Simulations on the CBM RPC layout

(and general status)

D. Gonzalez-Diaz, GSI
27-09-2007

1. Simulation studies (hit creation algorithm).
2. Mechanical integration.
3. R&D in high rate capability tRPCs.
4. On-going efforts on large systems.
5. Outlook.

1. Simulation studies
(hit creation algorithm).

Hit creation algorithm. Motivation.

The description of the response of multi-gap RPCs has some subtleties different from most gaseous detectors, since along the active gas volume several electrode planes are interlaid and the probability of secondary production in those is not negligible. In particular, we aim at:

- Evaluating the influence of the material budget of the detector on its response.

- Evaluating the influence of backscattered secondaries from neighbouring massive detectors (ECAL).

- Providing a general detector response with ability to provide energy, momentum and angle dependence, secondary production and a description of coincident tracks in the same cell.

- Do all this with a simplified algorithm that still contains the main features of the detector response.

Important effects like charge sharing and cross-talk may be introduced in the next version of the algorithm for 'hit creation'; this will depend on the final read-out scheme (to be decided).

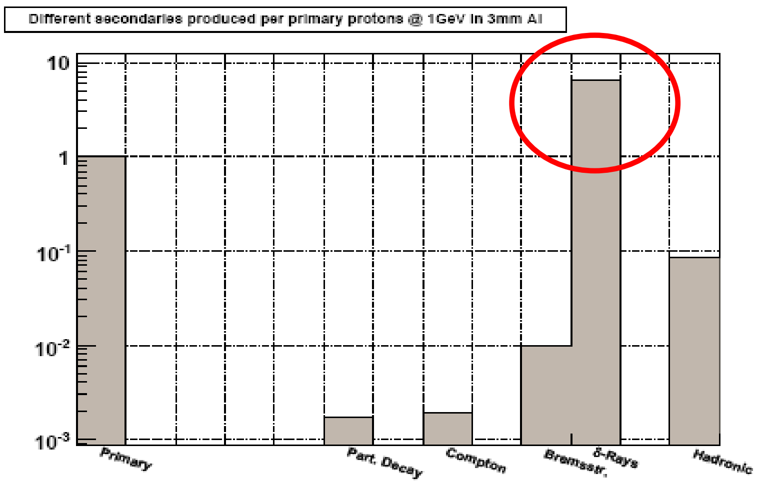
1.1. Secondary production.

P. Cabanelas

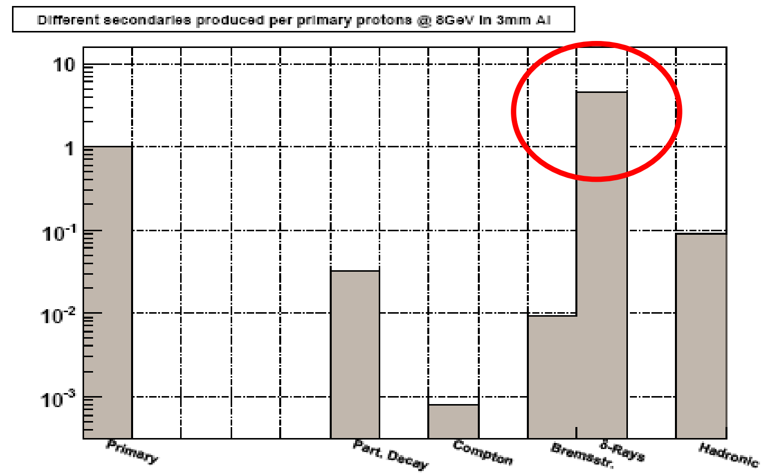
Secondary production (I).

3 mm Al

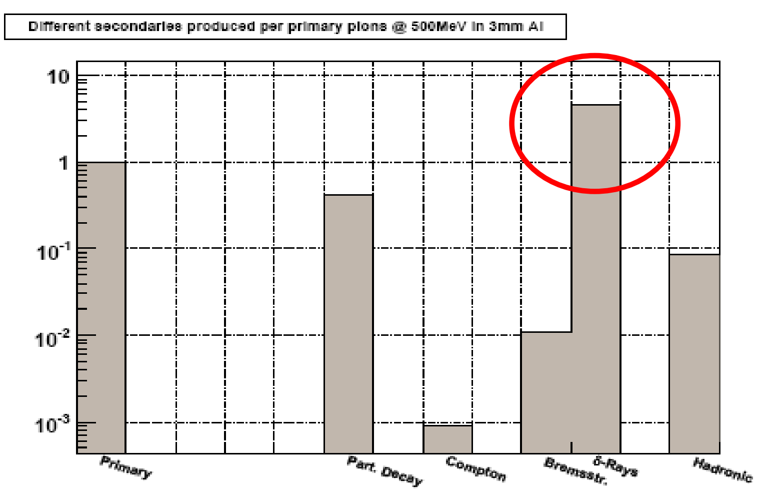
Protons, 1 GeV



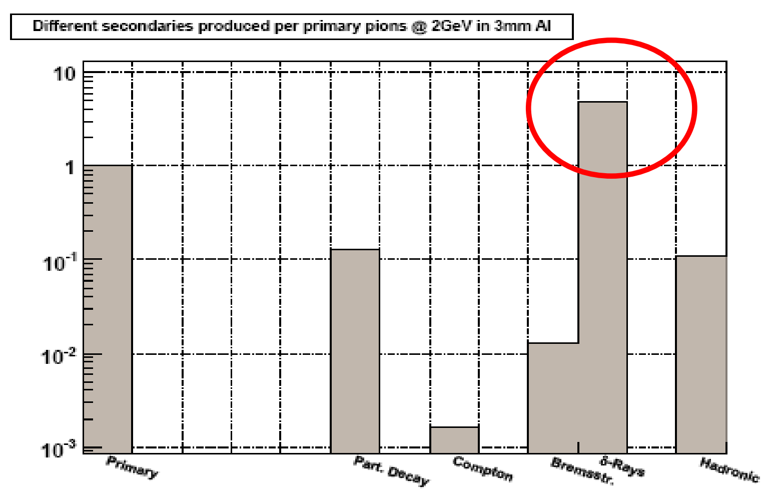
Protons, 8 GeV



Pions, 0.5 GeV



Pions, 2 GeV

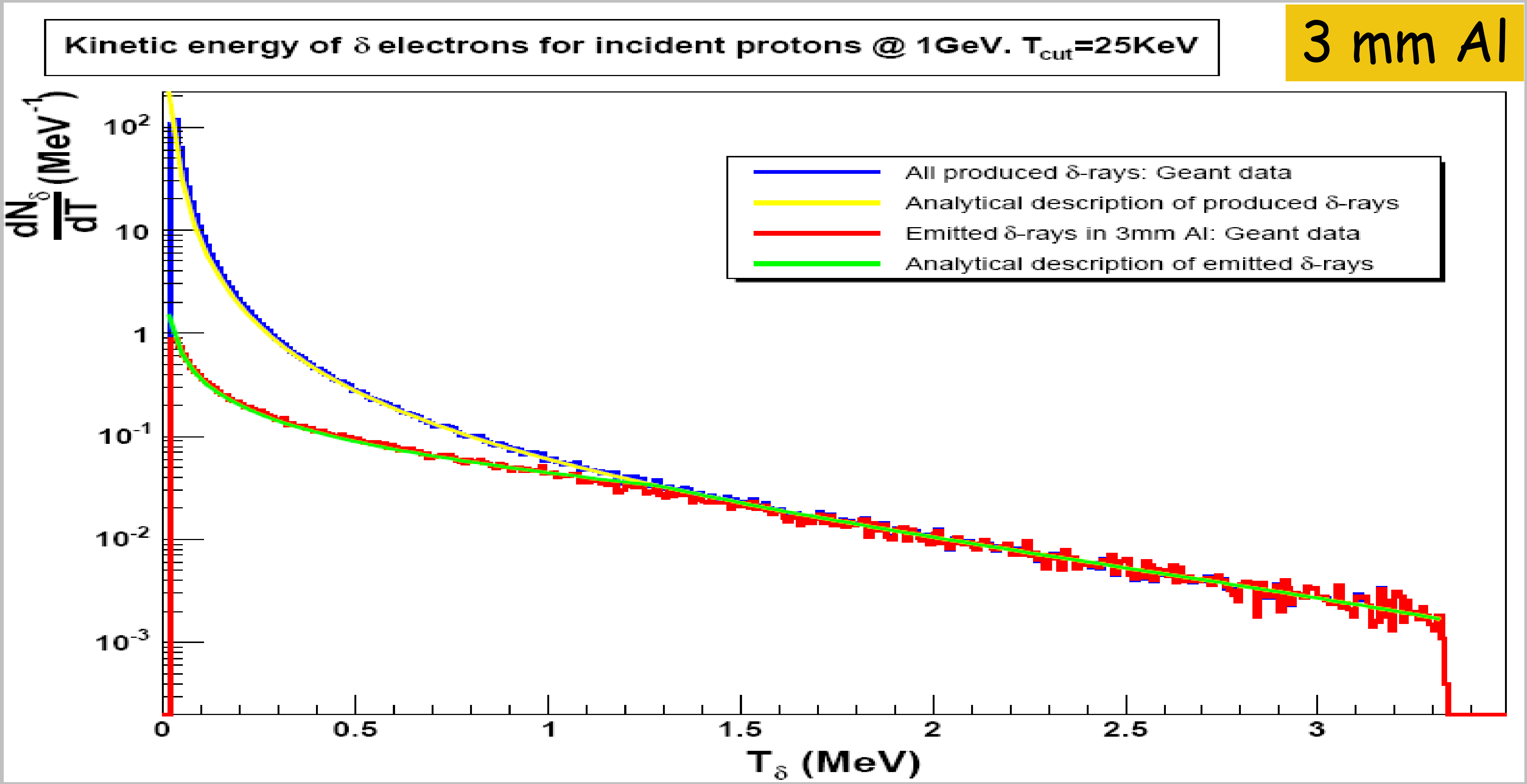


geant 3, standard energy cuts

P. Cabanelas

Secondary production (II). δ-ray production.

