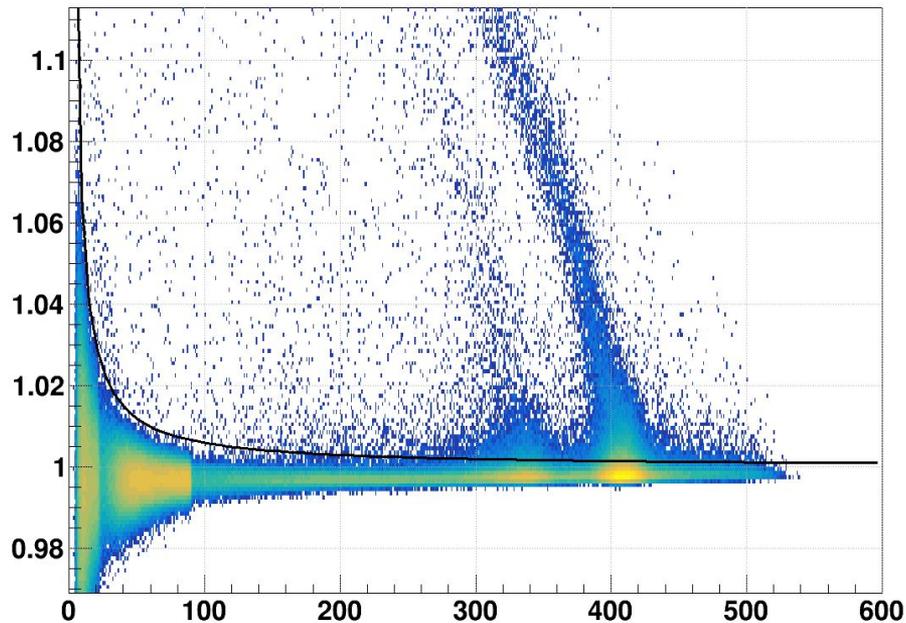
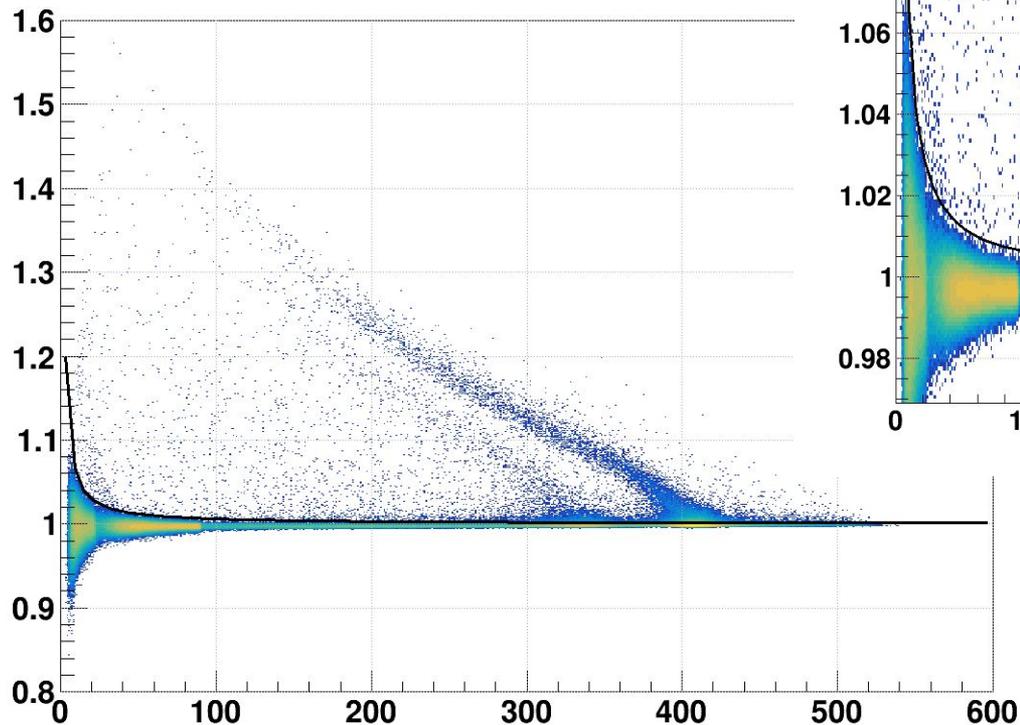
I added two regions of the flat-top where I pick energy values by averaging a certain amount of samples



