Straw based and solid state based TRDs for SAS

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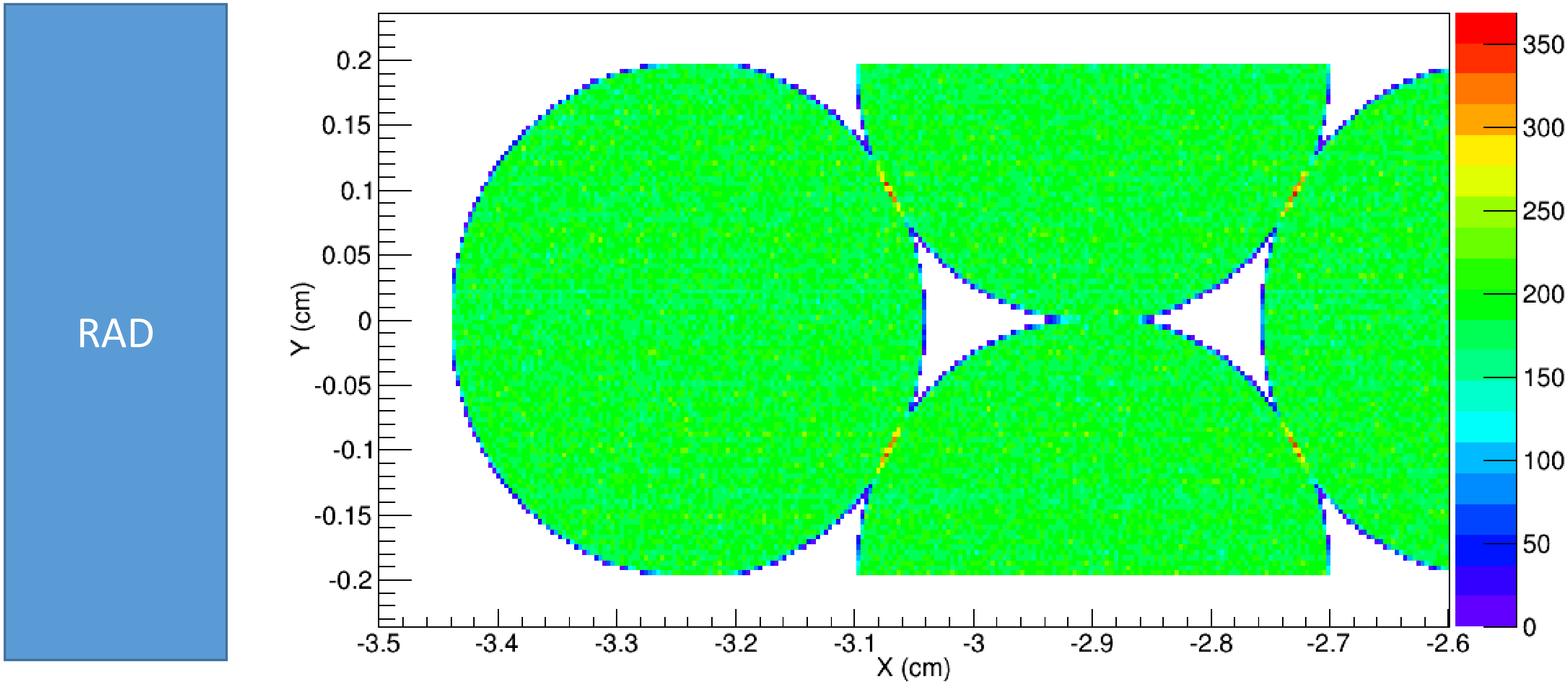
Introduction

- The aim of this work is twofold:
  - Study of the configuration of a single TRD module
  - Study of the performance of a multi-module TRD
- TRD configurations:
  - Straw:
    - Radiators with 200 foils and d1(μm)/d2(μm) = 15/300, 50/1000 and 100/2000 (hereafter thin, middle and thick configuration)
    - Up to 40 layers of straws (2 mm radius) in close pack configuration filled with Xe/CO2 80/20
  - Solid state:
    - Radiator with 200 foils and d1(μm)/d2(μm)=100/2000 (i.e. thick)
    - Up to 100 layers of silicon 60 μm thick
- Full Monte Carlo simulations implemented for both options
  - Computer Physics Communications 132 (2000) 110–123
  - Nuclear Instruments and Methods in Physics Research A 533 (2004) 322–343

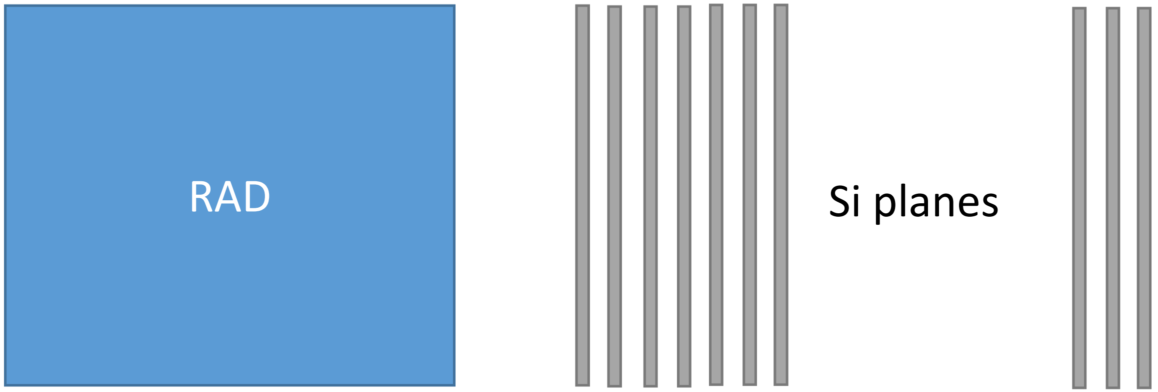
Straw TRD geometry



- Radiators with 200 foils and d1(μm)/d2(μm) = 15/300, 50/1000 and 100/2000 (thin, middle and thick configurations)
- Up to 40 layers of straws (2 mm of radius) in close pack configuration filled with Xe/CO2 80/20
- The events have been uniformly generated across the first straw tube
- The plot shows the position of the pair due to the ionization energy loss (10^5 events)
  - In this work we will use only the information on the energy loss

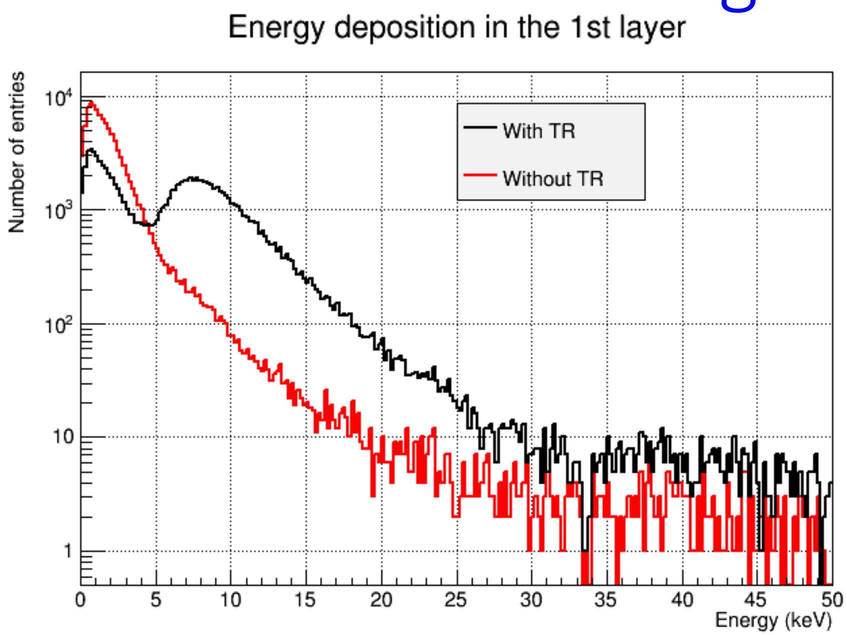
Solid state TRD module

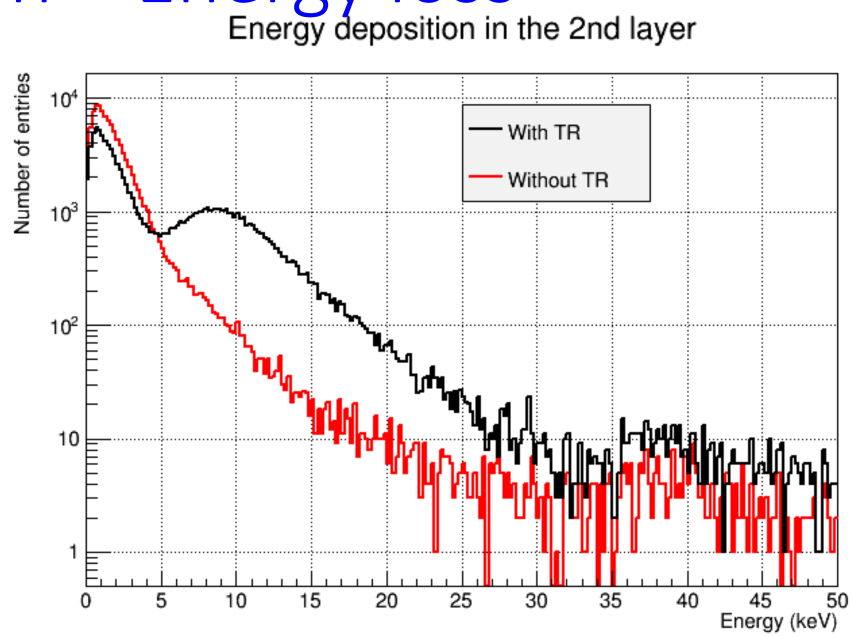
- The ionization energy loss in solid medium is usually larger than the TR energy
  - A magnetic field could be used to separate the particle from the TR photons (SiTRD concept)
  - This is unpractical for the SAS project
- A possible solution could be to minimize the solid state detector thickness
  - On the shelf we found silicon detectors of about 60 µm thickness
- Geometry of a single module:
  - Radiator with 200 foils and d1(µm)/d2(µm)=100/2000 (i.e. thick)
  - Up to 100 layers of silicon 60 µm thick