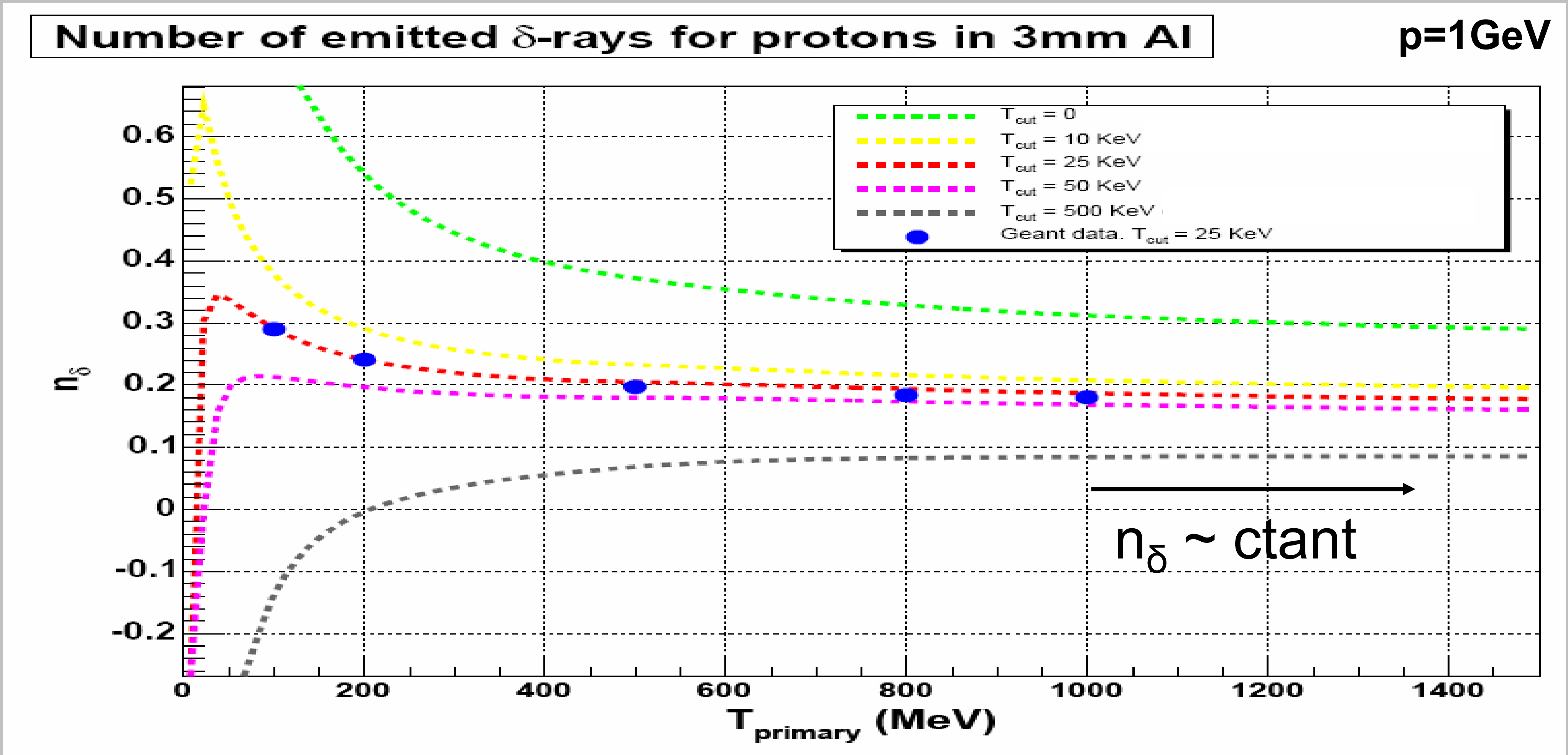
3 mm Al



The distributions of produced (in the aluminium) and emitted (from the aluminium) δ-electrons can be obtained analytically and reproduce the MC results.

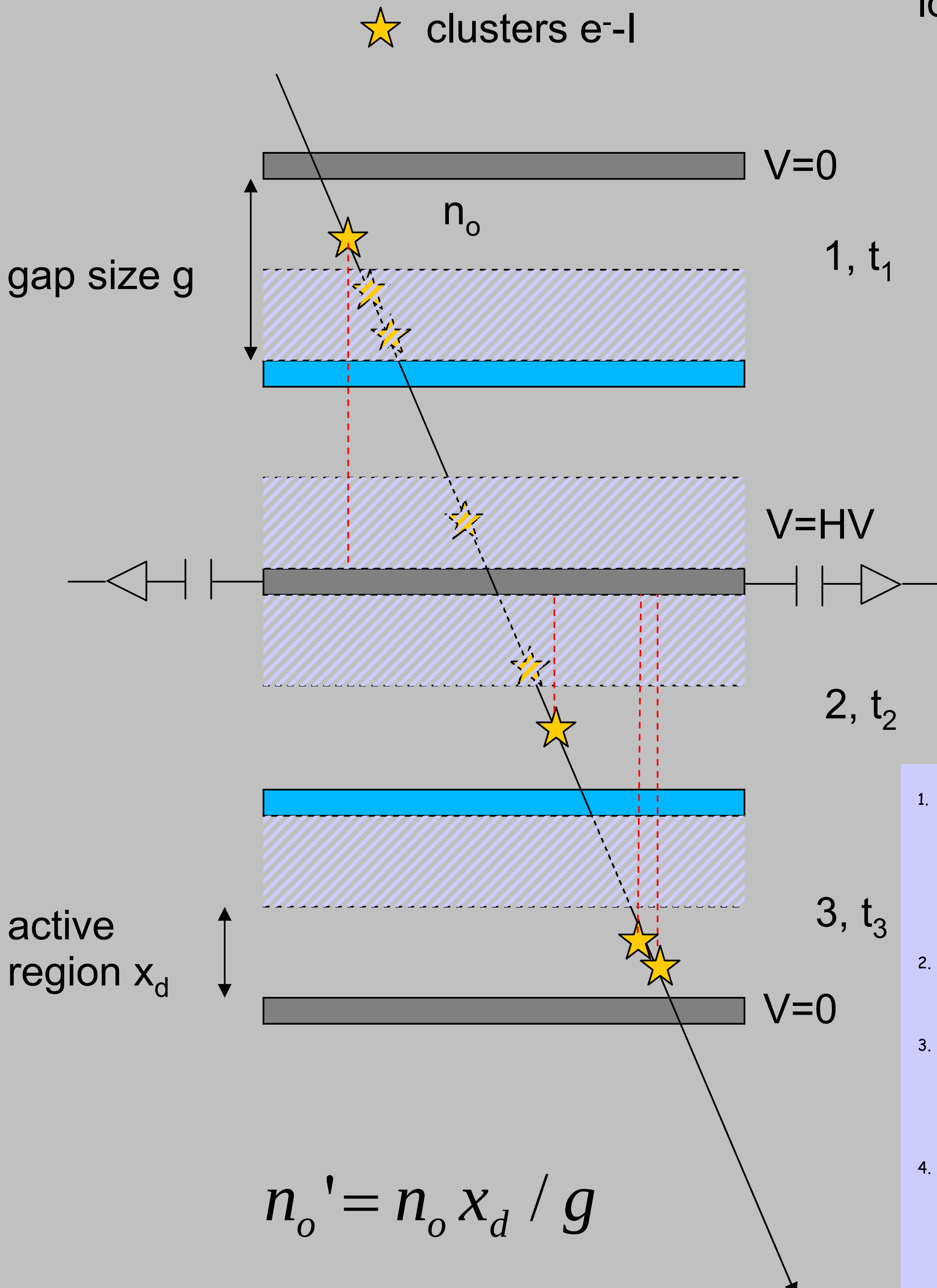
P. Cabanelas

Secondary production (III). δ-ray production.