sQ2p2/sQ2p1:sQ2p1 {fQua==4&&fTel==2}

Cleaning cut on p_2/p_1

sQ2p2/sQ2p1:sQ2p1 {fQua==4&&fTel==2}

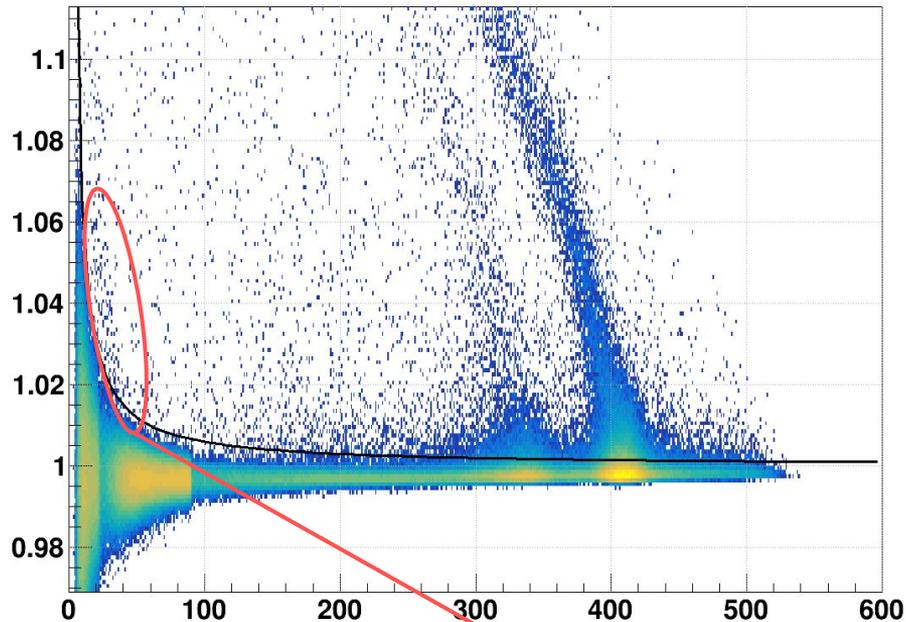
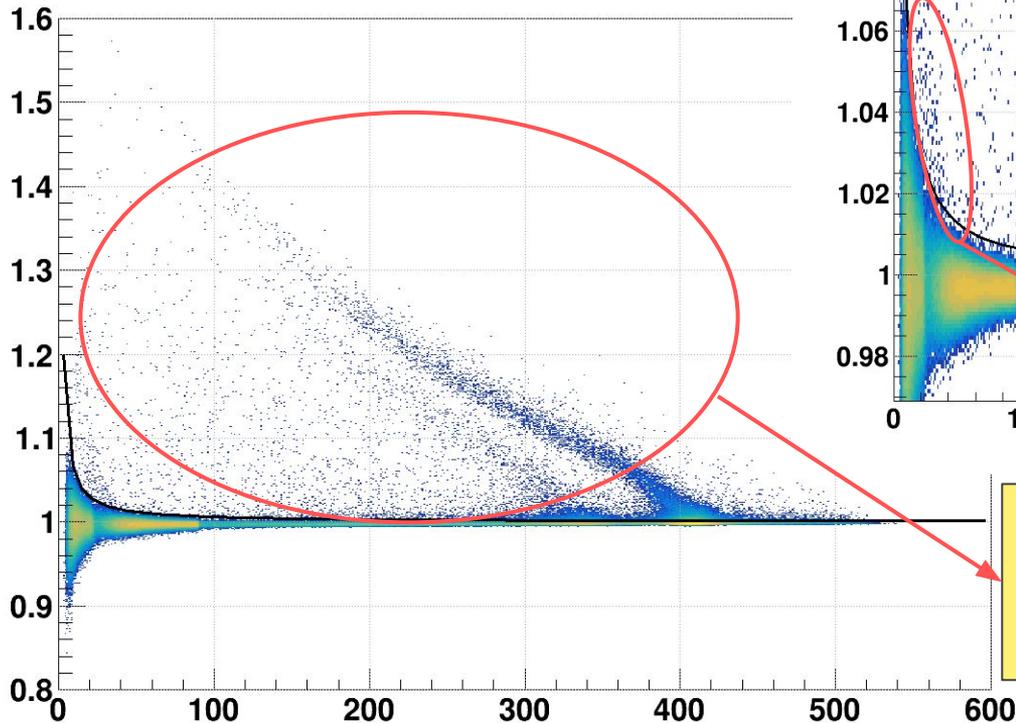