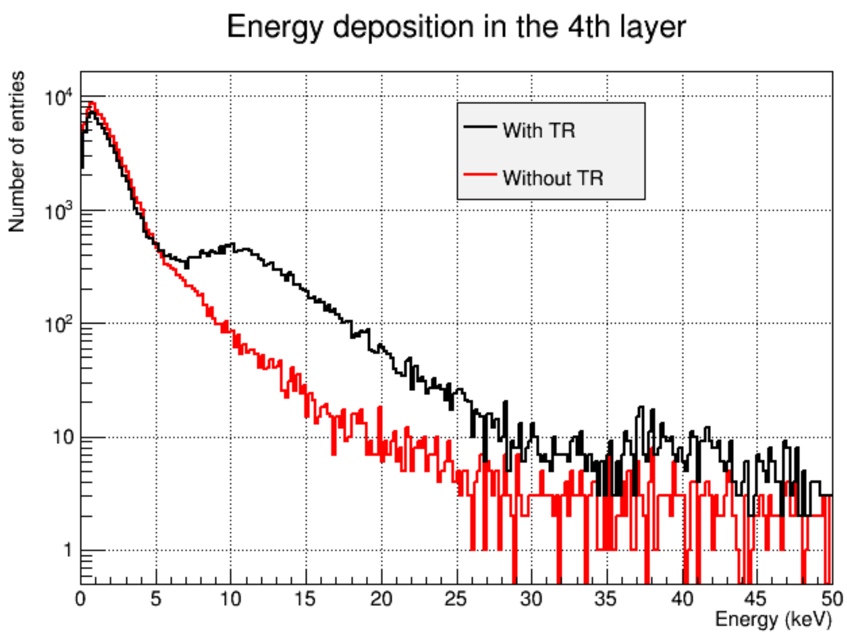


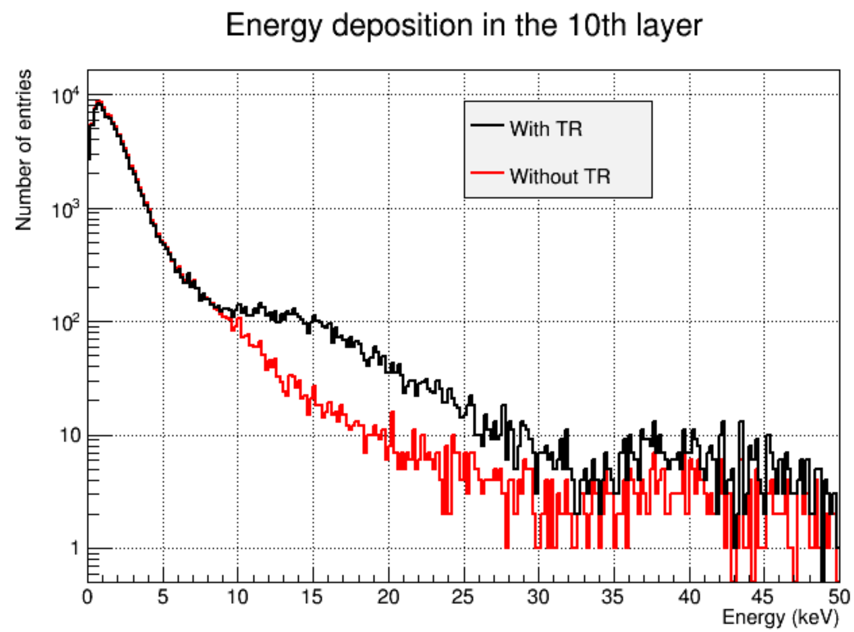
Straw based TRD

Thin configuration – Energy loss



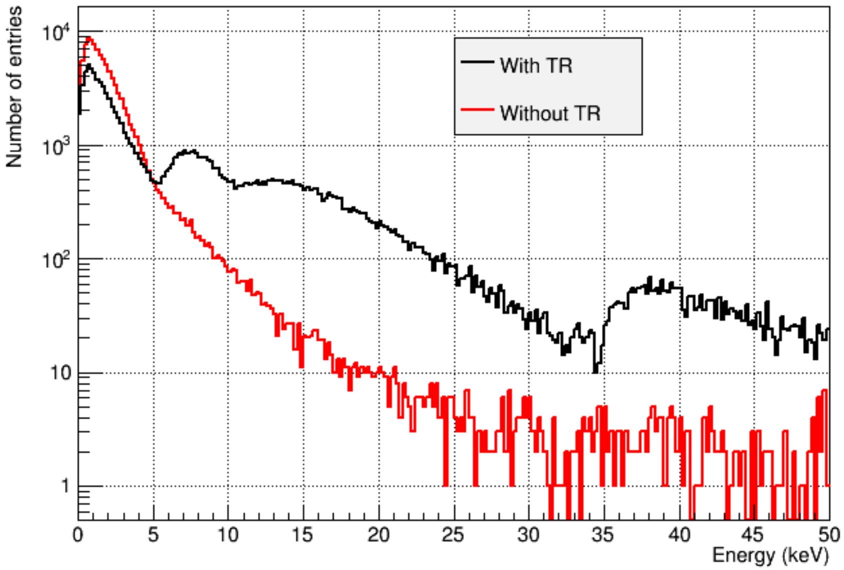




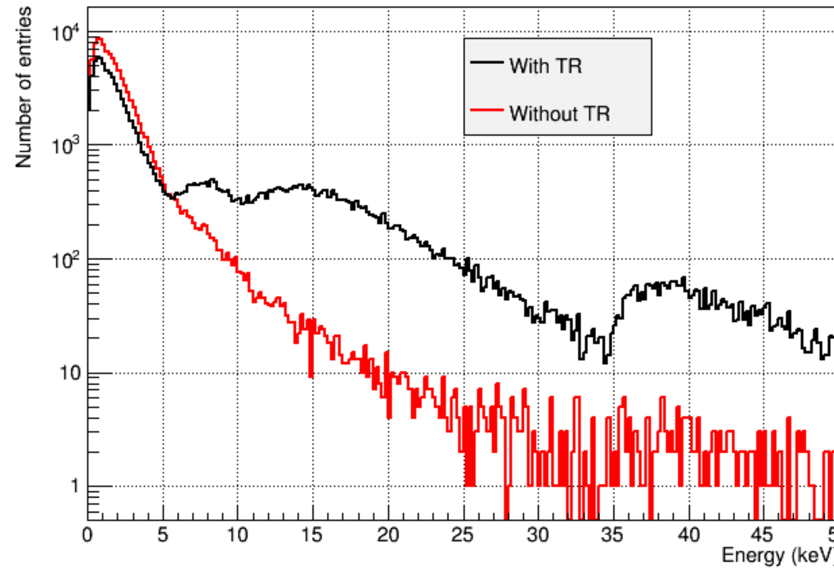


Middle configuration – Energy loss

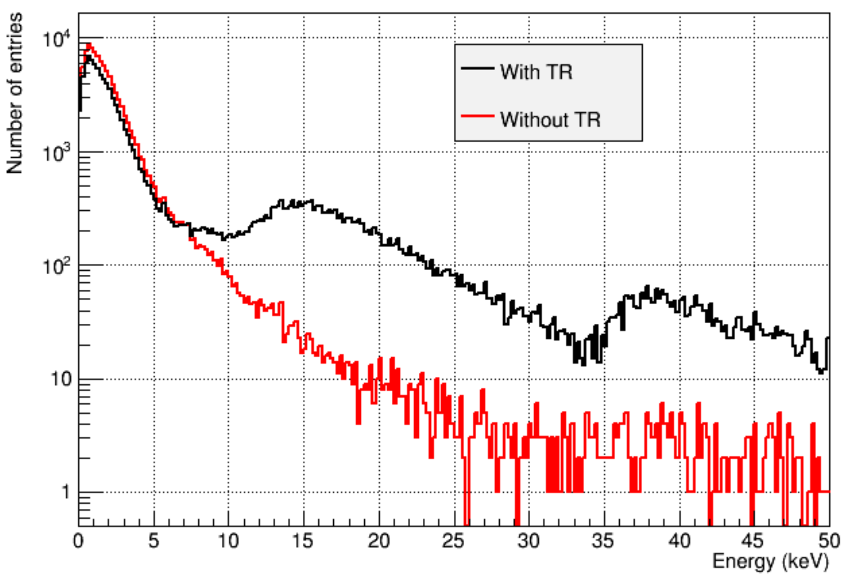
Energy deposition in the 1st layer



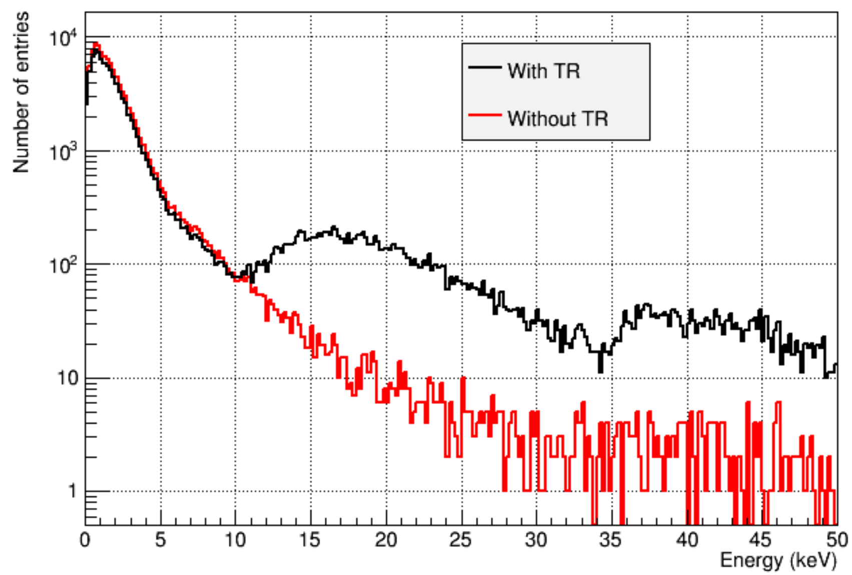
Energy deposition in the 2nd layer



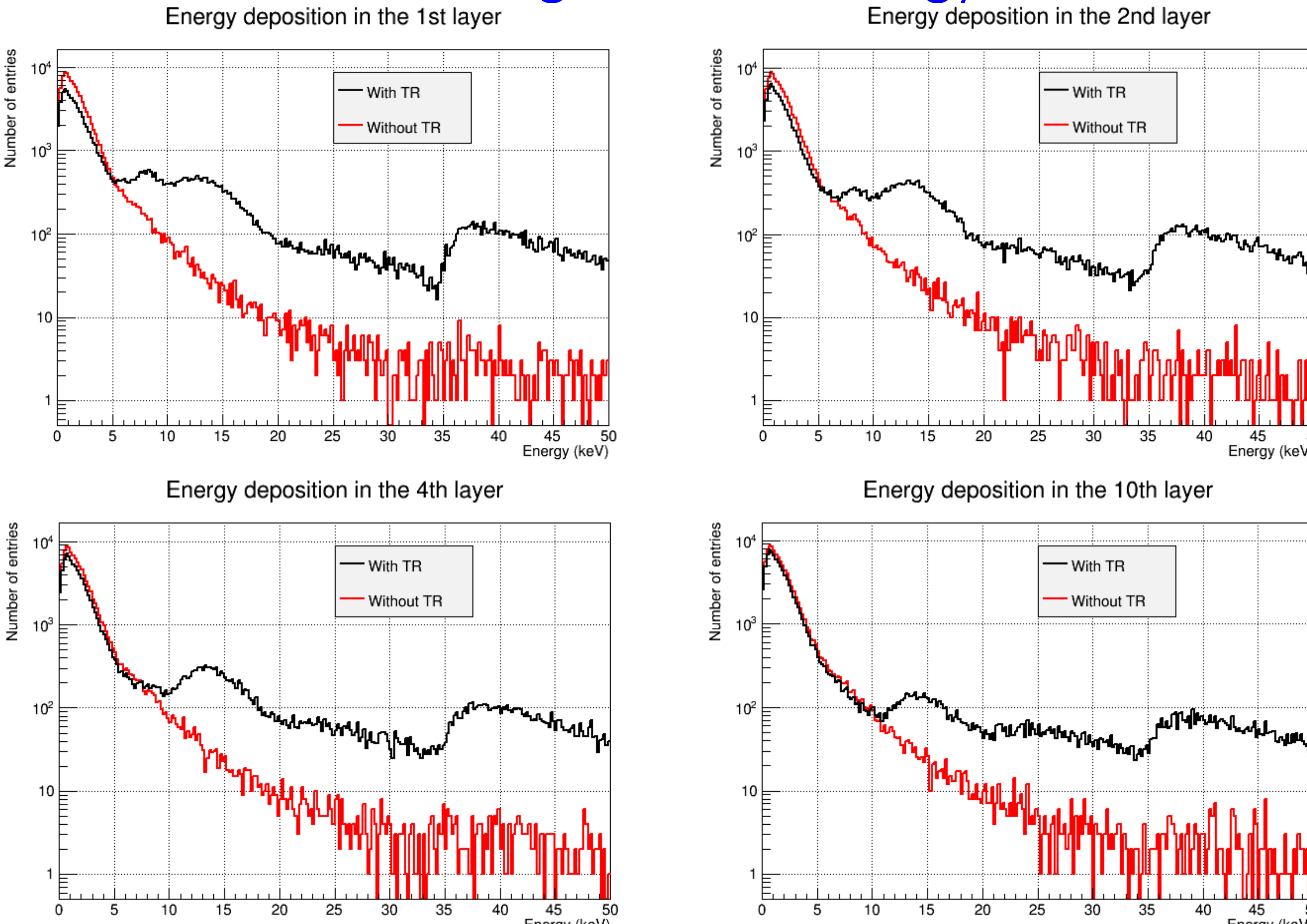
Energy deposition in the 4th layer



Energy deposition in the 10th layer



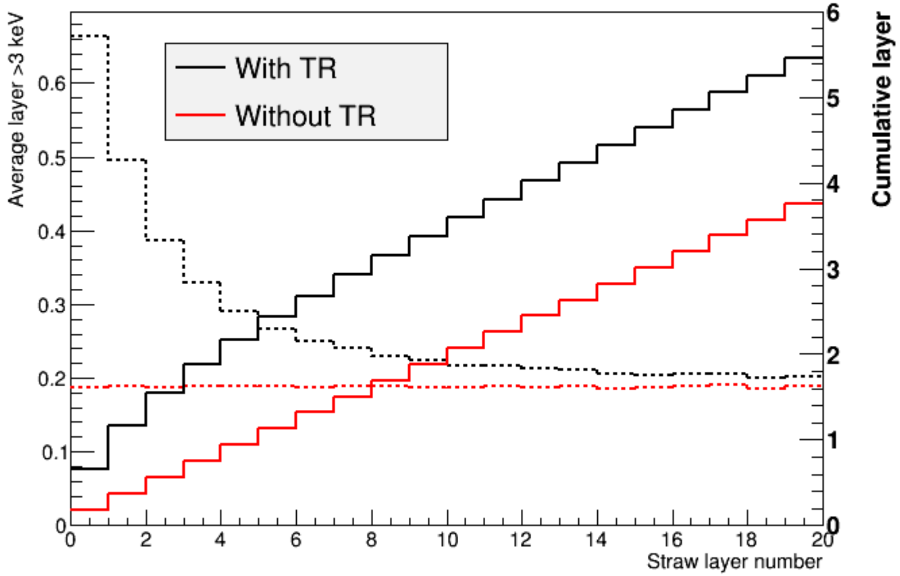
Thick configuration – Energy loss

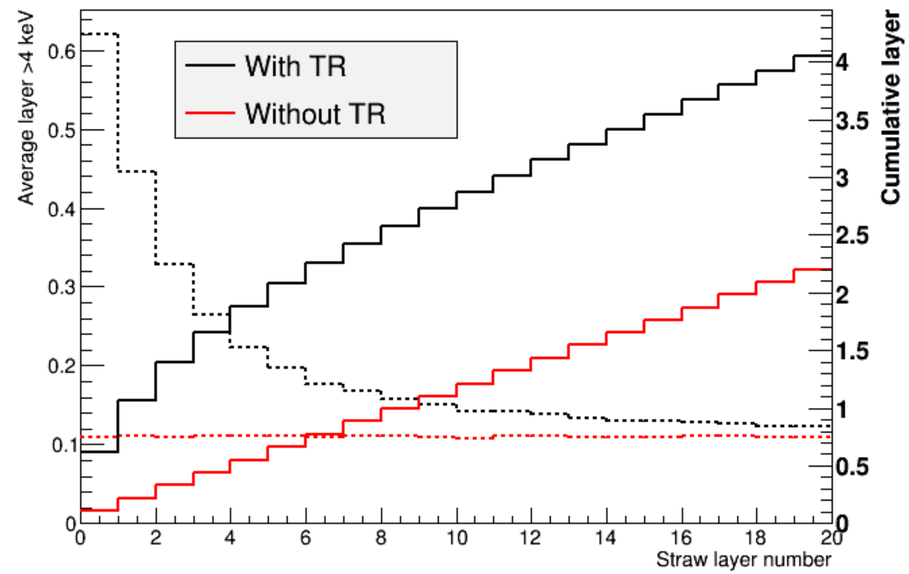


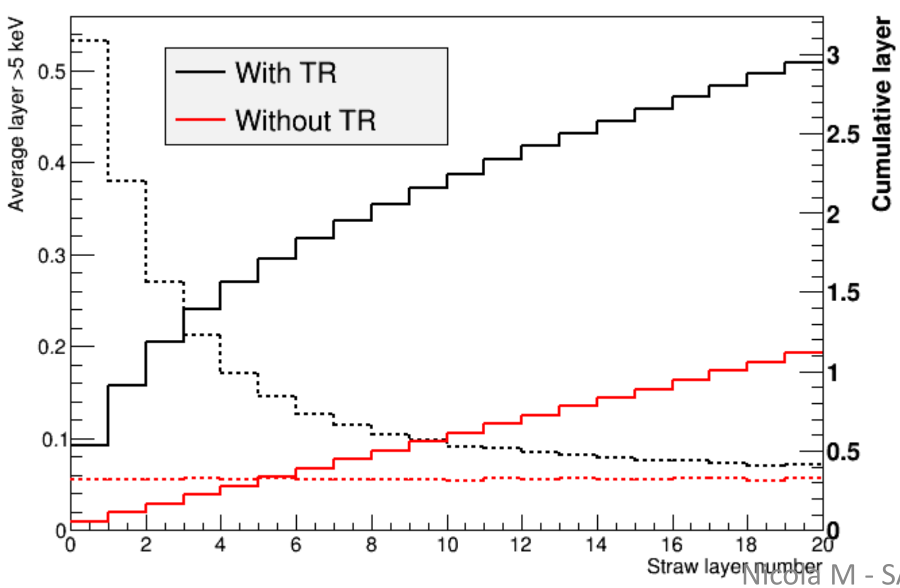
Single module analysis

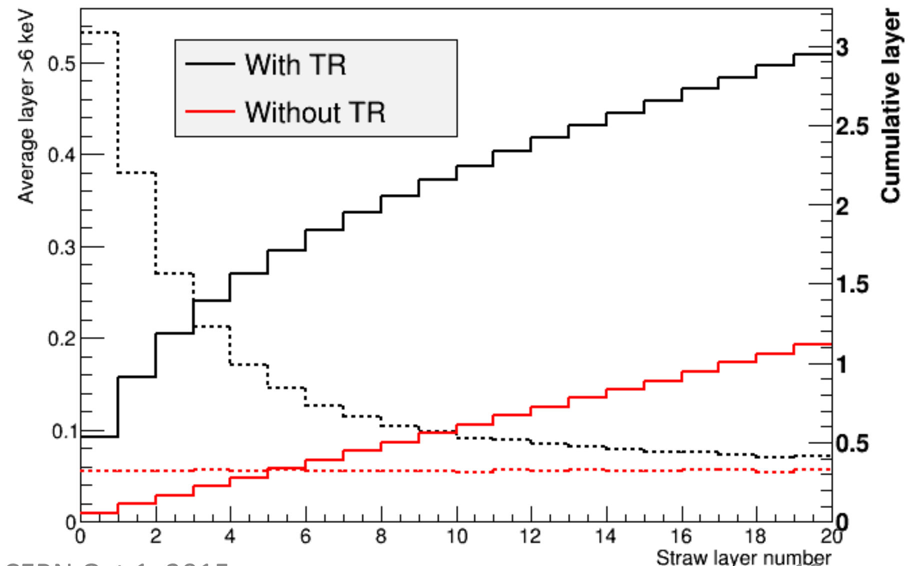
- Number of fired layers as a function of the energy threshold (i.e. 3, 4, 5 and 6 keV)
- Efficiency as a function of the energy threshold (i.e. 3, 4, 5 and 6 keV)
  - The efficiency has been evaluated averaging the energy losses in a given number of first layers
- These studies have been performed in the saturation regime, i.e. with 10 TeV pions