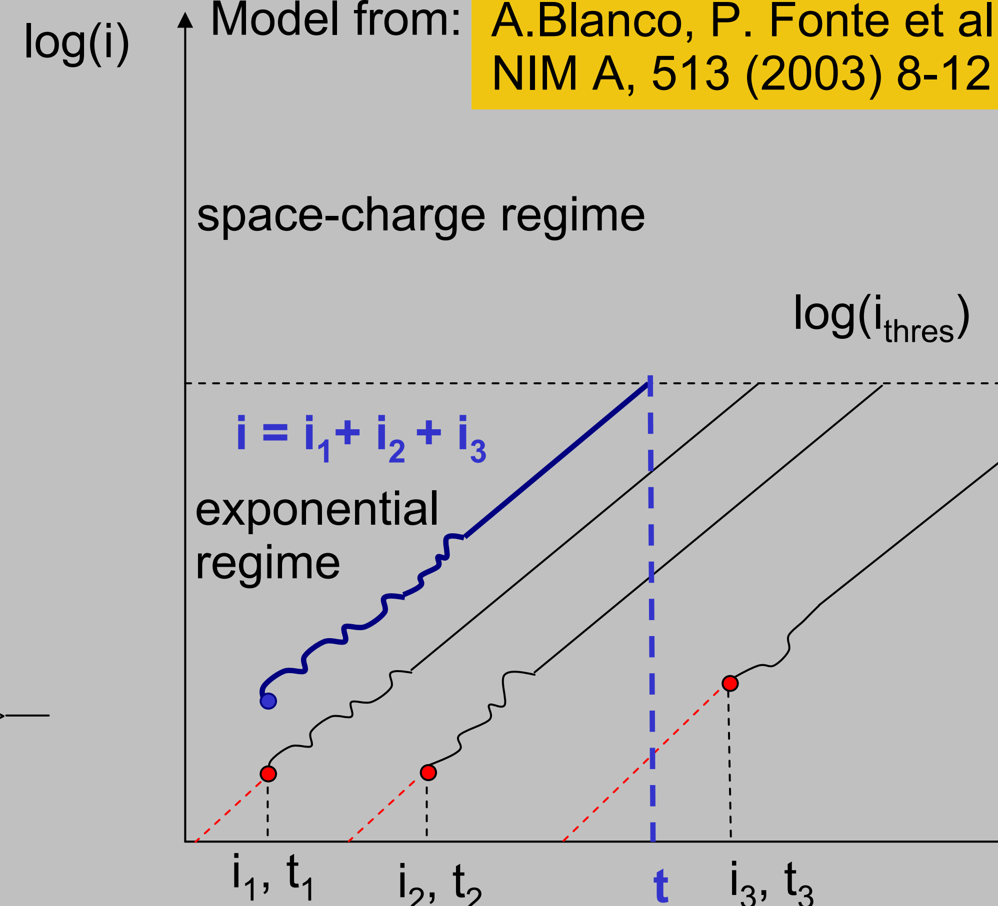
Analytical distributions of emitted δ-electrons agree well with MC. The number of those that are emitted ranges from **20-30%** (the last, extrapolating to zero kinetic energy)

1.2. Very short introduction to **signal formation** in multi-gap RPCs.



$$n_o' = n_o x_d / g$$

Model from: A.Blanco, P. Fonte et al. NIM A, 513 (2003) 8-12

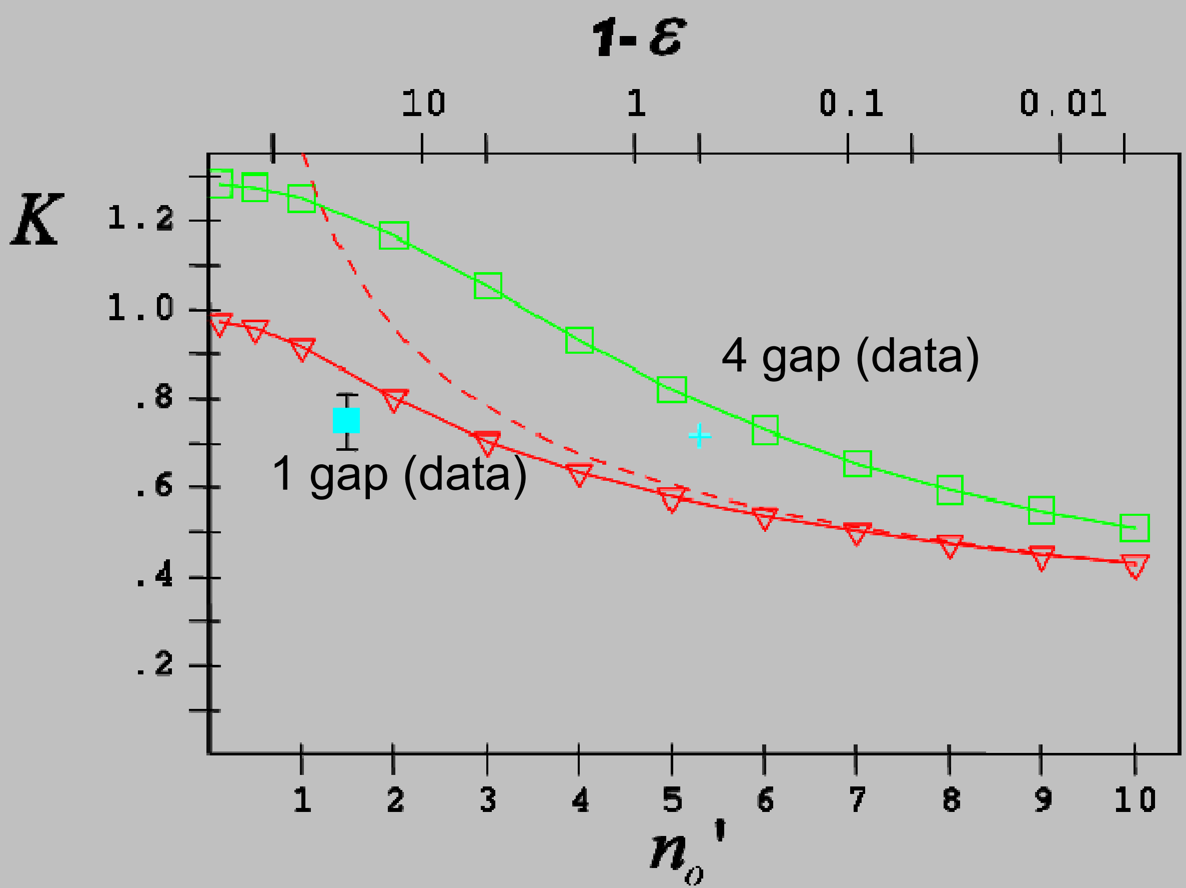


1. Separate fluctuations in avalanche multiplication and primary ionization, from deterministic multiplication in exponential regime.
2. Assume that only multiplication inside the active region is relevant.
3. Back-extrapolate the corresponding probability distributions for avalanche multiplication and primary ionization to t=0.
4. Obtain from the back-extrapolated distribution of the current i_o, the distribution of times at threshold (time response) assuming operation in exponential regime.

Signal formation and its analytic solution.

For the case where the avalanche multiplication follows the **Furry law**, the model is analytically solvable. The time response function is then:

$$P(t) = e^{(\tau' - (\alpha-\eta) v_d t) - \exp(\tau' - (\alpha-\eta) v_d t)} \frac{n_o' I_1\left(2\sqrt{n_o' e^{(\tau' - (\alpha-\eta) v_d t)}}\right)}{(e^{n_o'} - 1)\sqrt{n_o' e^{(\tau' - (\alpha-\eta) v_d t)}}}$$



$$\sigma_T = \frac{K(n_o')}{(\alpha-\eta) v_d}$$

$$t_o = \frac{\ln(\tau'/n_o')}{(\alpha-\eta) v_d}$$

$$\varepsilon = 1 - e^{-n_o'}$$

A. Mangiarotti et al., NIM A, 533 (2004) 16-21

How to compute the detector response in a fast way that can be used for realistic physics simulations?

- The contribution (for timing) of all the avalanches at the level of the comparator was calculated assuming a model for the avalanche fluctuations (A.Blanco, P. Fonte et al. NIM A, 513 (2003) 8-12).

- The detector growth coefficient was taken from P. Fonte. CBM (2002).