$$p_2 < a + b * p_1$$

sQ2p2/sQ2p1:sQ2p1 {fQua==4&&fTel==2}

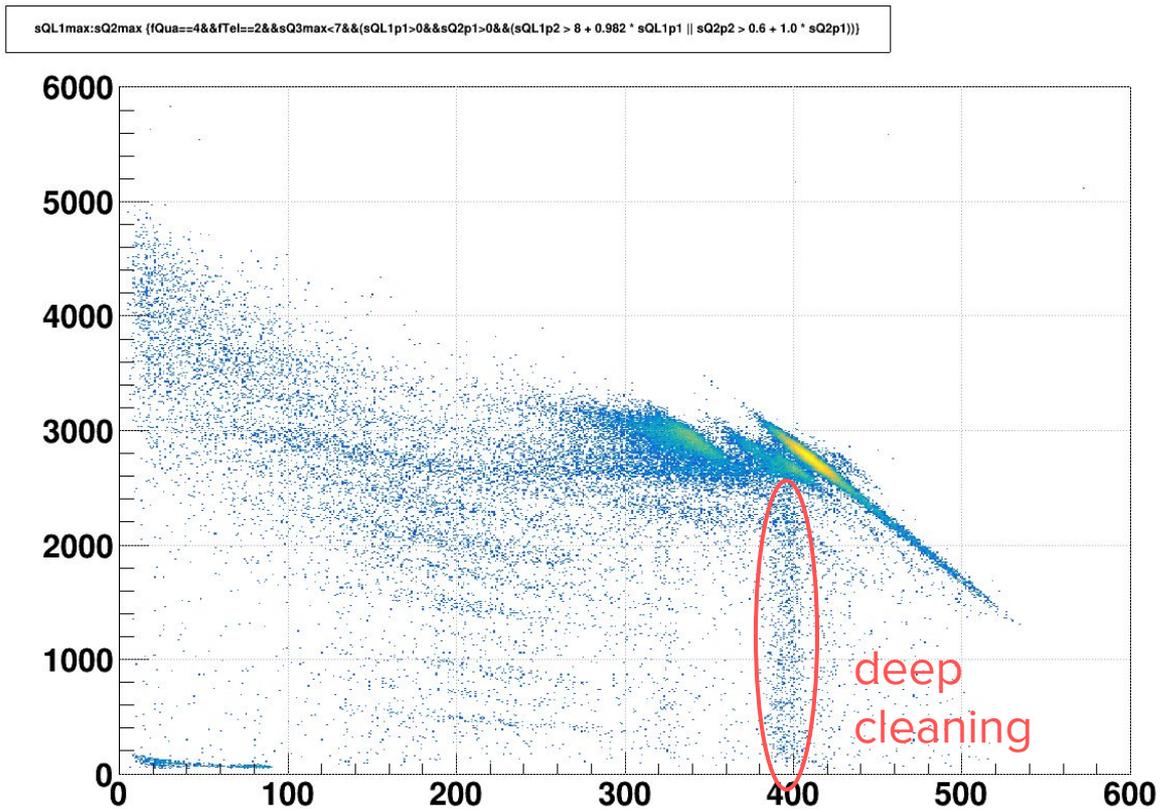
Cleaning cut on p_2/p_1

sQ2p2/sQ2p1:sQ2p1 {fQua==4&&fTel==2}



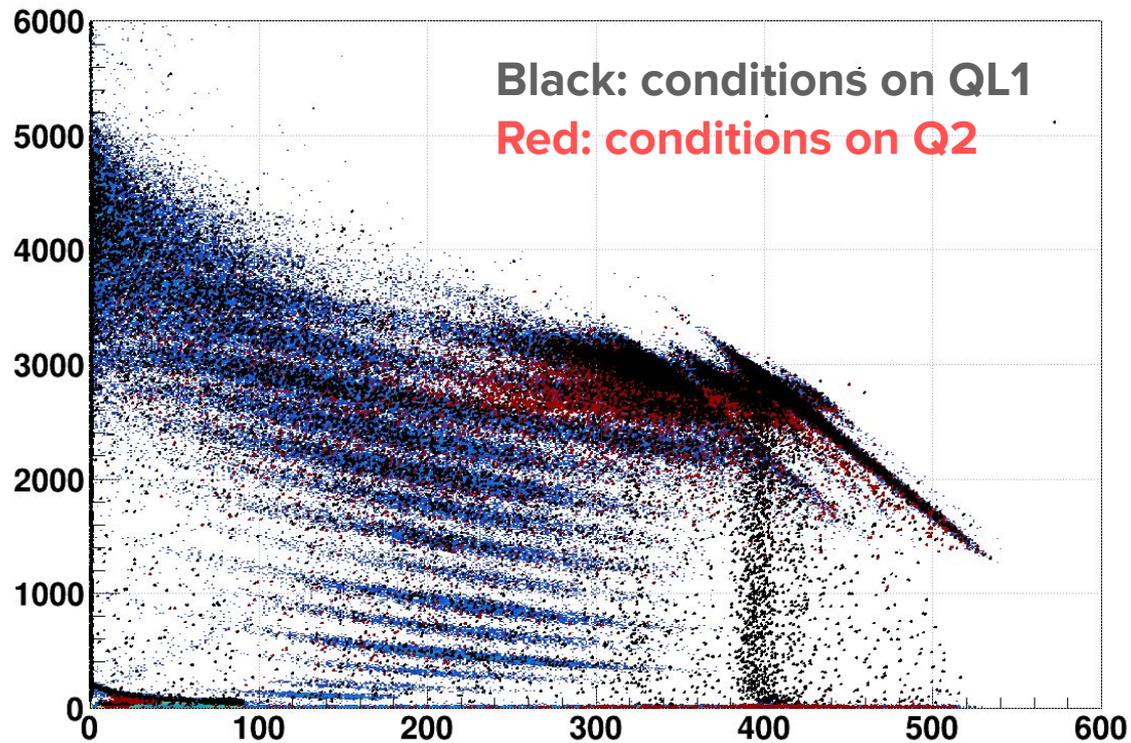
Larger effect on heavier particles than on LCP

p_2/p_1 cut effect



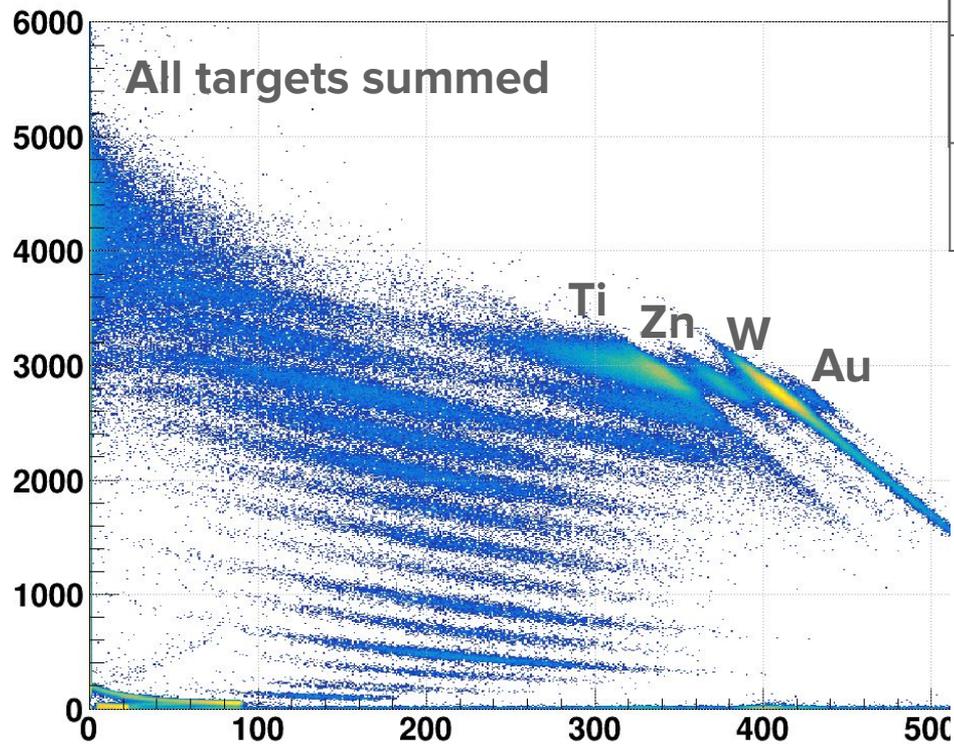
Cleaning combined effect

sQL1max:sQ2max {fQua==4&&fTel==2&&sQ3max<7}



Clean Si1 vs Si2 correlation

```
sQL1max:sQ2max [(Qum=4&&Ffel=2&&sQ3max<7&&(sQL1p1<0)|(sQ2p1<0)|(sQL1p2<8+0.982*sQL1p1&&sQ2p2<0.6+1.0*sQ2p1))&&sQL1ofd20<1300&&sQ2ofd20<1400]
```



No conditions	1088902	100.0 %
CFD	3293	0.3 %
p_2 / p_1	75306	6.9 %
Clean	1011560	92.9 %

TO DO: new FoM calculation on clean spectrum for all telescopes

Thanks for your attention