Thin configuration – Fired layers

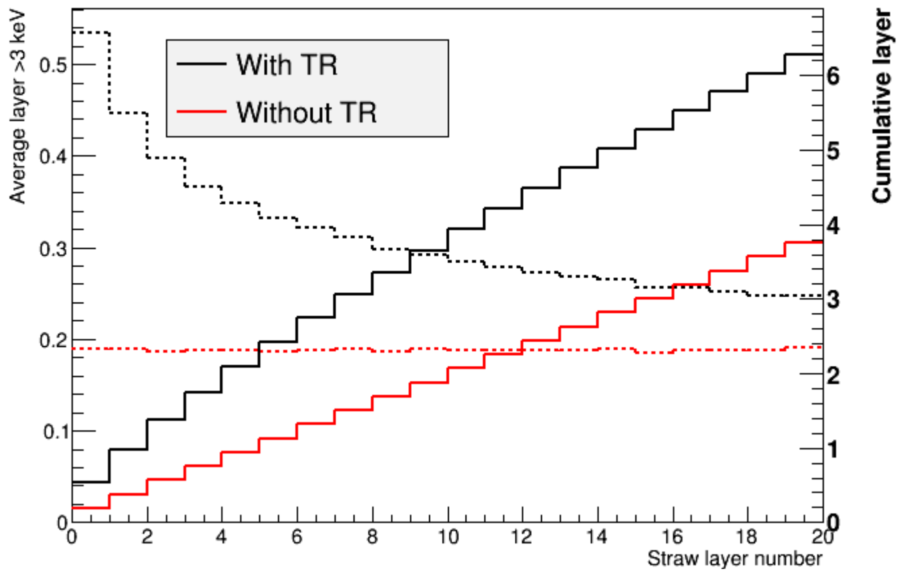


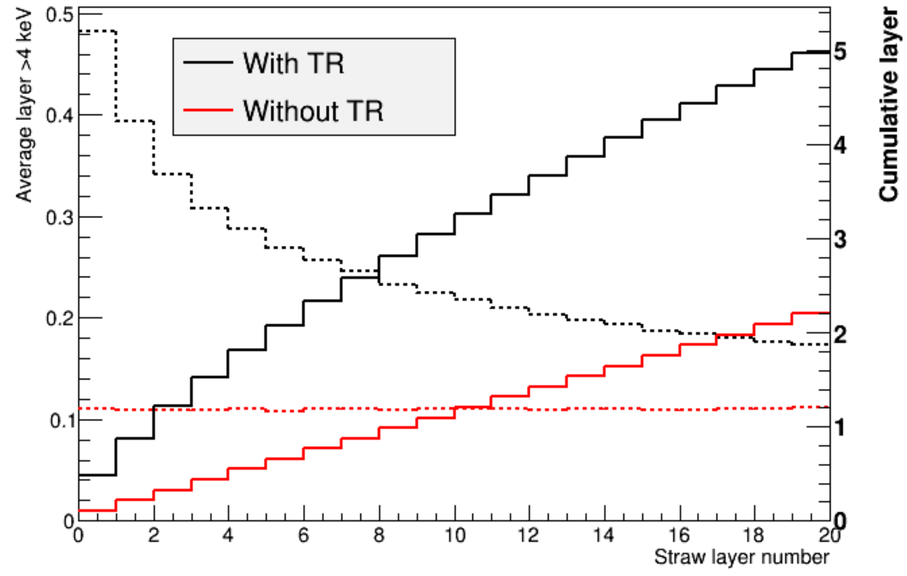


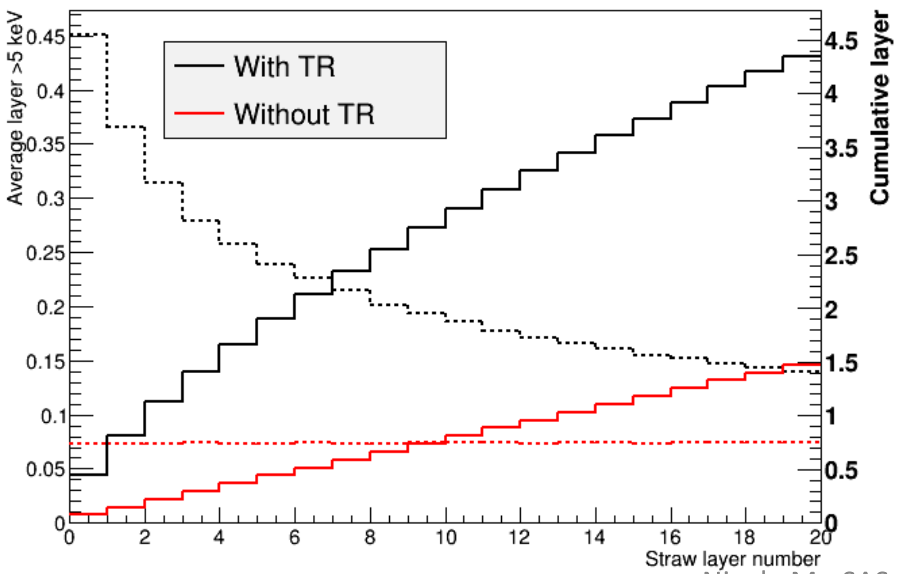


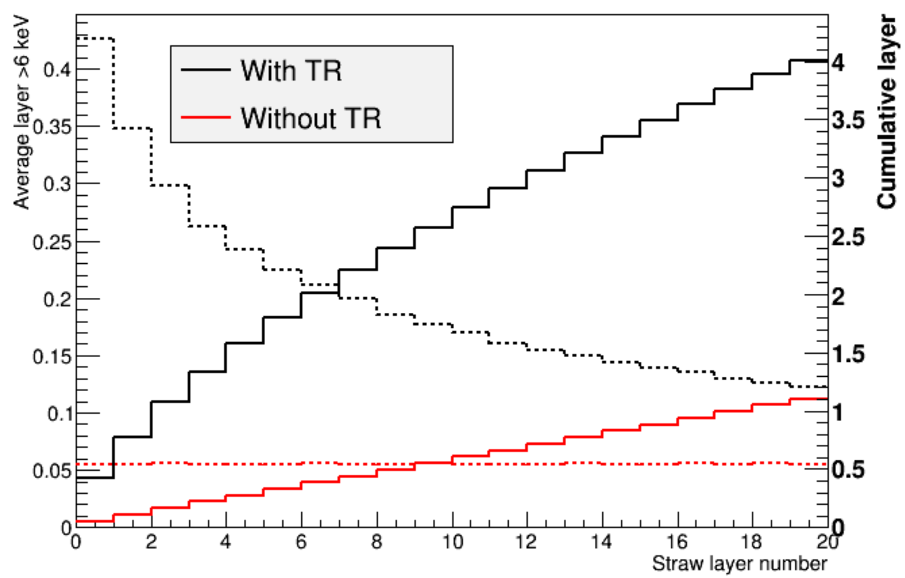


Middle configuration – Fired layers

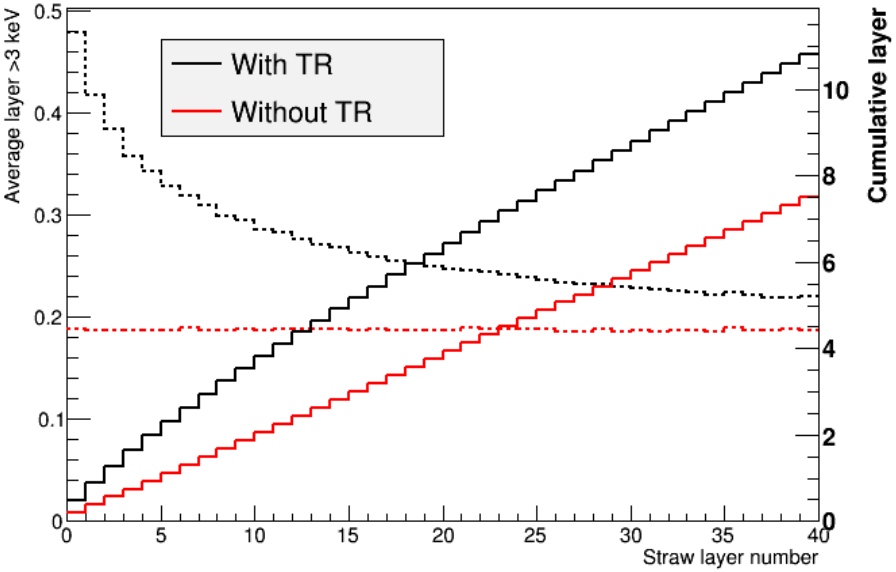


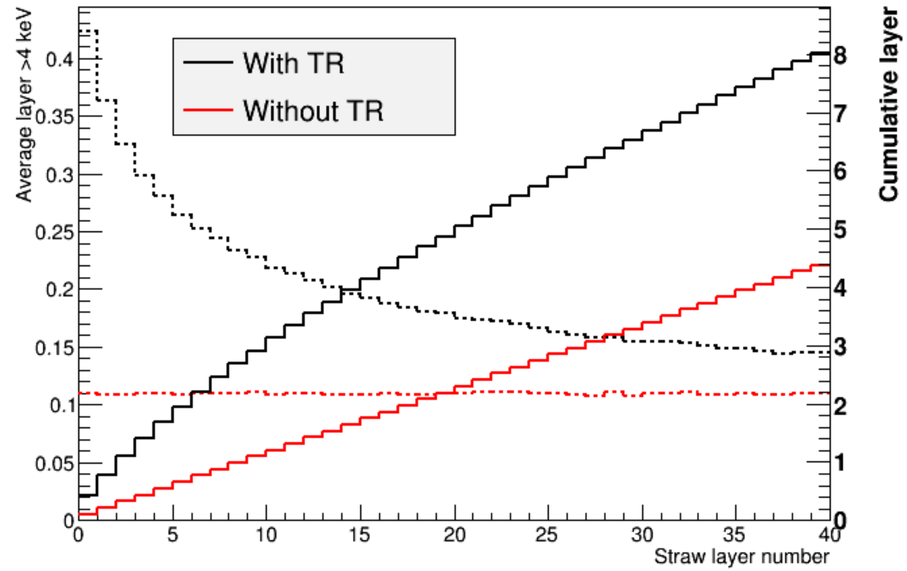


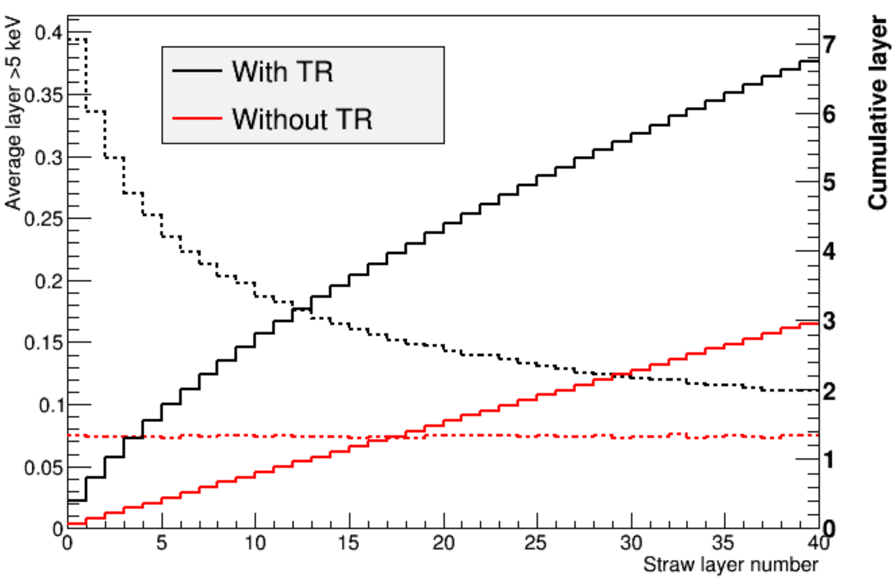


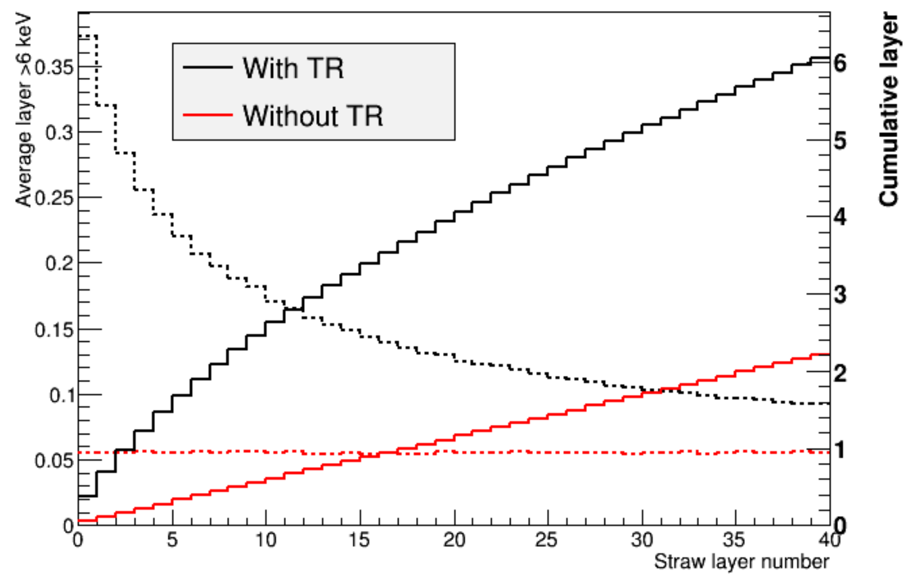


Thick configuration – Fired layers

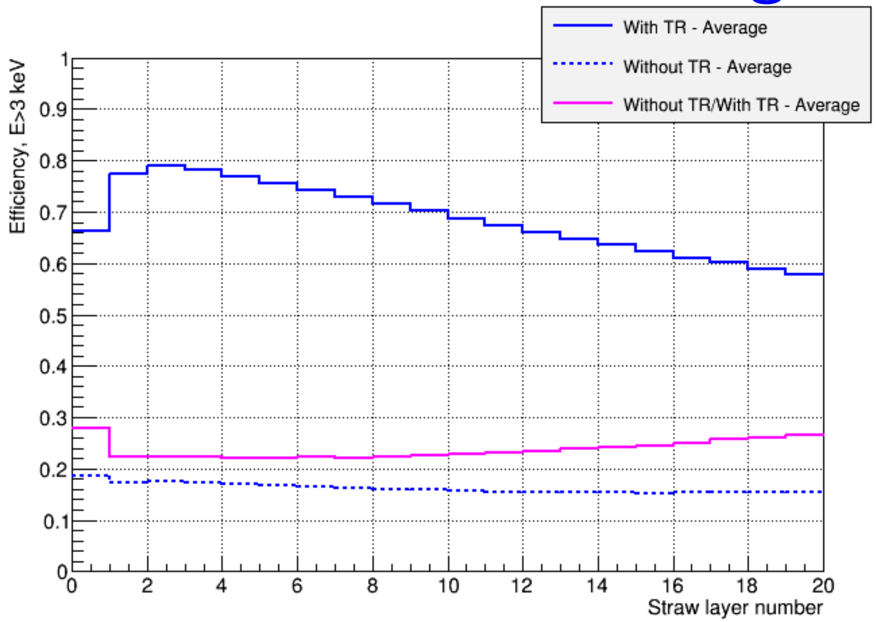


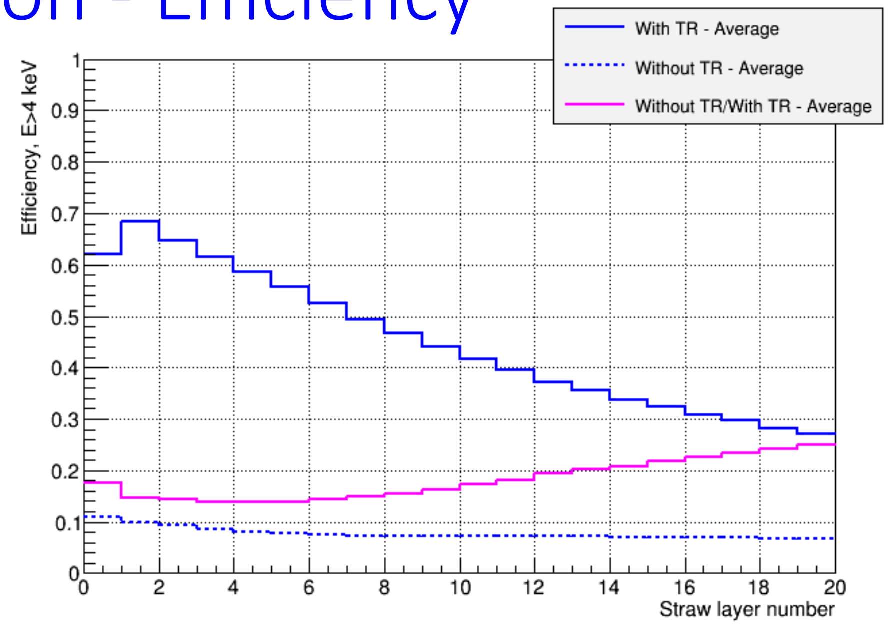


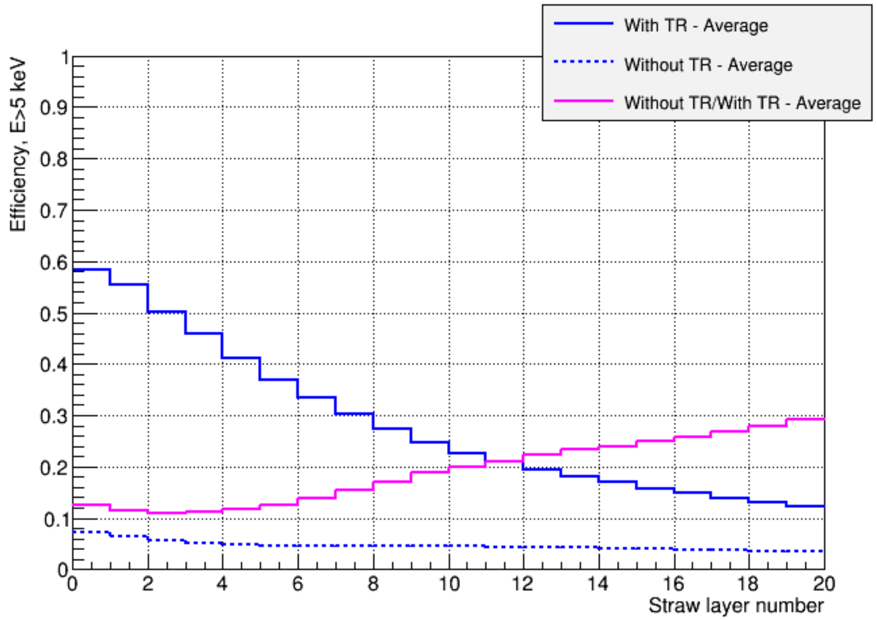


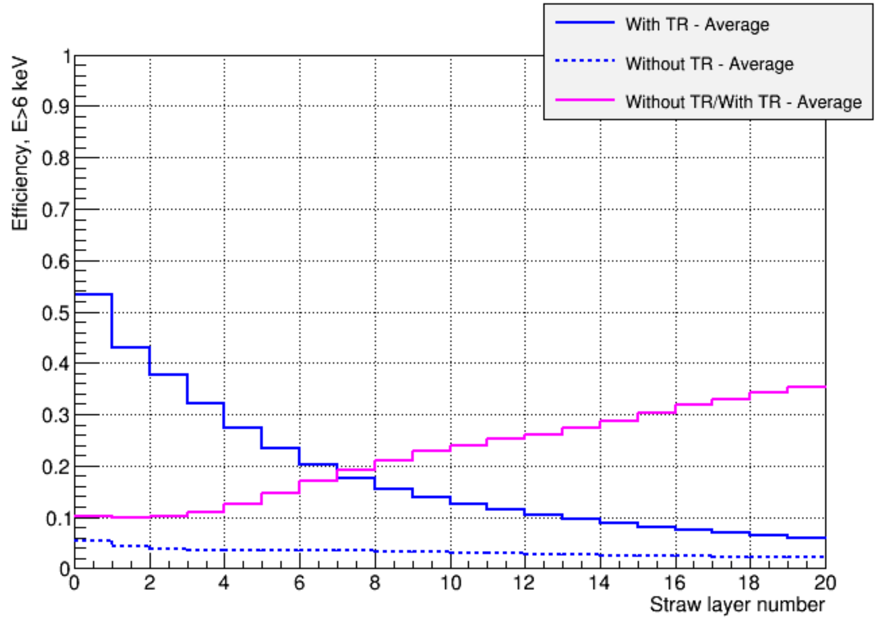


Thin configuration - Efficiency

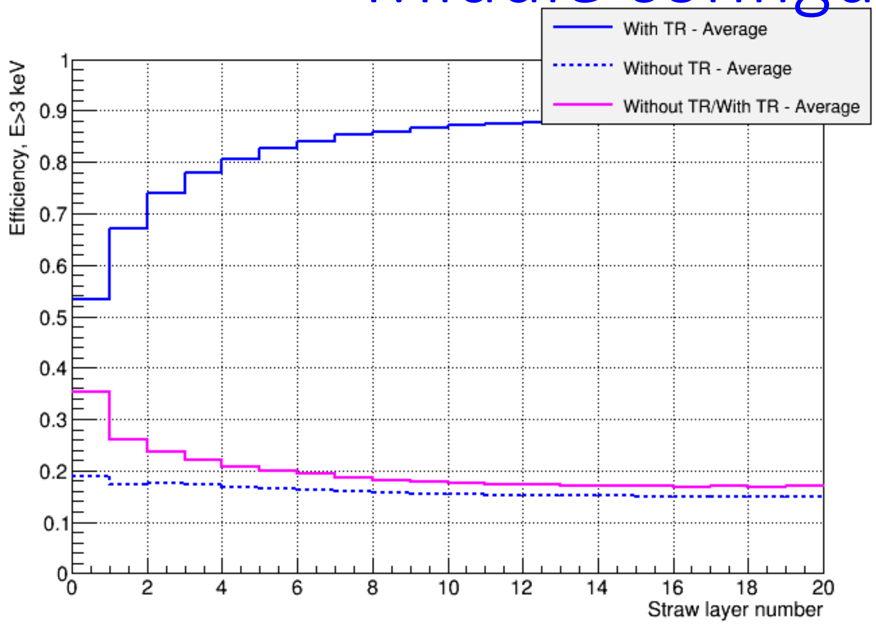


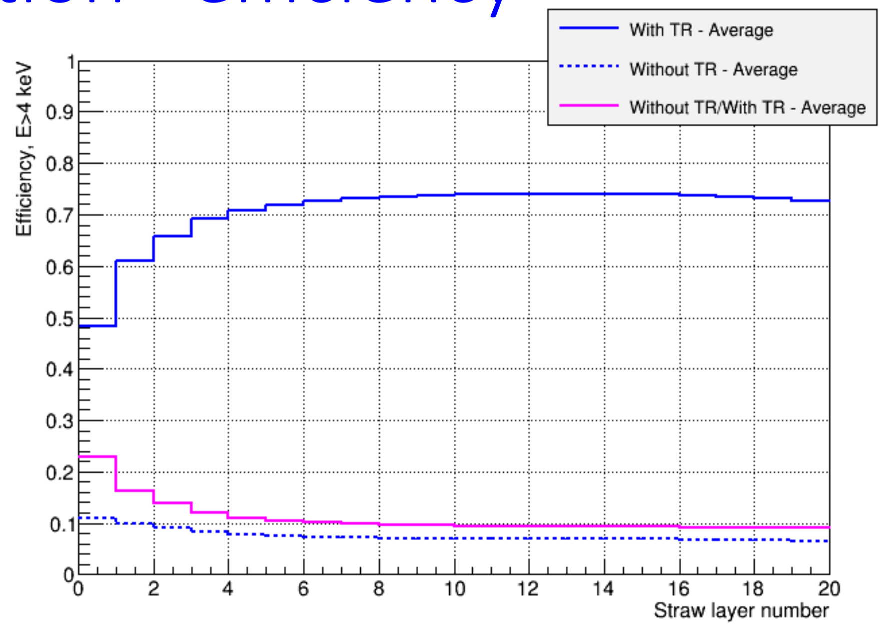


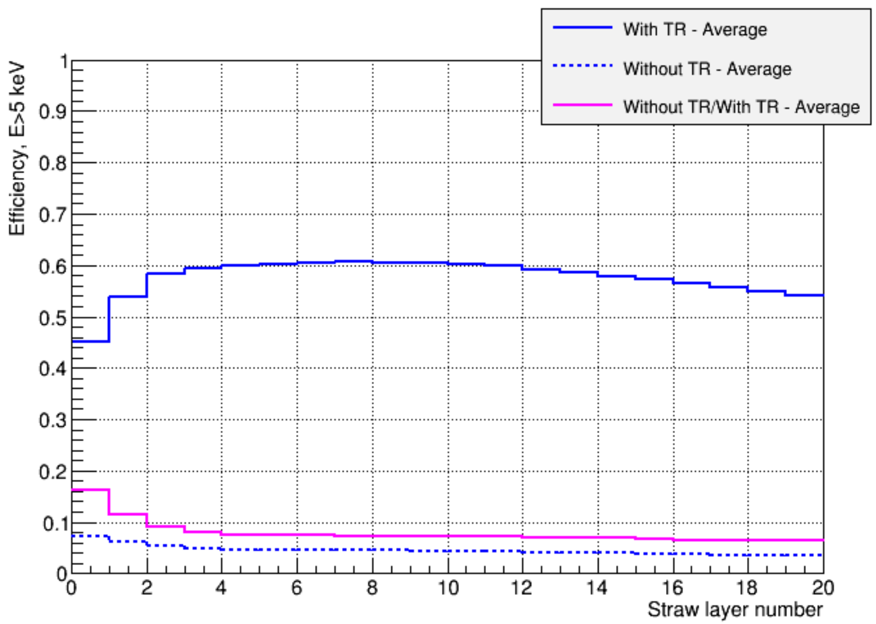


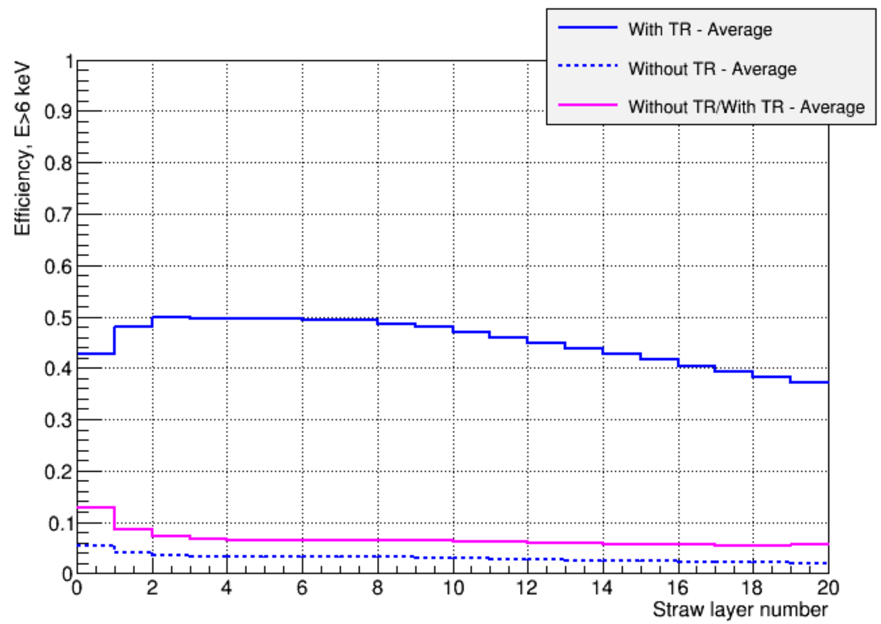