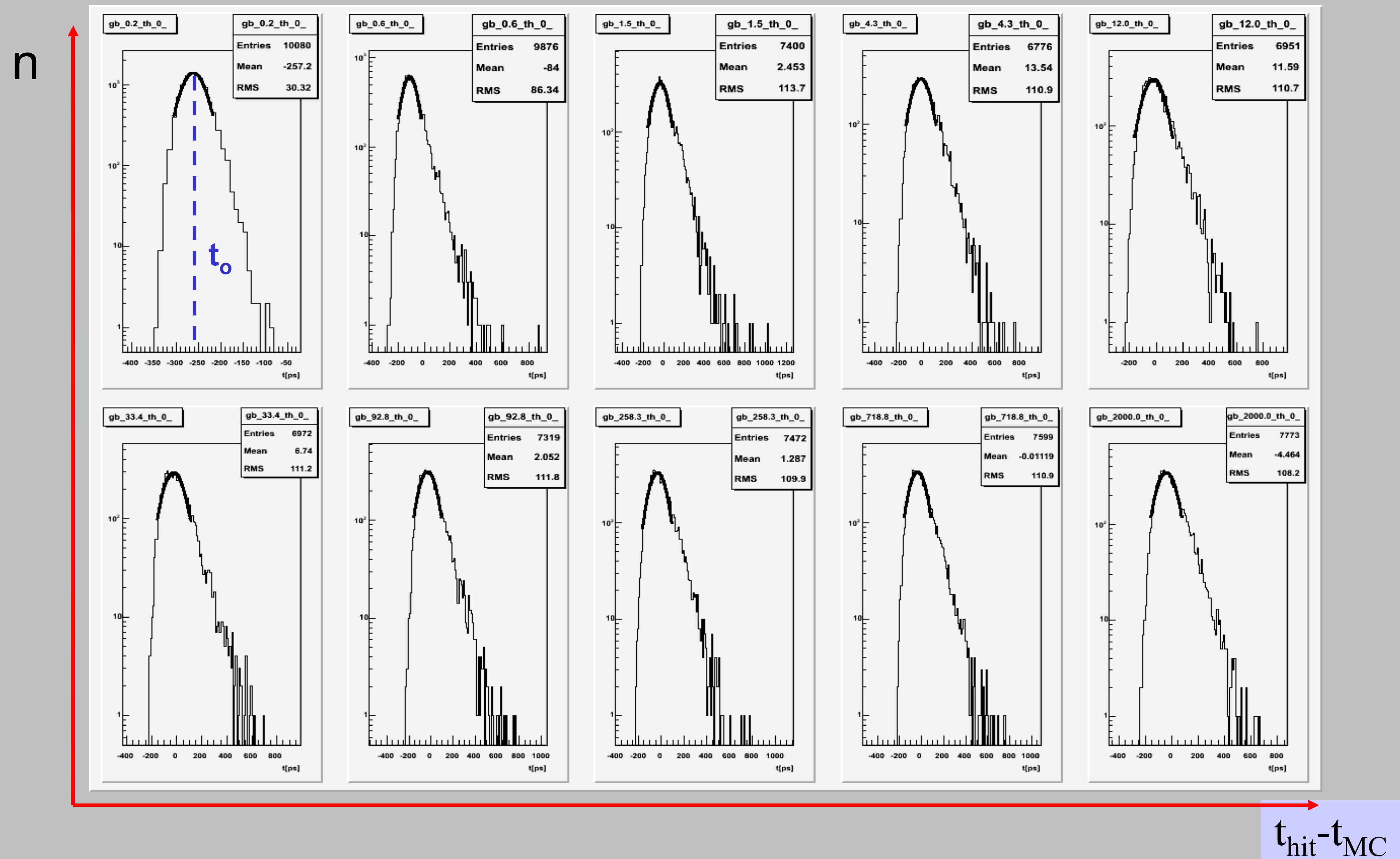
- The average density of ionization was parameterized following previous works (W. Riegler, C. Lippmann, NIM A 518(2004)86) using HEED (that reproduces measured RPC performances). For each value of $\gamma\beta$ the ionization density is obtained and re-scaled by the local track length in the gap to obtain the average ionization. Fluctuations in this value are obtained by assuming a Poisson distribution in the number of ionizing clusters.

- The efficiency is obtained from the initial number of clusters and the comparator threshold.

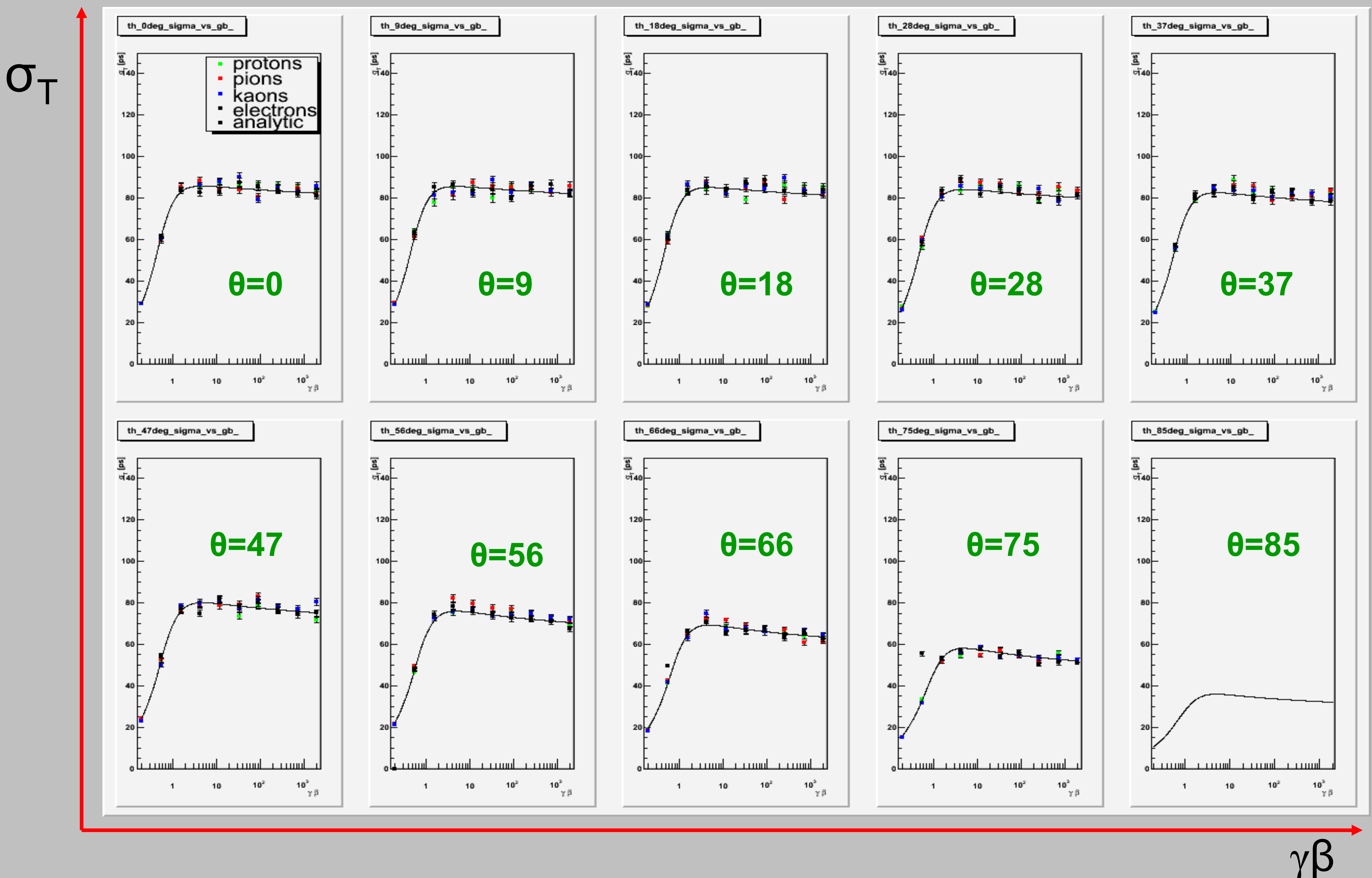
- The algorithm provides a general description for all the physical cases (different angles of incidence, different number of gaps crossed, different energy loss, secondary production and in particular response to multiple tracks in the same cell)

1.3. Results.

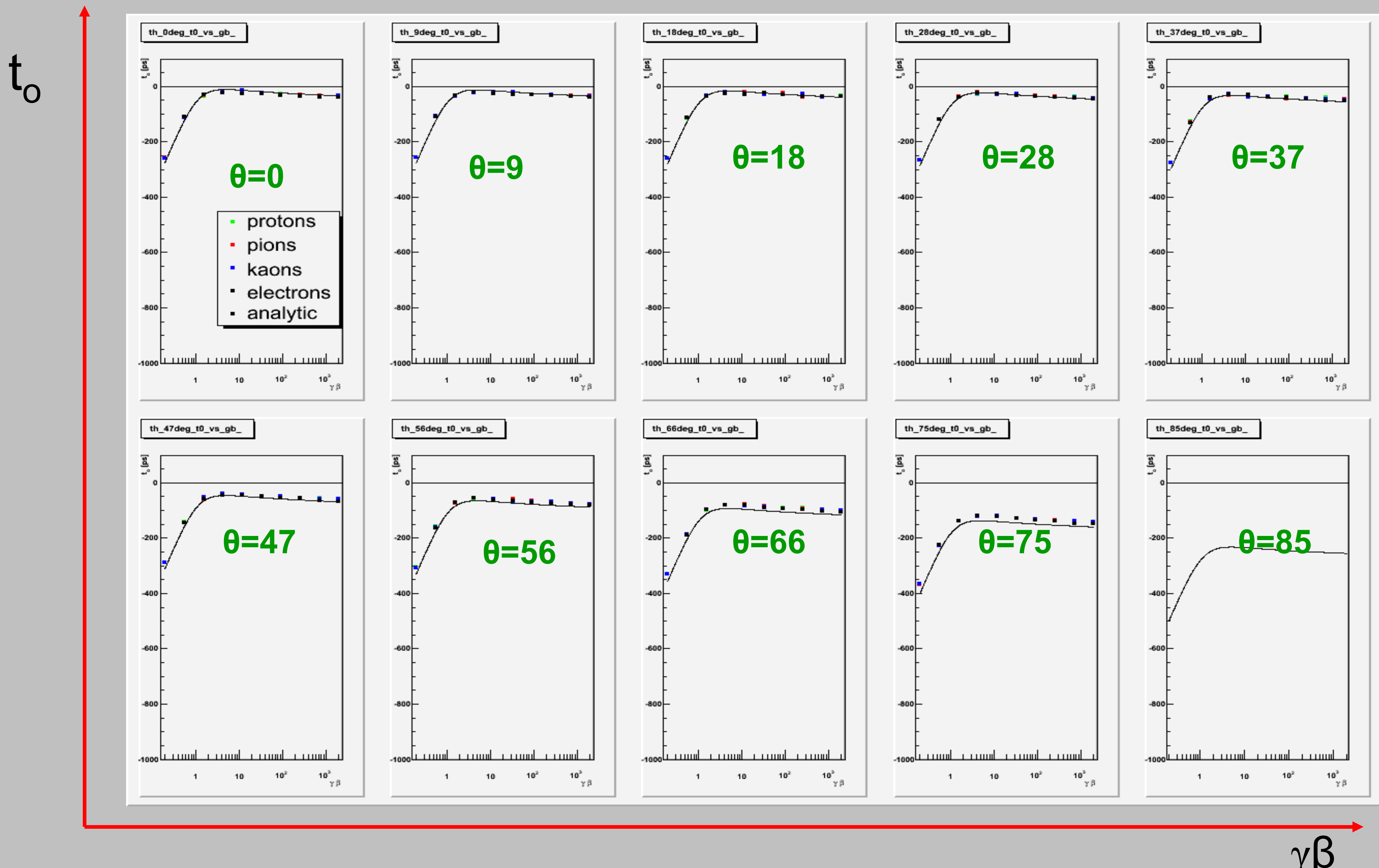
Typical time residuals after hit creation.



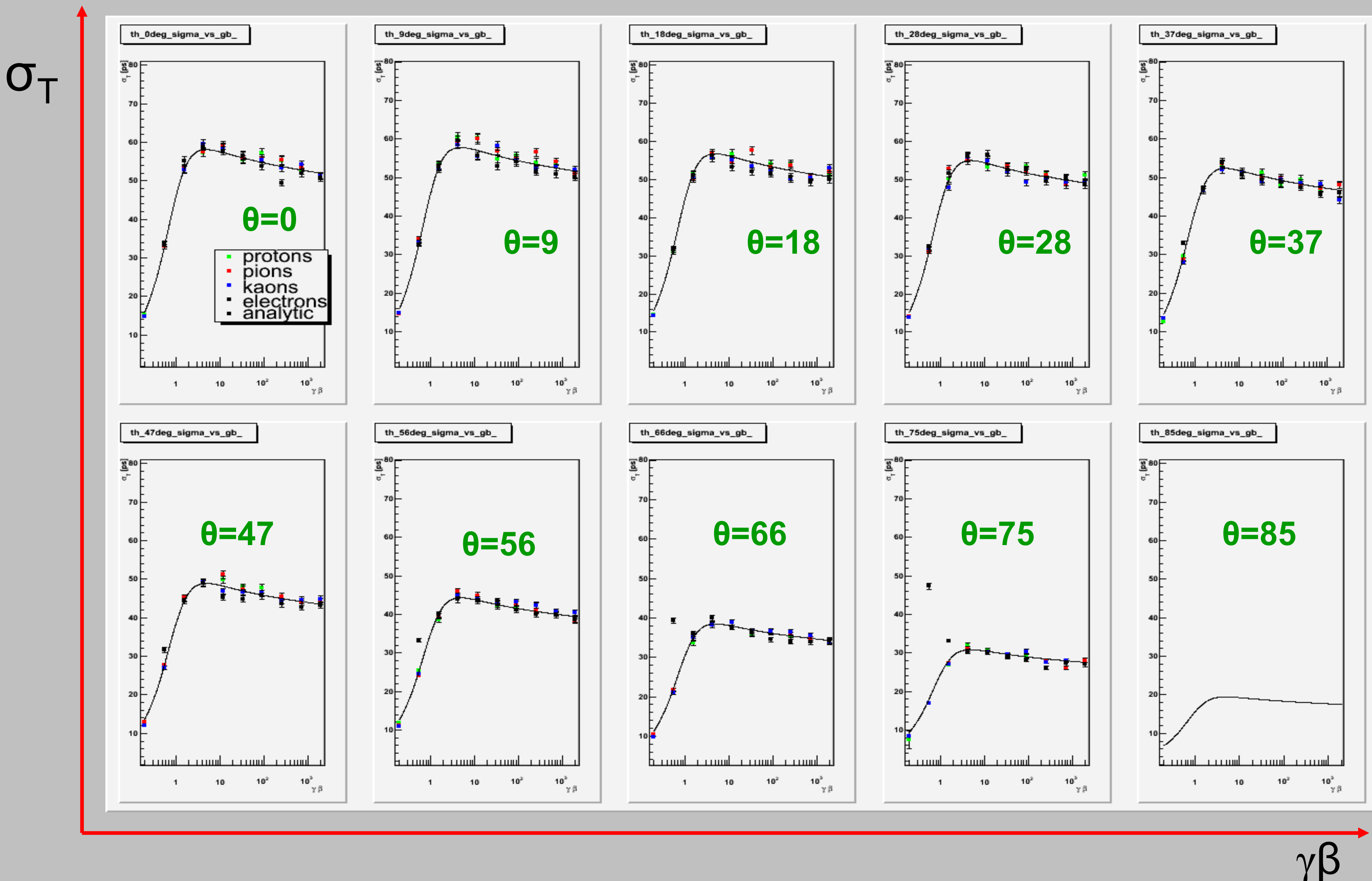
Comparison with analytic formula: 1 gap (no secondaries)



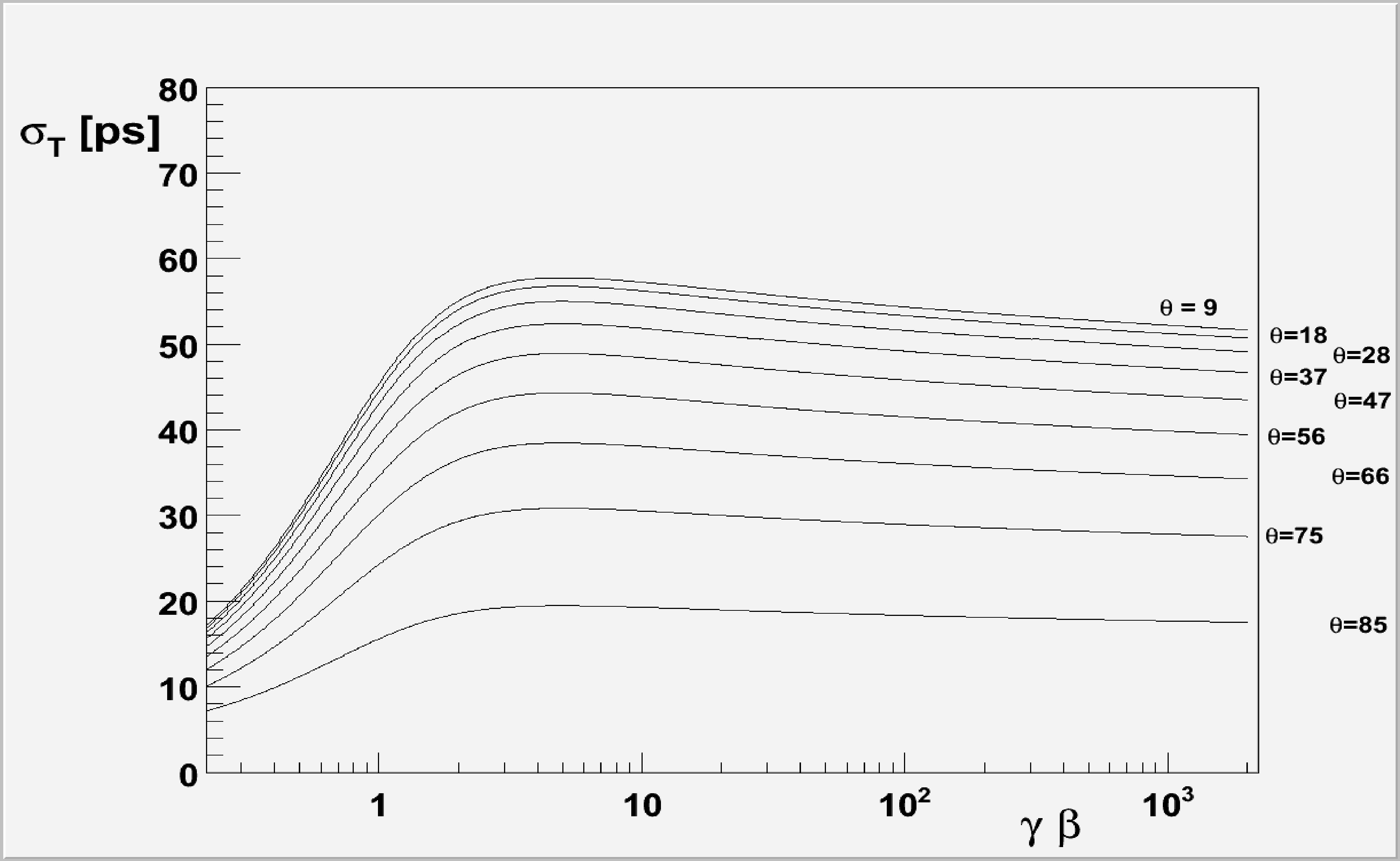
Comparison with analytical formula: 1 gap (no secondaries)