Middle configuration - efficiency

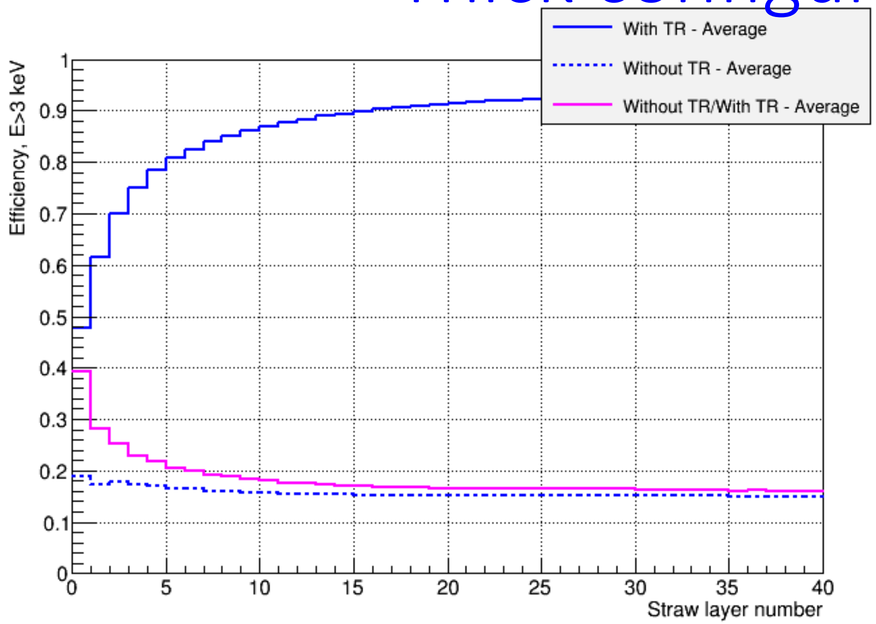


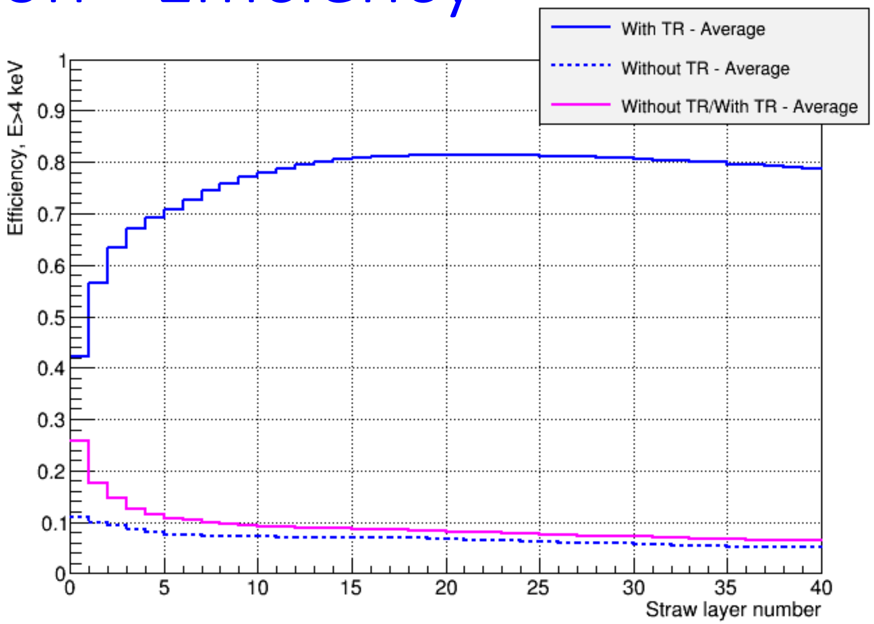


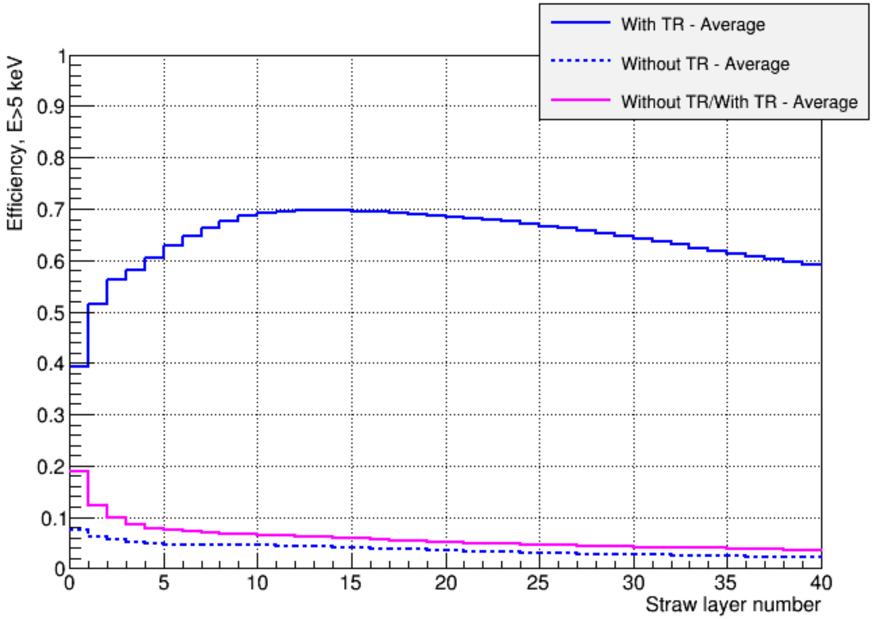


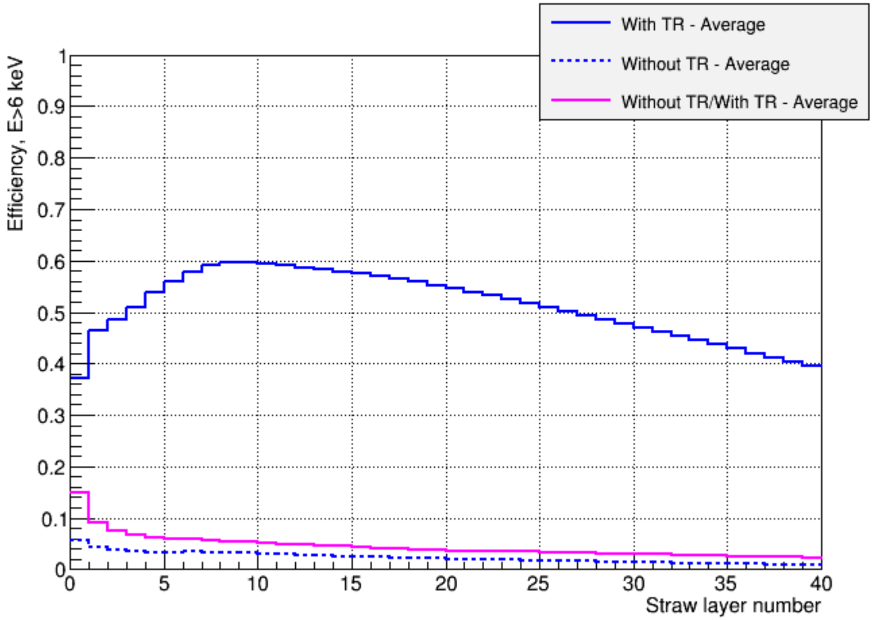


Thick configuration - Efficiency





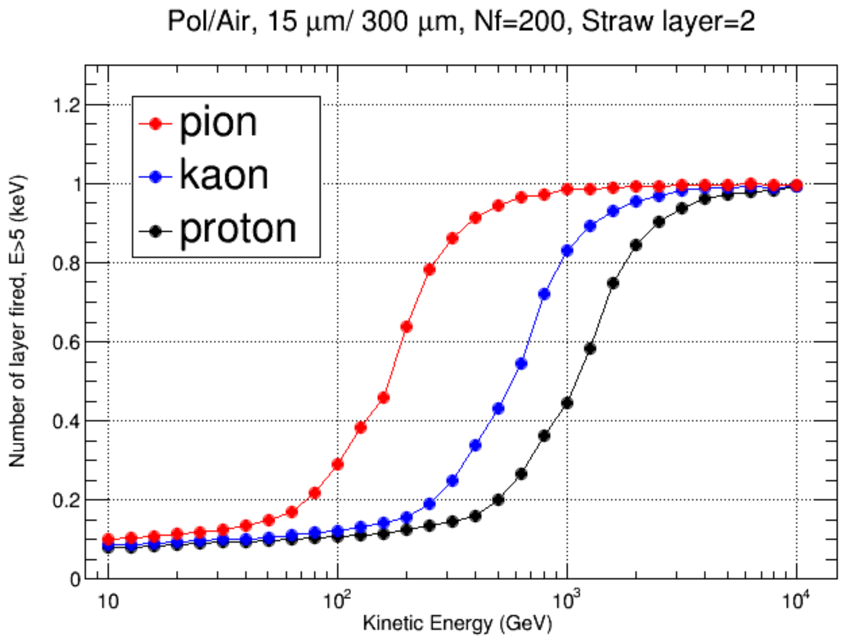


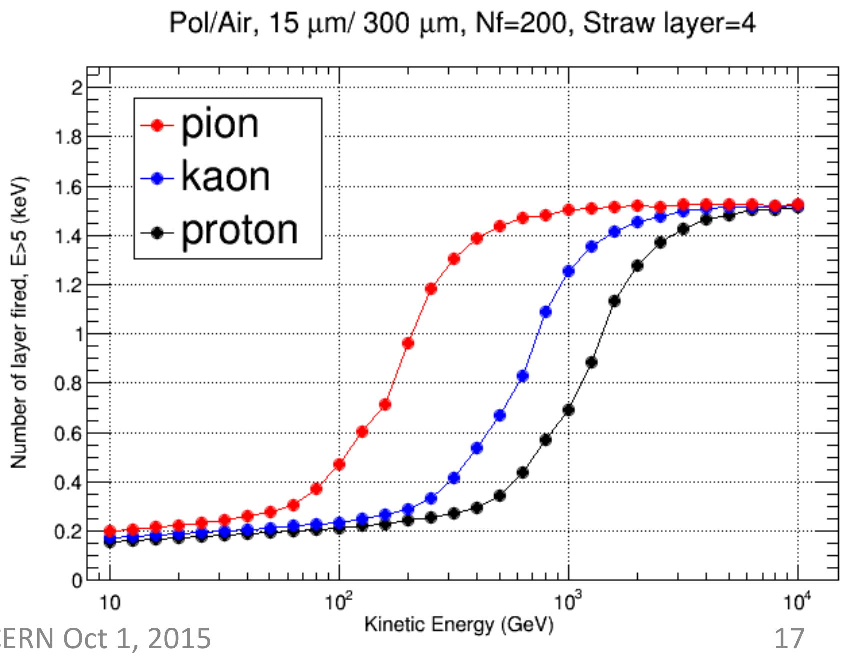


Configuration of a straw TRD module

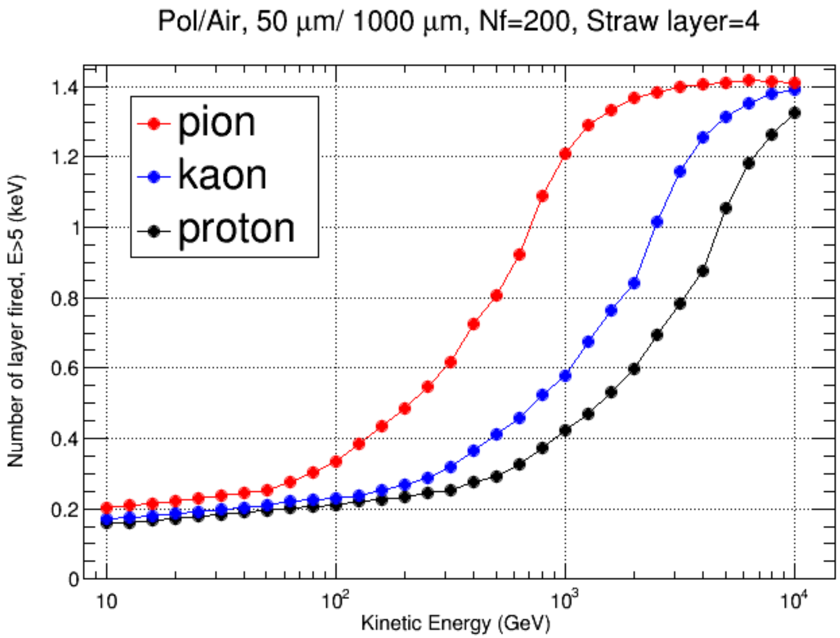
- According to the results shown in the previous slides the optimal number of straw layers for a single TRD module could be:
  - Thin configuration: 4 straw layers
    - 2 layers could work the same
  - Middle configuration: 8 straw layers
    - 4 layers could work the same
  - Thick configuration: 16 straw layers
    - 8 layers could work the same

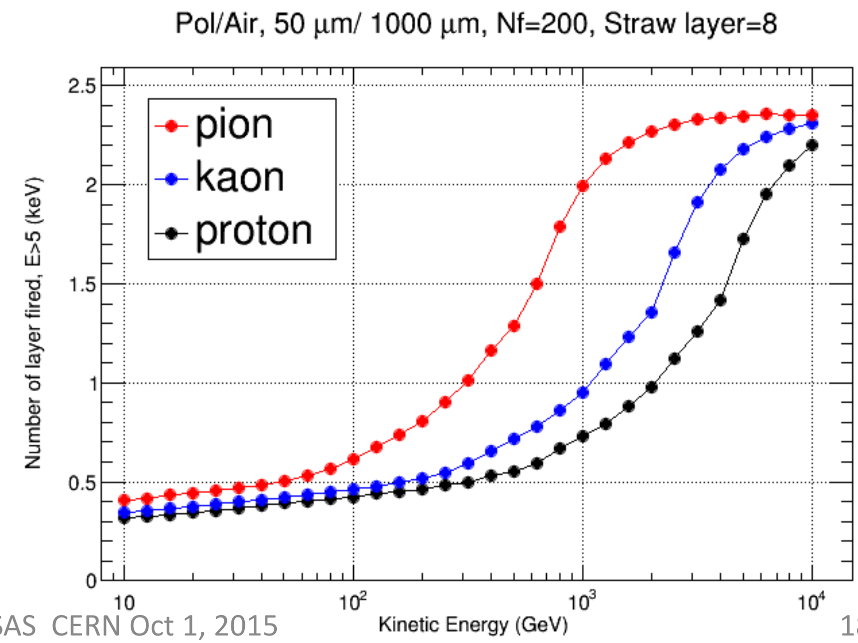