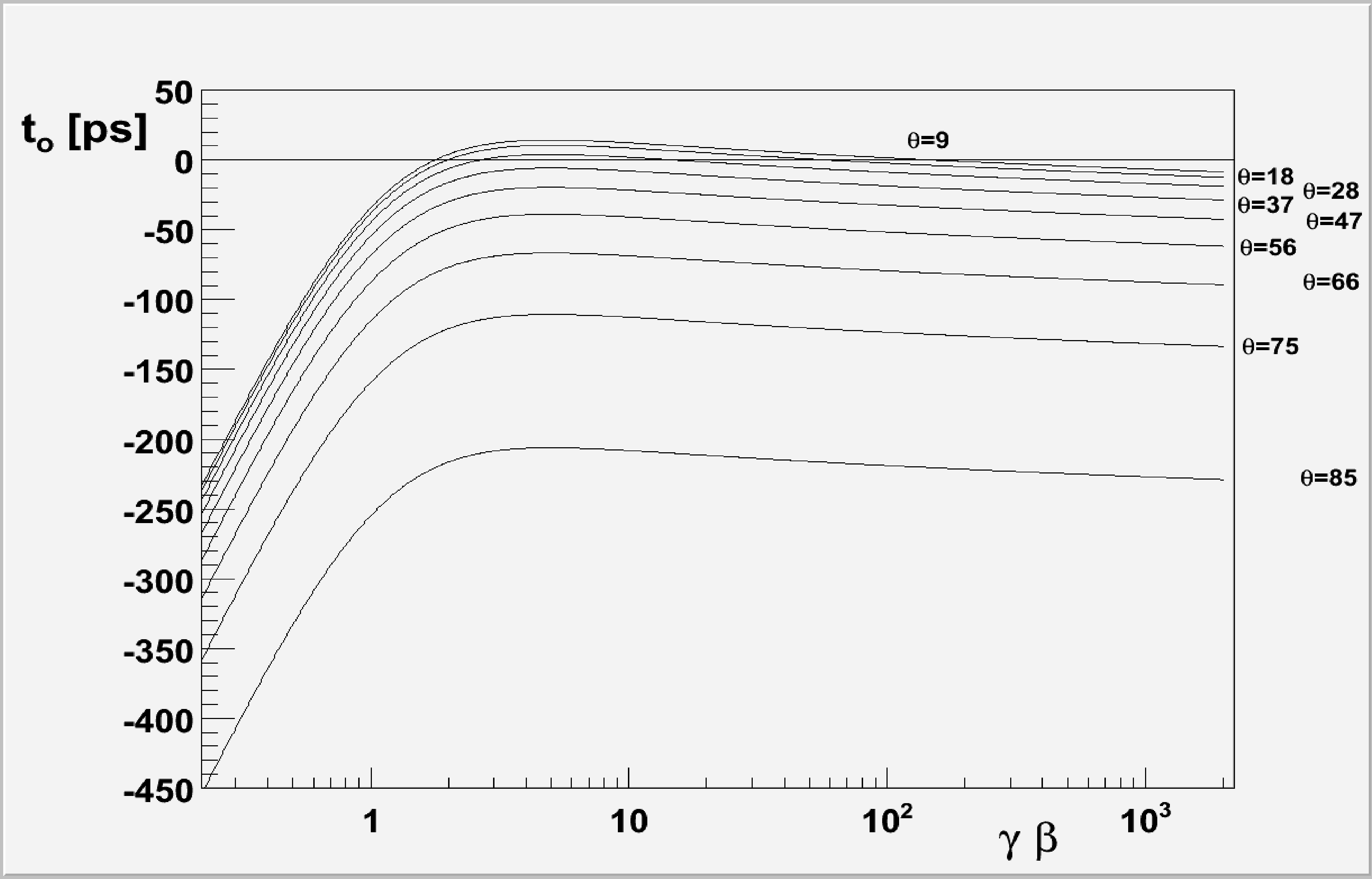
Comparison with analytical formula: 4 gaps (no secondaries, no electrodes)



σ_T (4 gaps). Summary.



t_o (4 gaps). Summary.



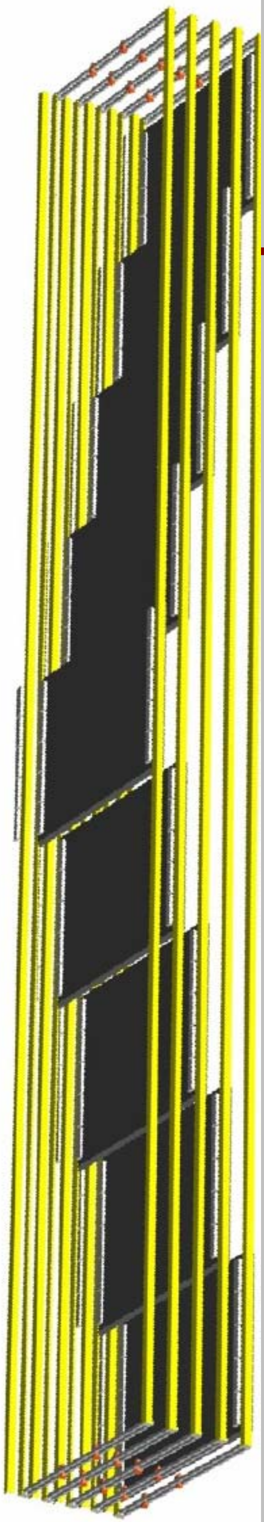
1.4. Systematic results including secondary production and detector geometry will come soon.

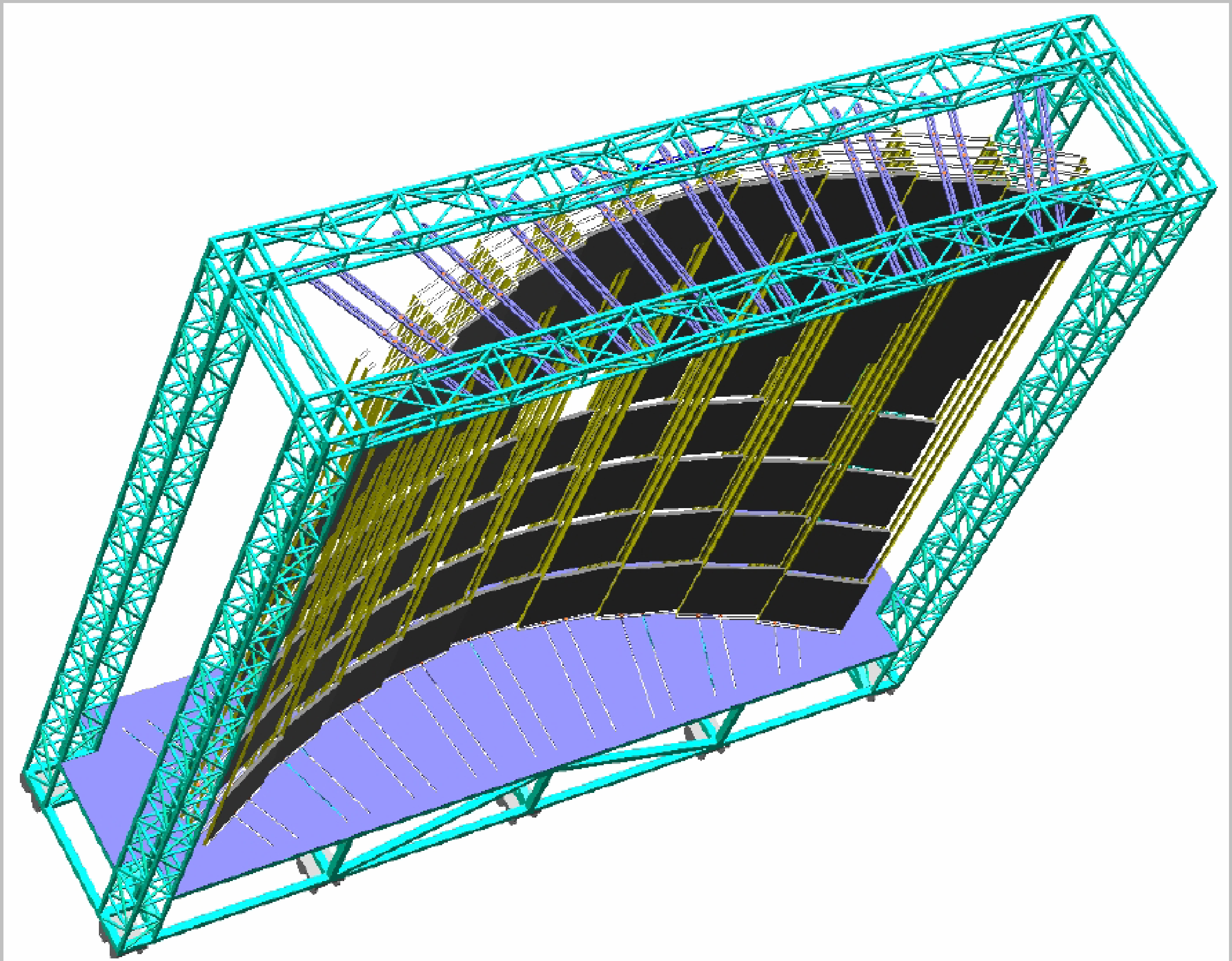
2. Mechanical integration.

S. Belogurov, S. Iovenko

Mechanical integration.

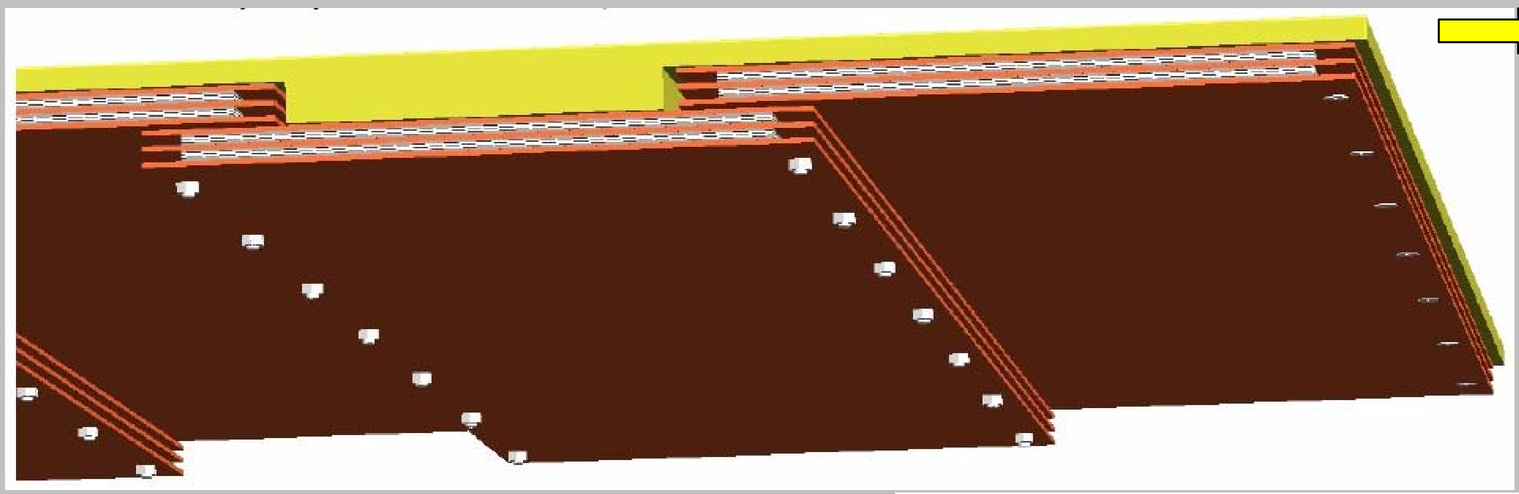
- **New** metallic bands (more resistant to torsion than previously)





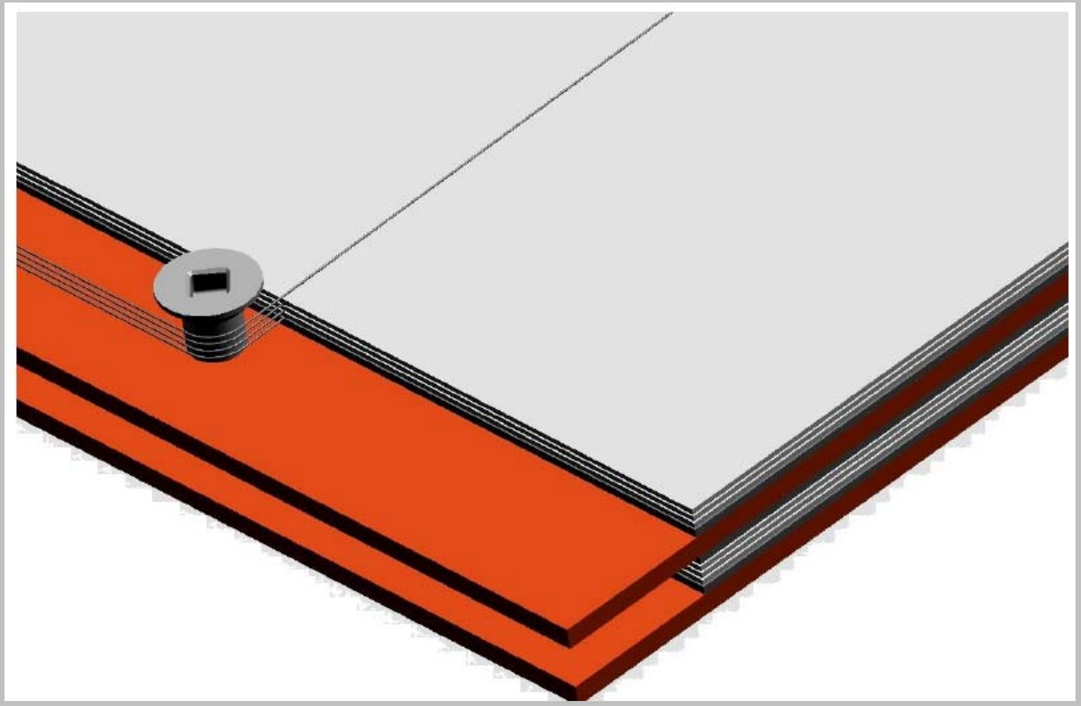
S. Belogurov, S. Iovenko

A first sub-module concept.