Thin configuration – Number of hit layers



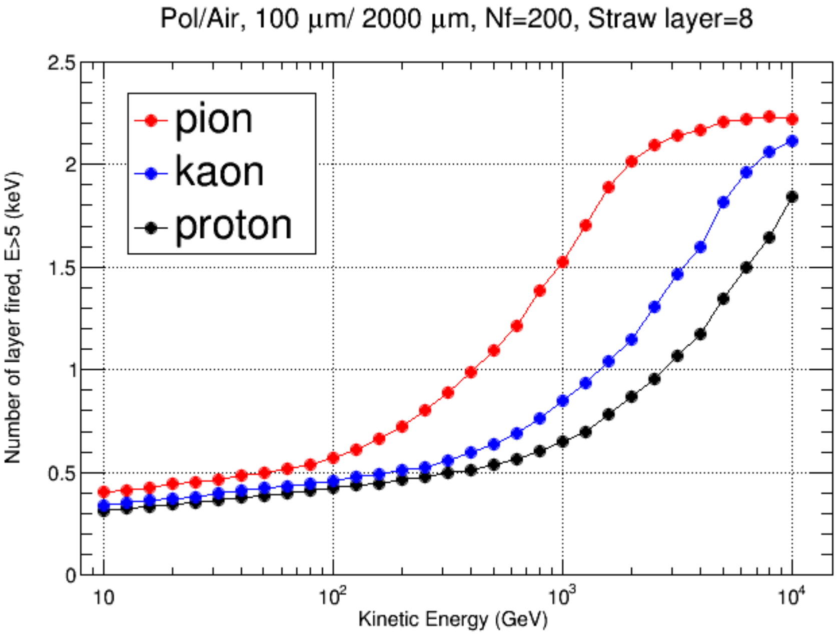


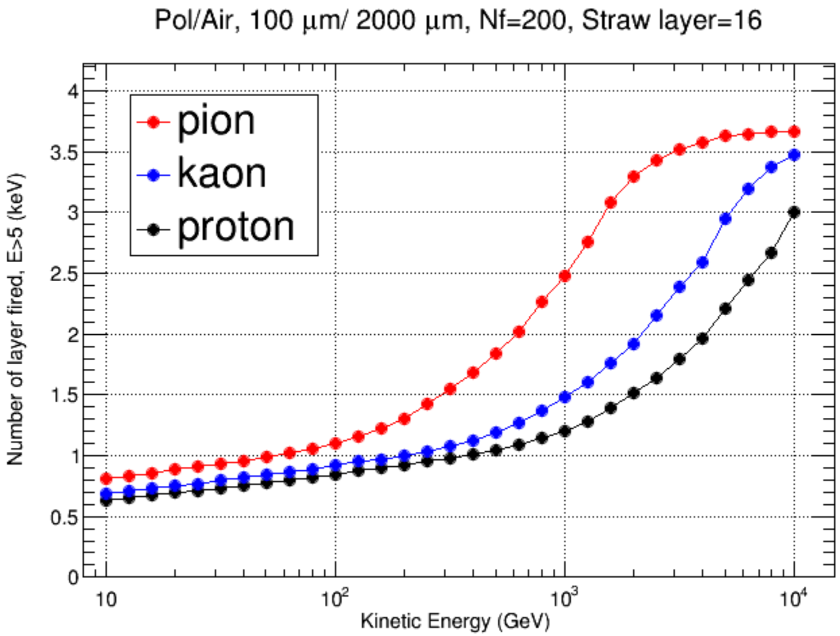
Middle configuration – Number of hit layers





Thick configuration – Number of hit layers





Likelihood analysis (for multiple modules)

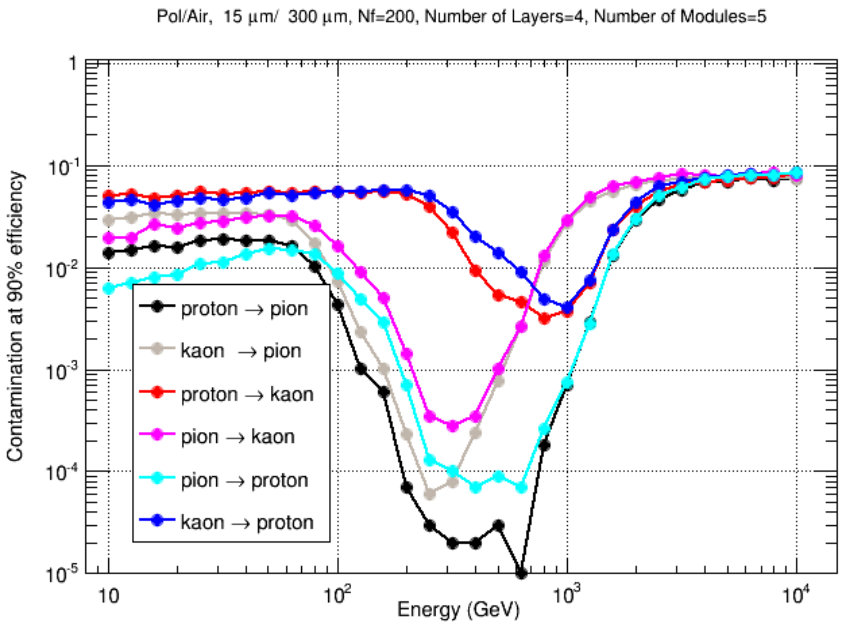
- For each configuration, the distributions of the average energy deposited in the layers composing a module has been evaluated
- A (pseudo) multi-module configuration has been simulated extracting sets of random energy values $\{E_i\}$ from the single module distribution
- The likelihood function for particles of the species A and B is defined as

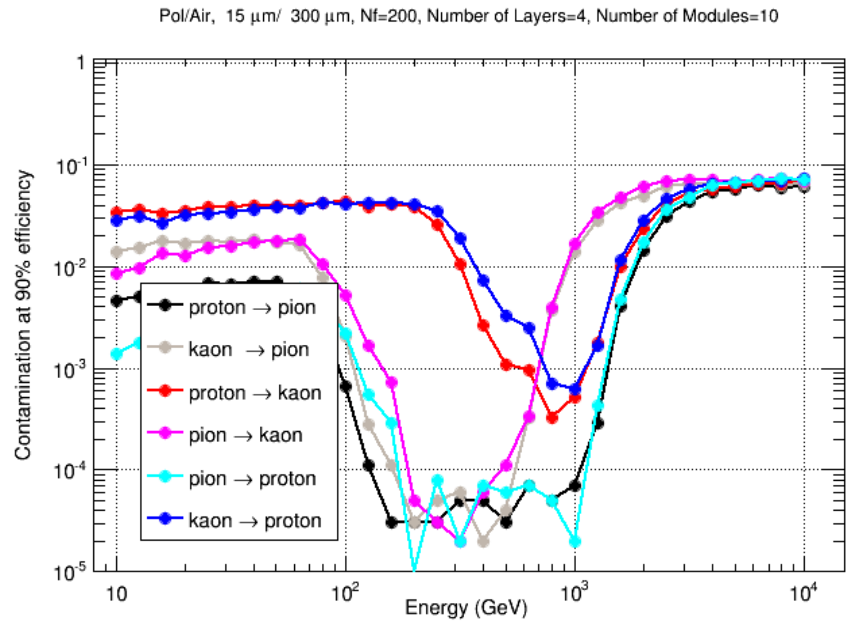
$$\mathcal{L}_A = \frac{P_A}{P_A + P_B}$$

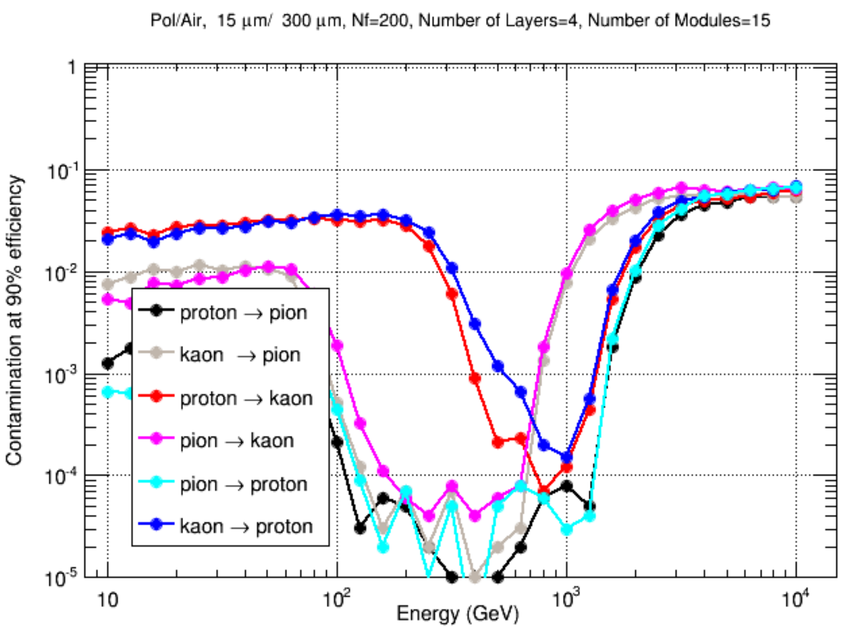
$$P_A = \prod_i^N P_A(E_i),\ P_B = \prod_i^N P_B(E_i)$$

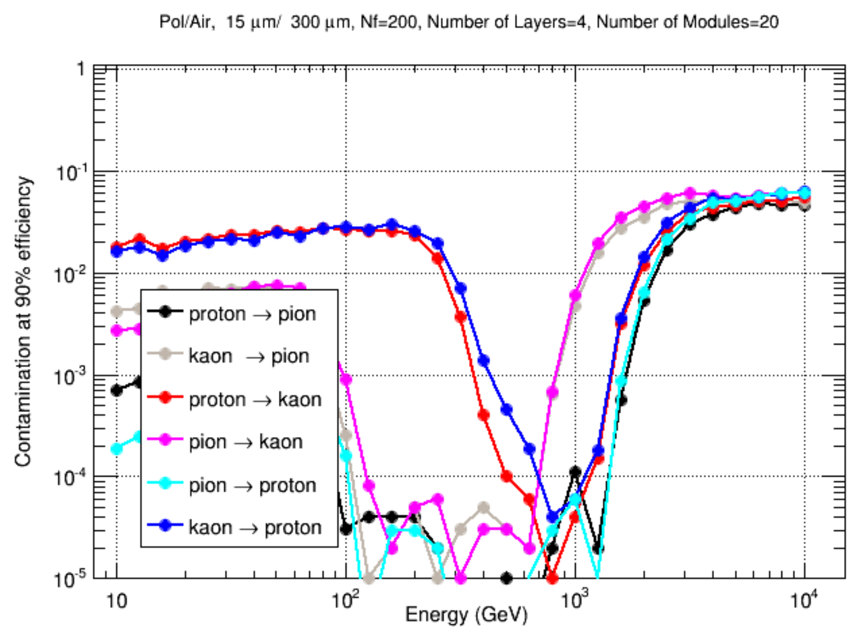
- The contamination of a particle B is then calculated at 90% efficiency of the particle A
- By definition:
  - if $A{\sim}B \Longrightarrow \mathcal{L}\_A \sim 0.5$
    - contamination $\Longrightarrow 0.1$
  - if $A{\neq}B$ the distribution of $\mathcal{L}_A$ ($\mathcal{L}_B$) peaks at 1 (0)

Thin configuration – multi-module

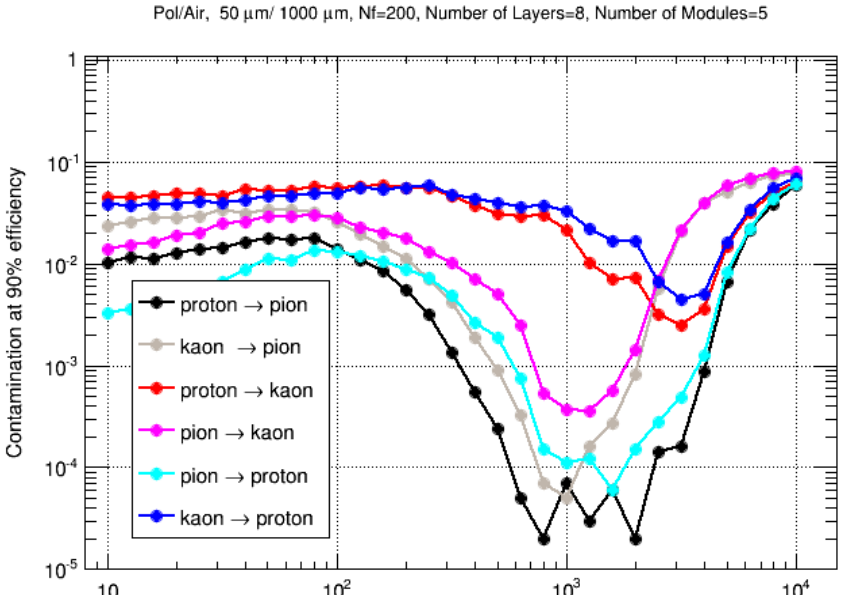


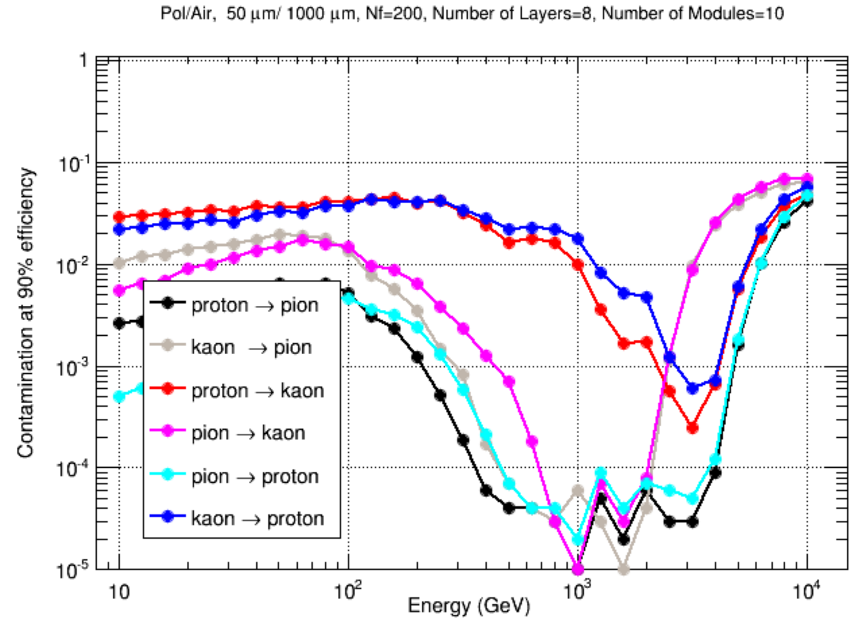


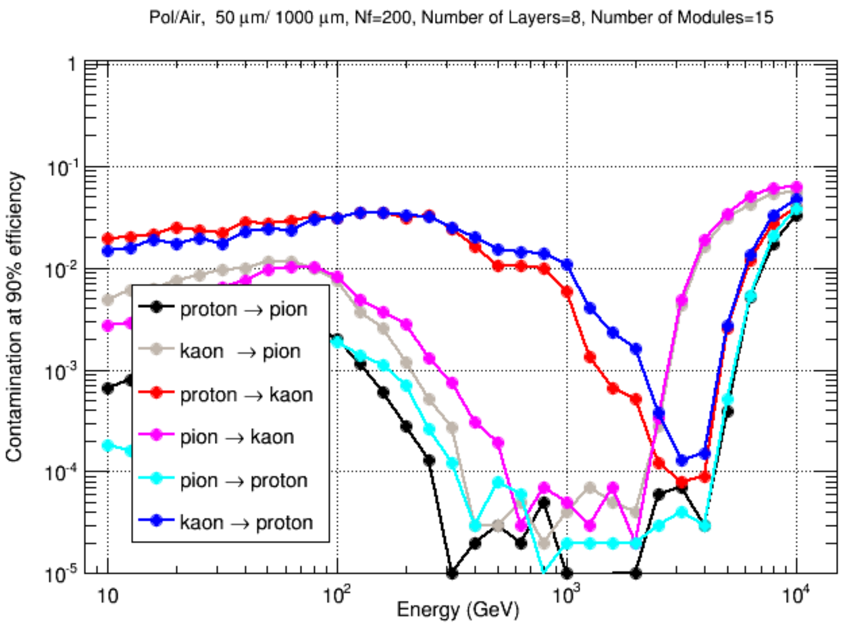


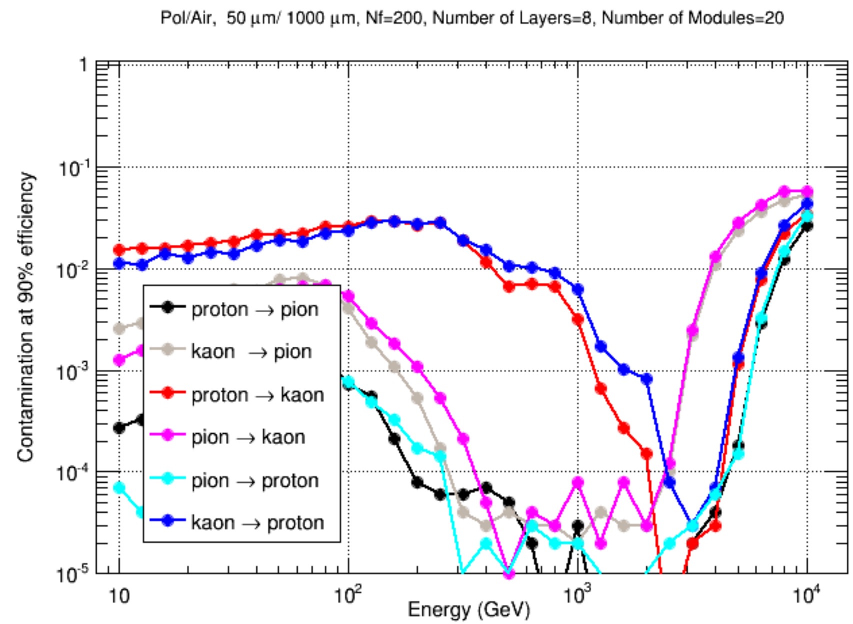


Middle configuration – multi-module

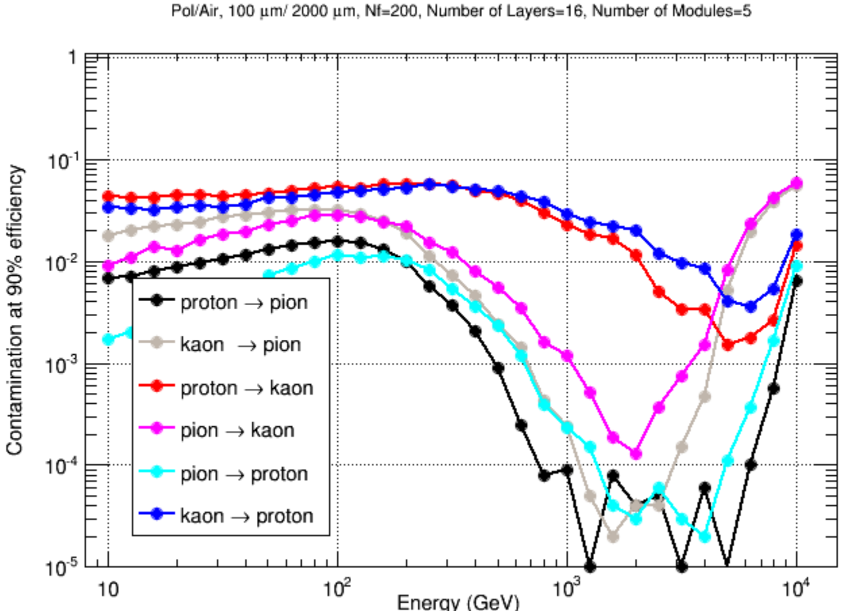


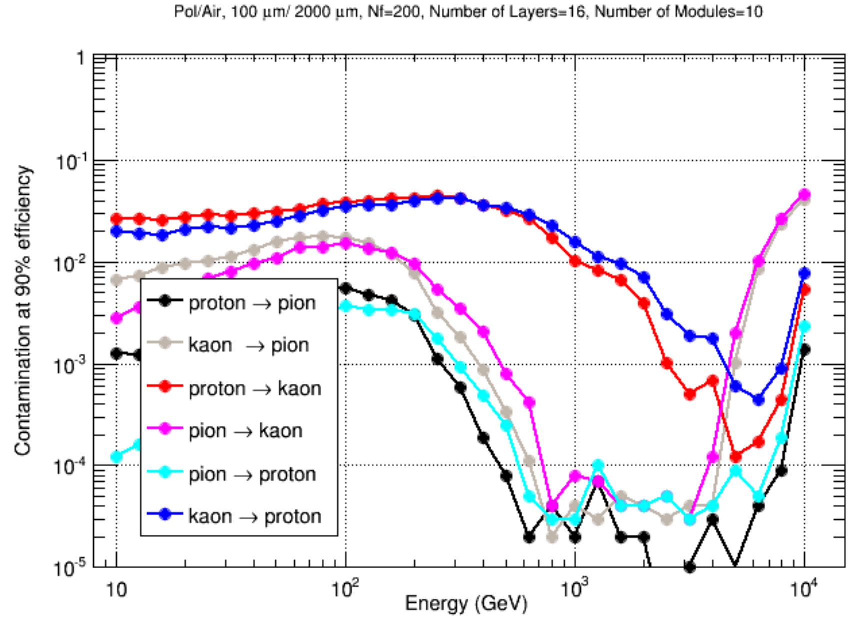


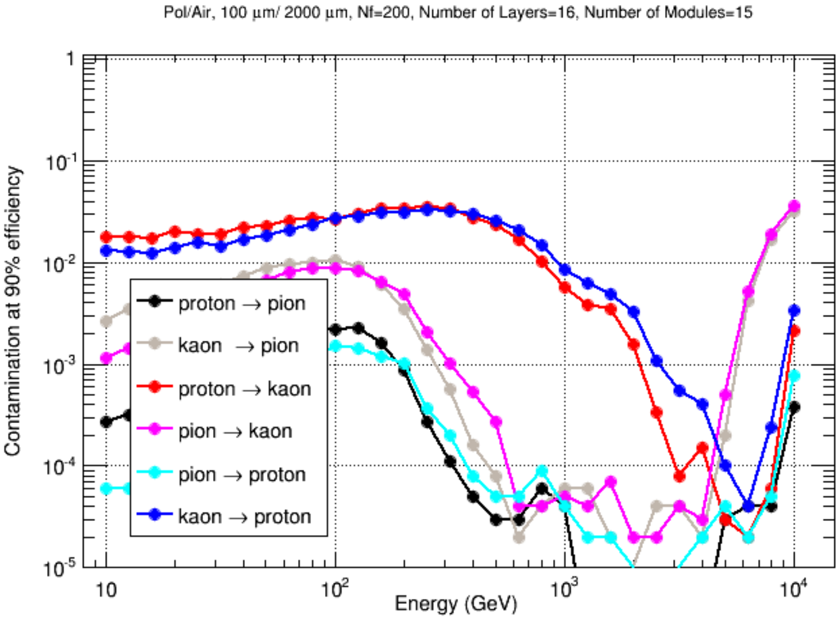


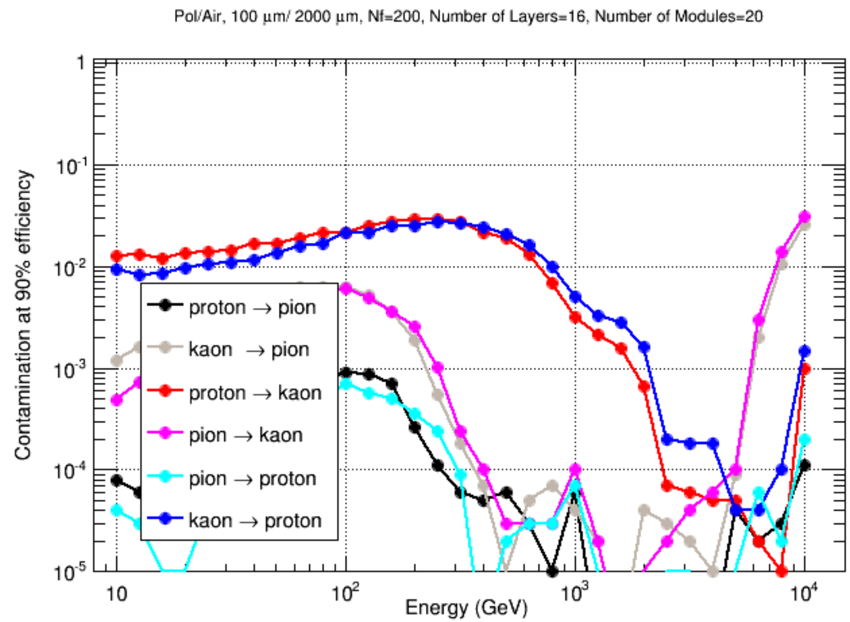


Thick configuration – multi-module







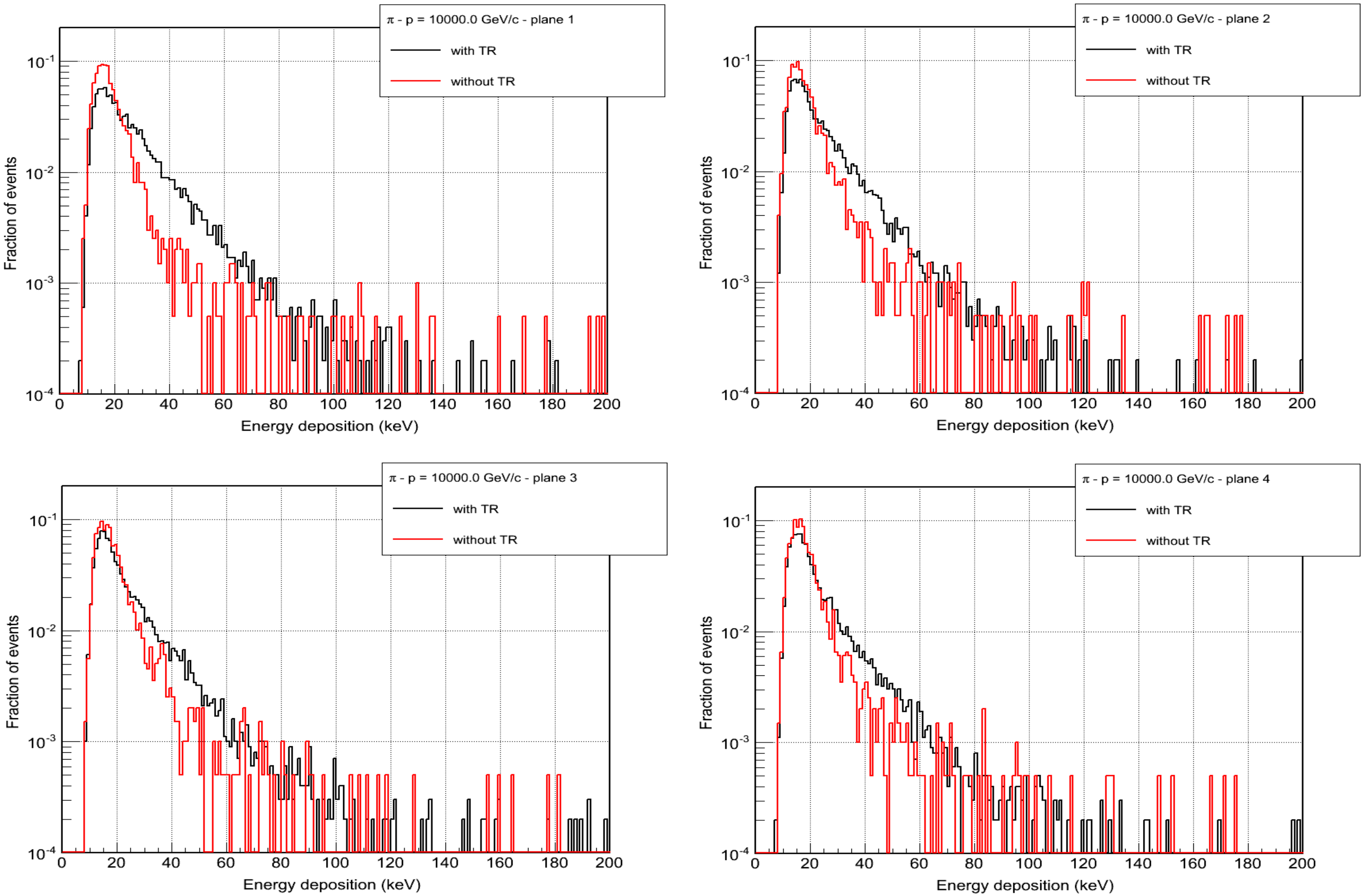


Solid state TRD

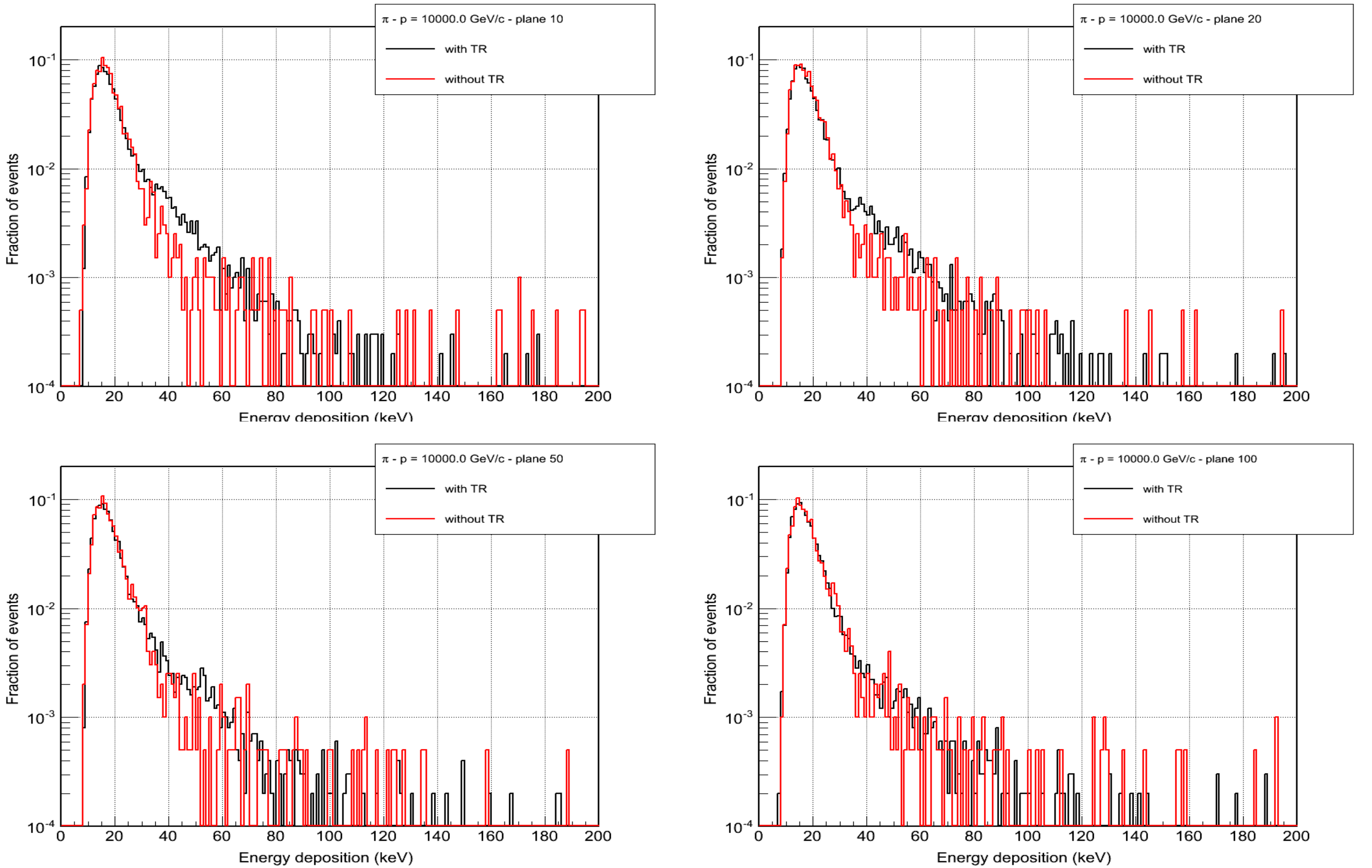
Analysis steps

- Study of the distributions of energy deposited in the individual silicon planes
- Number of fired layers as a function of the energy threshold (i.e. 20, 30, 40 and 50 keV)
- Efficiency as a function of the energy threshold (i.e. 20, 30, 40, 50 keV)
  - The efficiencies of individual layers have been evaluated
  - For each value of the threshold the overall efficiency has been evaluated as a function of the minimum number of fired layers
- These studies have been performed in the saturation regime, i.e. with 10 TeV pions

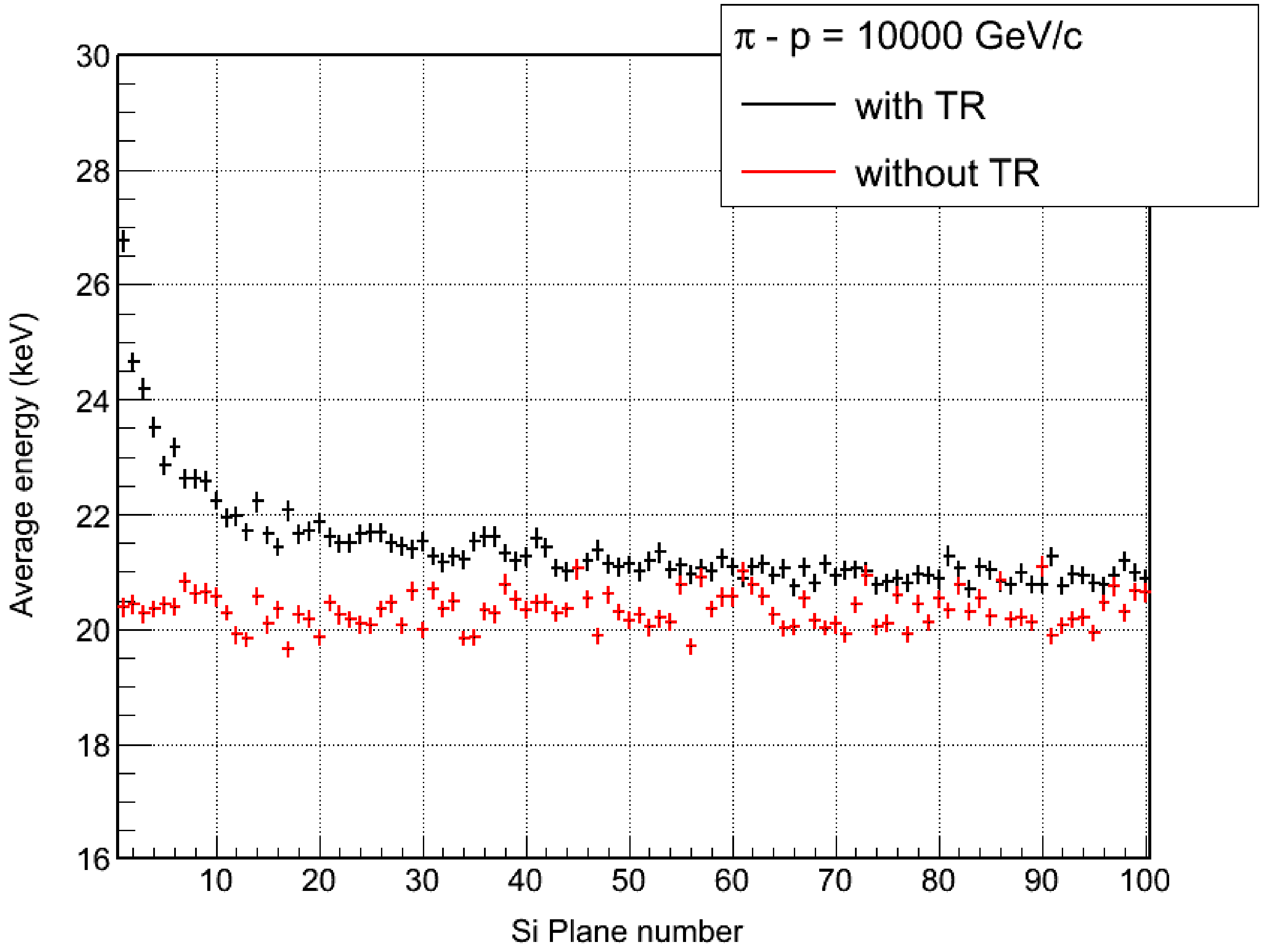
Energy depositions in the silicon planes (1)



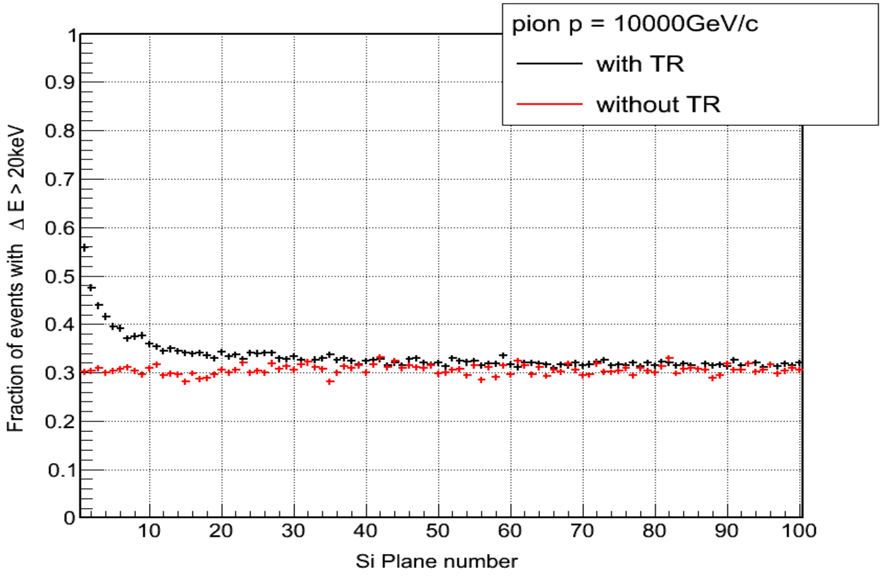
Energy depositions in the silicon planes (2)

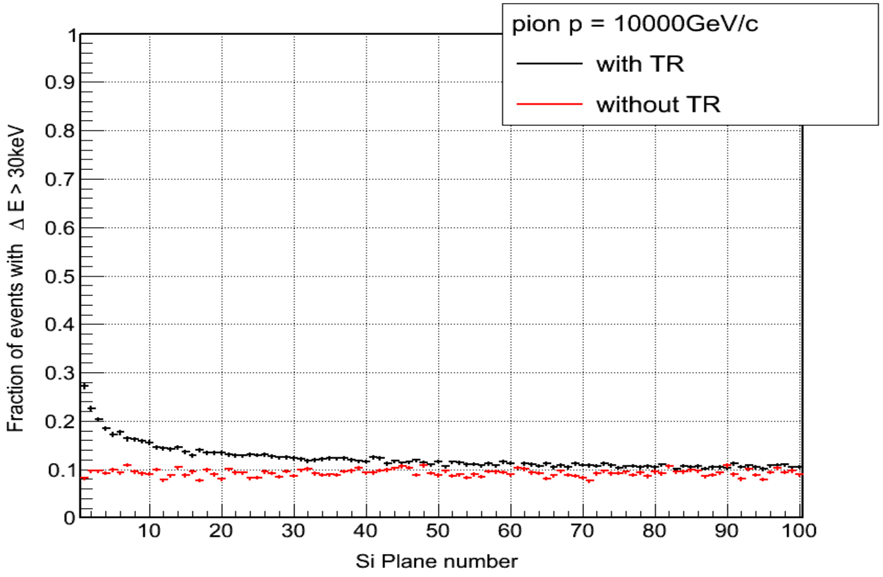


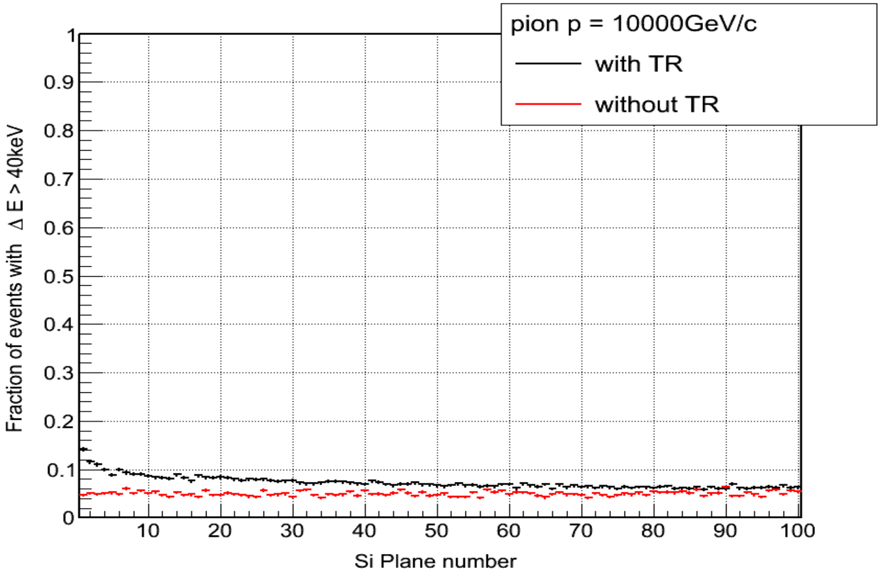
Average energy depositions in Si planes

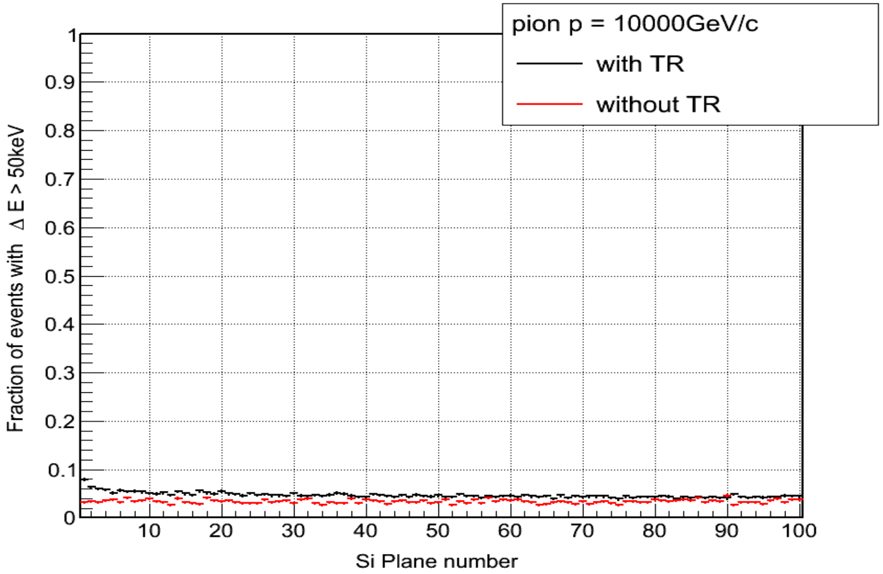


Efficiency of individual Si planes

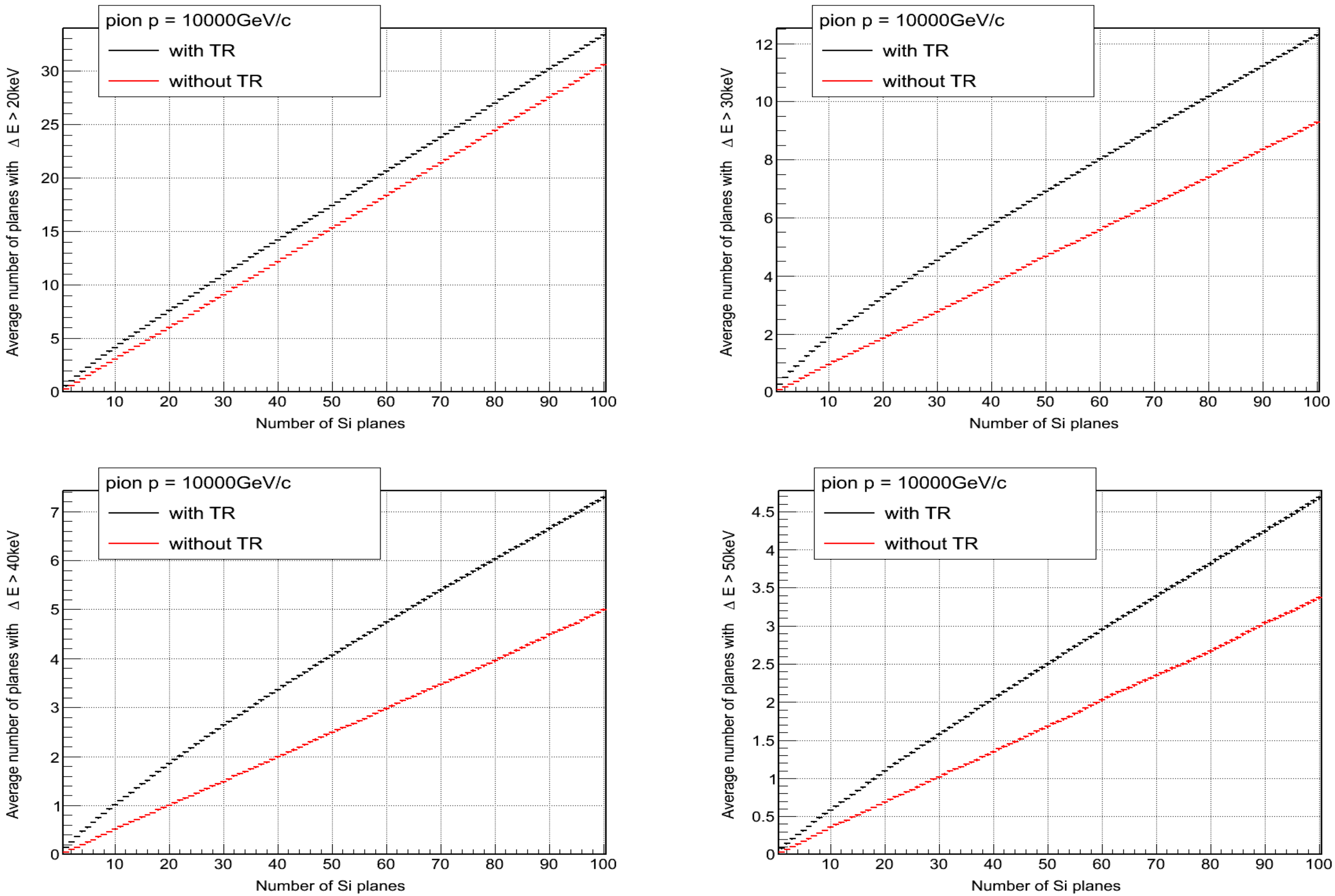




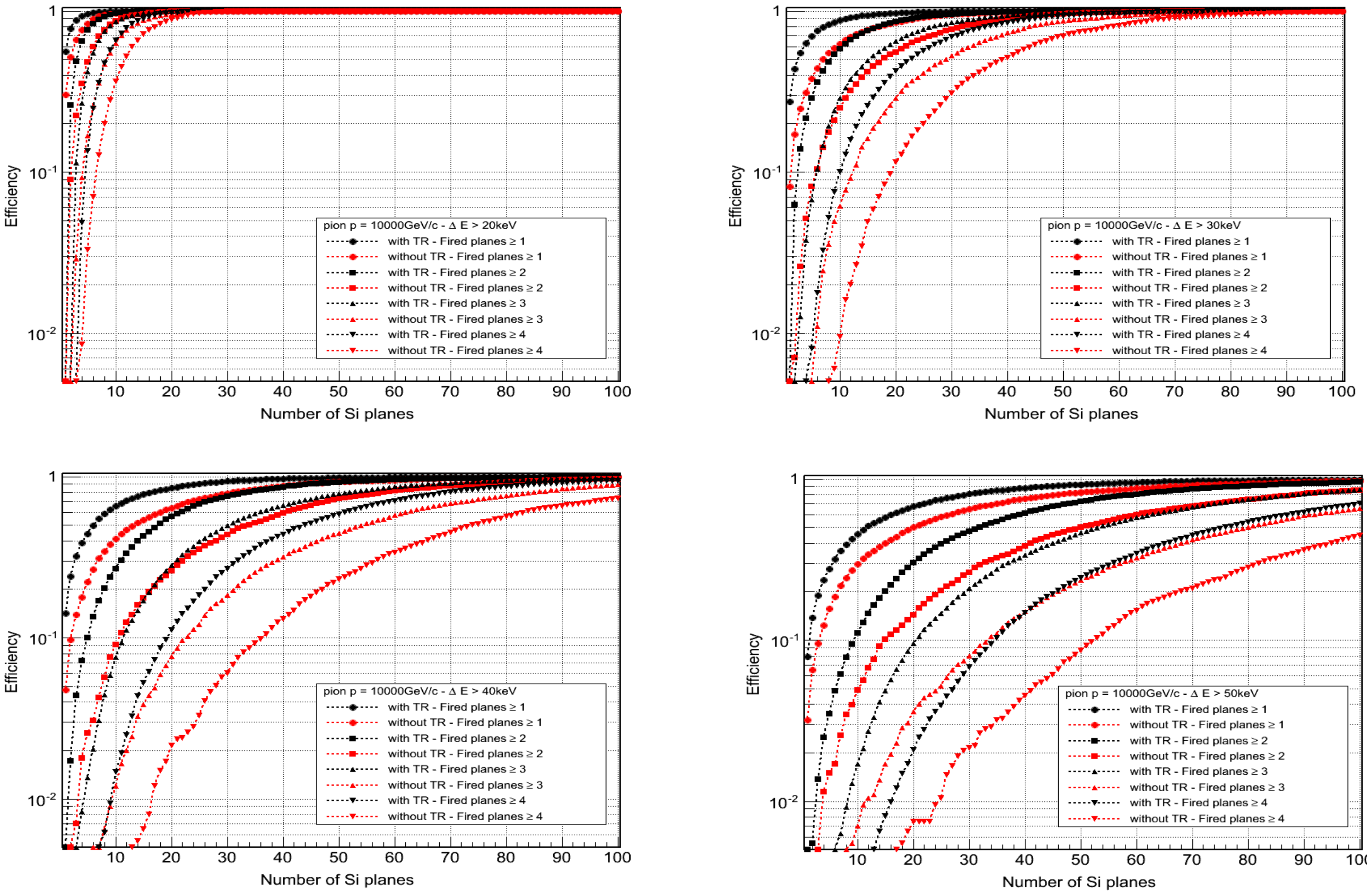




Number of fired planes



Efficiency vs number of planes

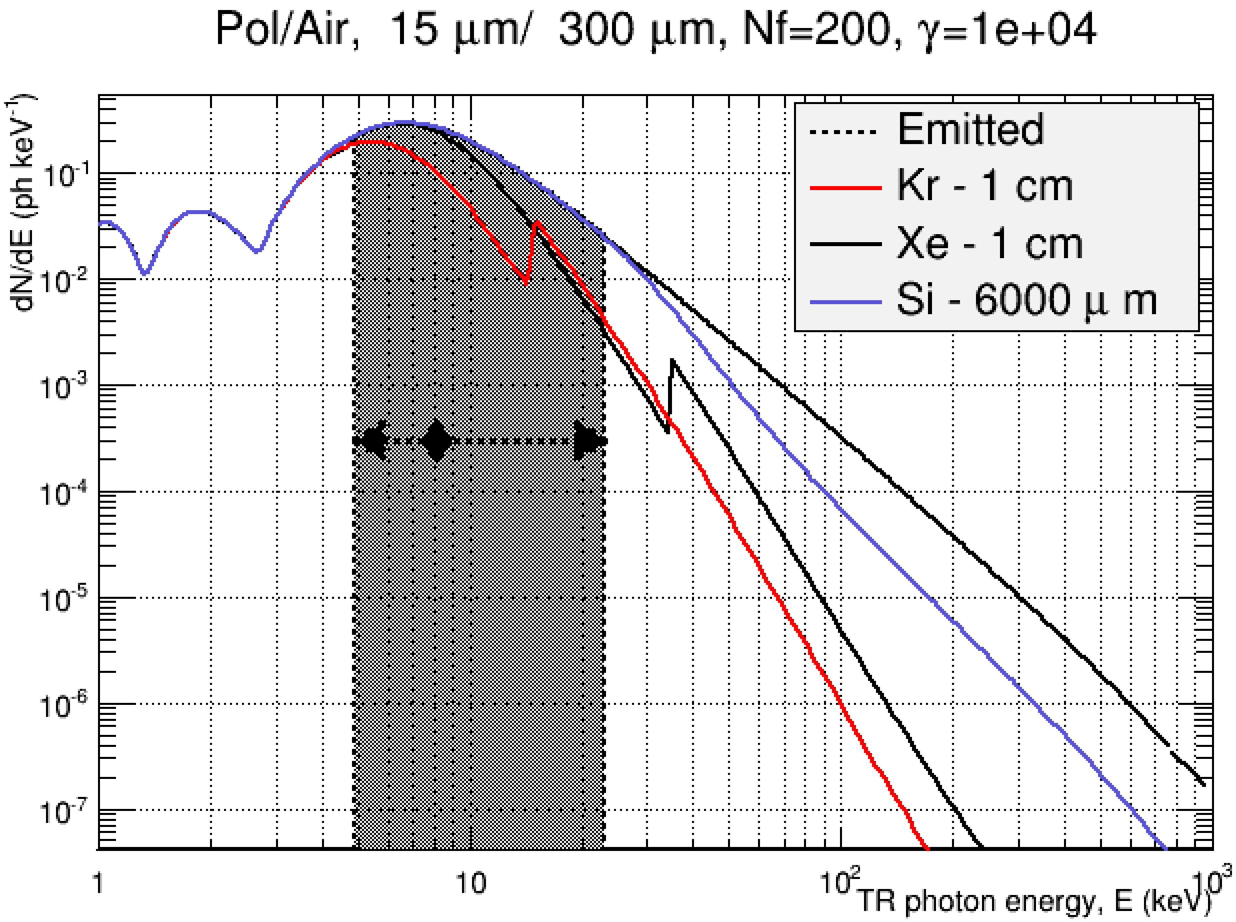


Conclusions

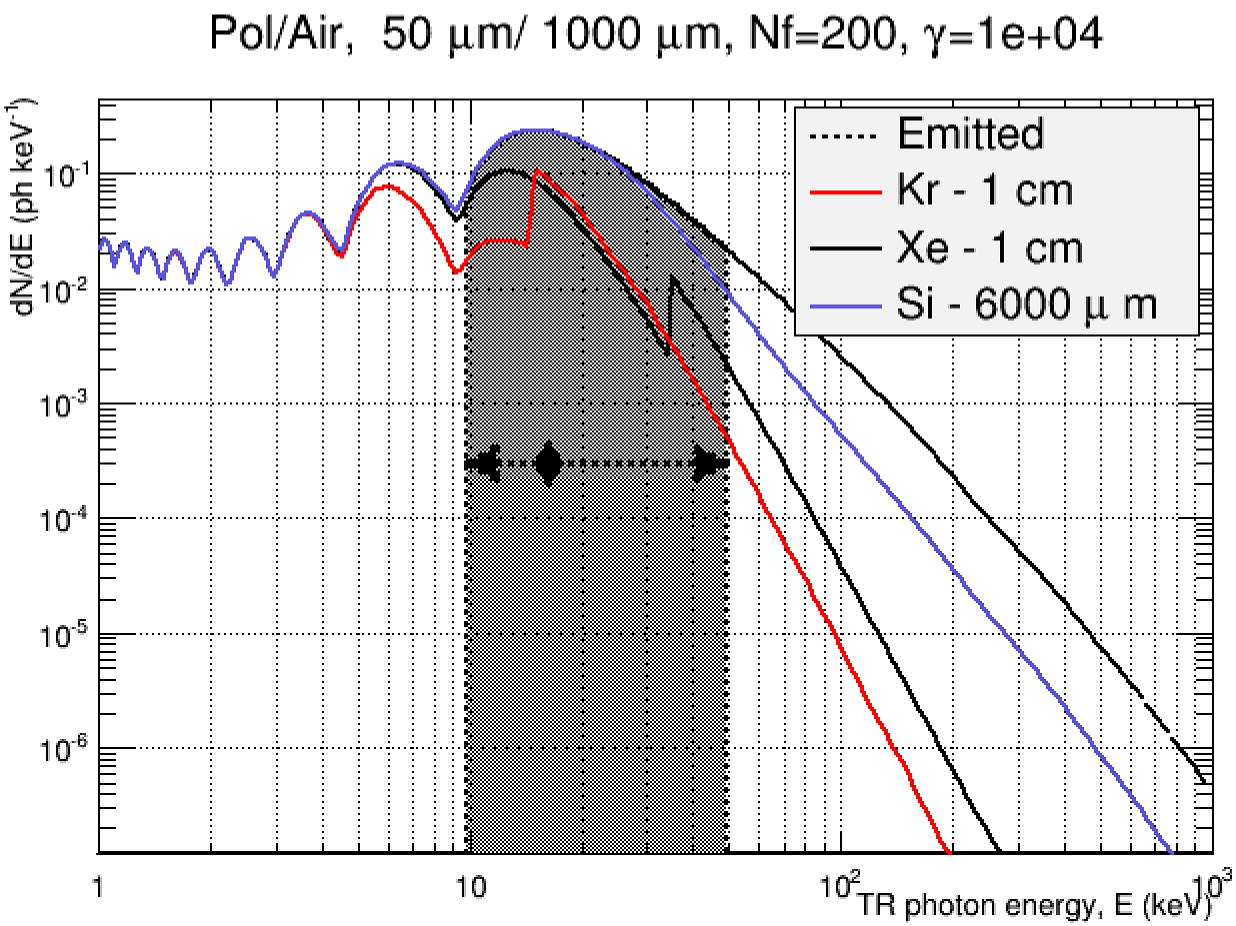
- The work is still in progress!!!
- The straw based TRD could work even with radiators made with thick foils
- The solid state based TRD with thin silicon detectors needs to be further investigated, but…
  - It does not provide a clean identification of radiating/non-radiating particles, even with a high number of silicon planes
  - Although we chose a configuration with very thin silicon detectors, the MIP energy loss in each plane is close to the TR X-ray energies
  - Better result could be obtained applying a maximum likelihood analysis to the energy depositions in each silicon plane (to be investigated)
  - It could work with thicker radiator foils (harder X-rays) or thinner Si detectors (lower ionization losses)
  - However a silicon pixel detector could be used in case of a RingTRD, since in this case the TR X-rays will be separated from the ionizing particle
- Bonus: good tracking devices even at high rates!

Extra slides

Thin RAD - spectrum



Middle RAD - spectrum



Thick RAD - spectrum