honeycomb

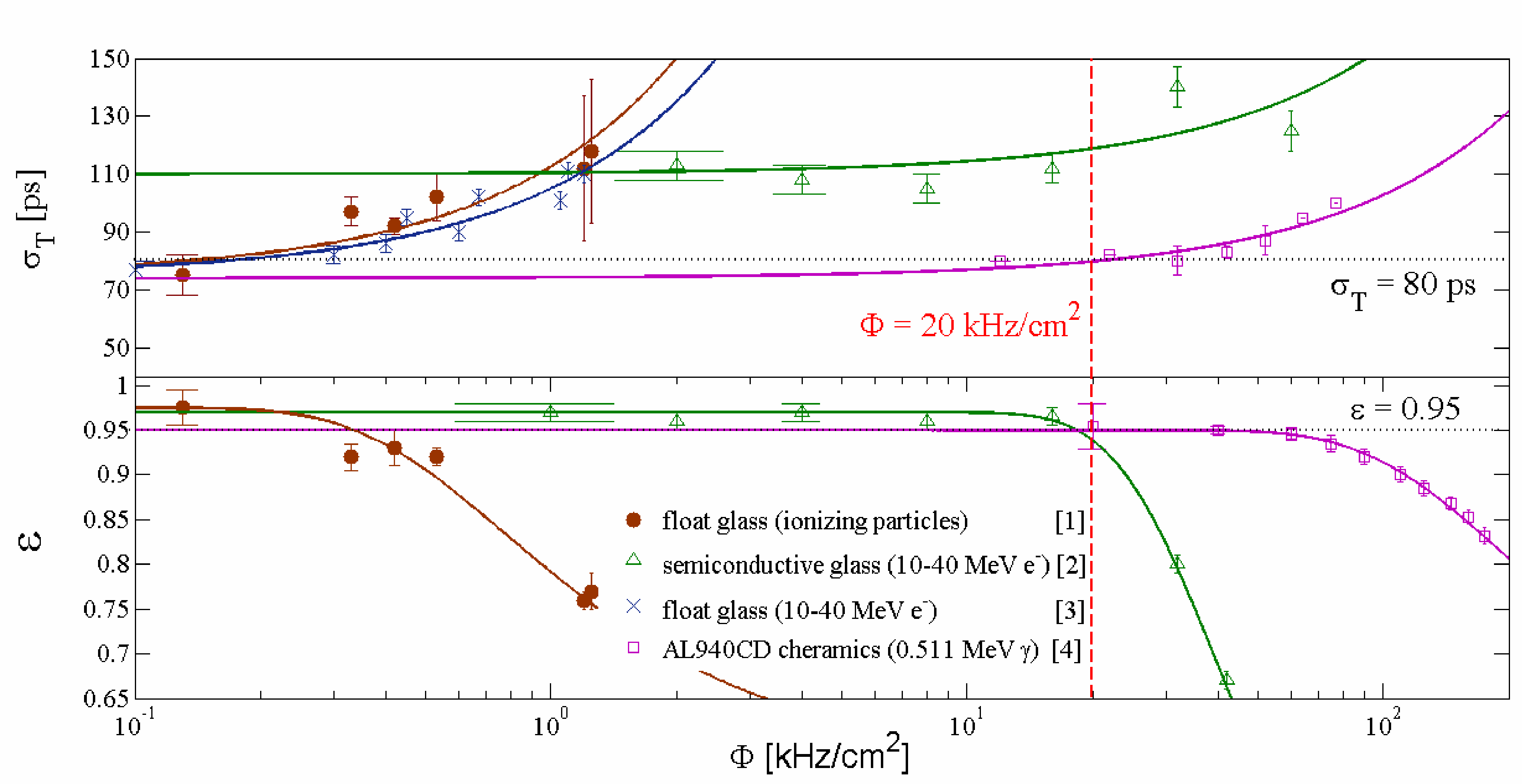
stesalit



Screws for rolling
nylon spacers

3. R&D in high rate capability tRPCs.

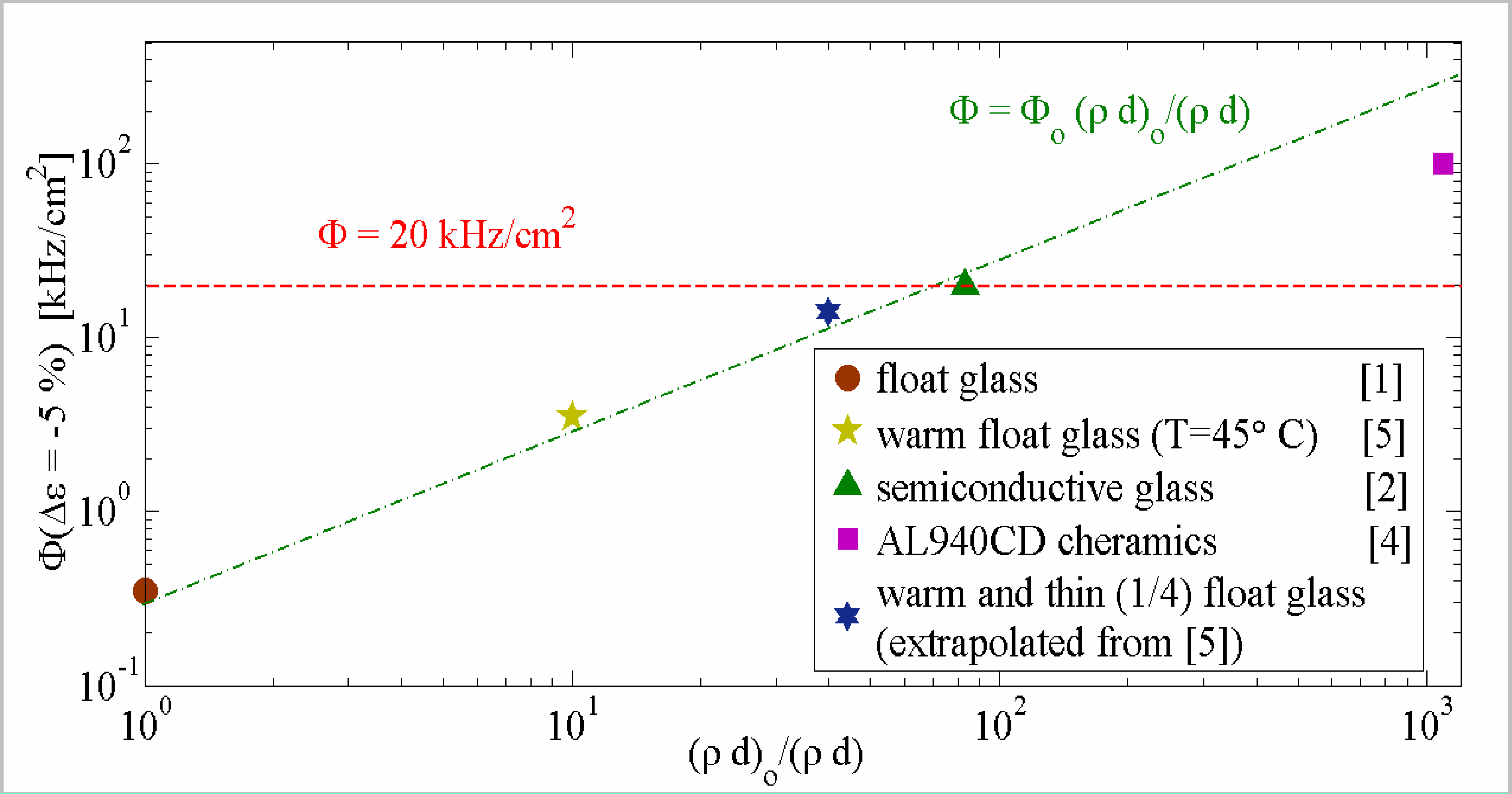
Rate capability (I). Efficiency and time resolution.



[1] H. Alvarez-Pol et al., NIM A, 535(2004)277, **[2]** V. Ammosov et al. NIM A, 576(2007)331, **[3]** R. Kotte et al. NIM A(2006)155, **[4]** L. Lopes et al., Nucl. Phys. B (Proc. Suppl.), 158(2006)66, **[5]** D. Gonzalez-Diaz et al., NIM A, 555(2005)72.

fit from model of: D. Gonzalez-Diaz et al. Nuc. Phys B (proc. Suppl.) 158(2006)47

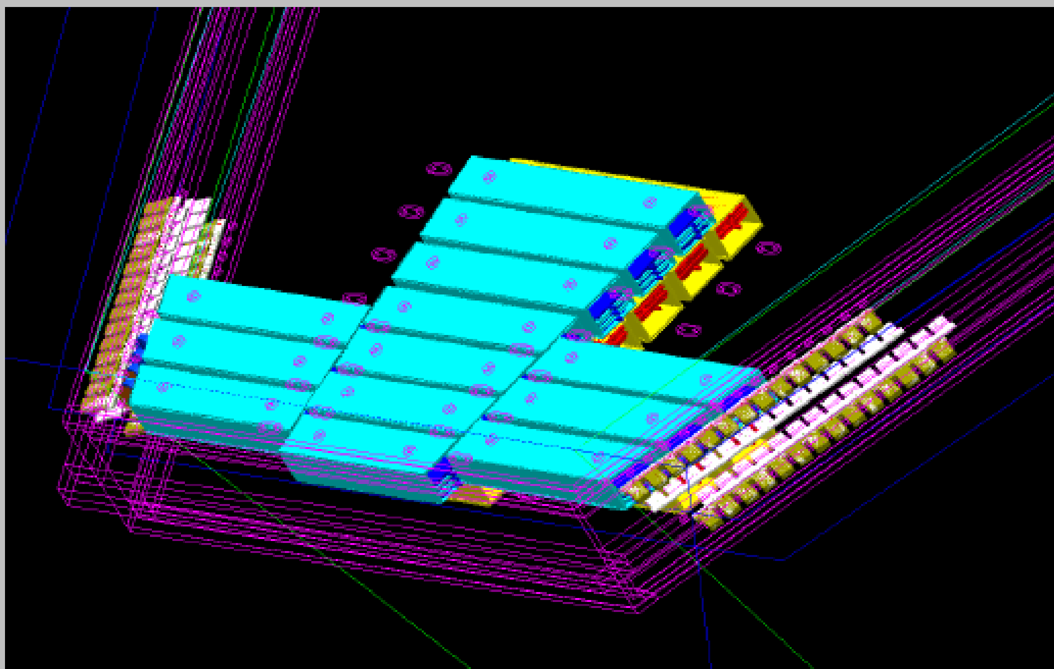
Systematics on rate capability (II).

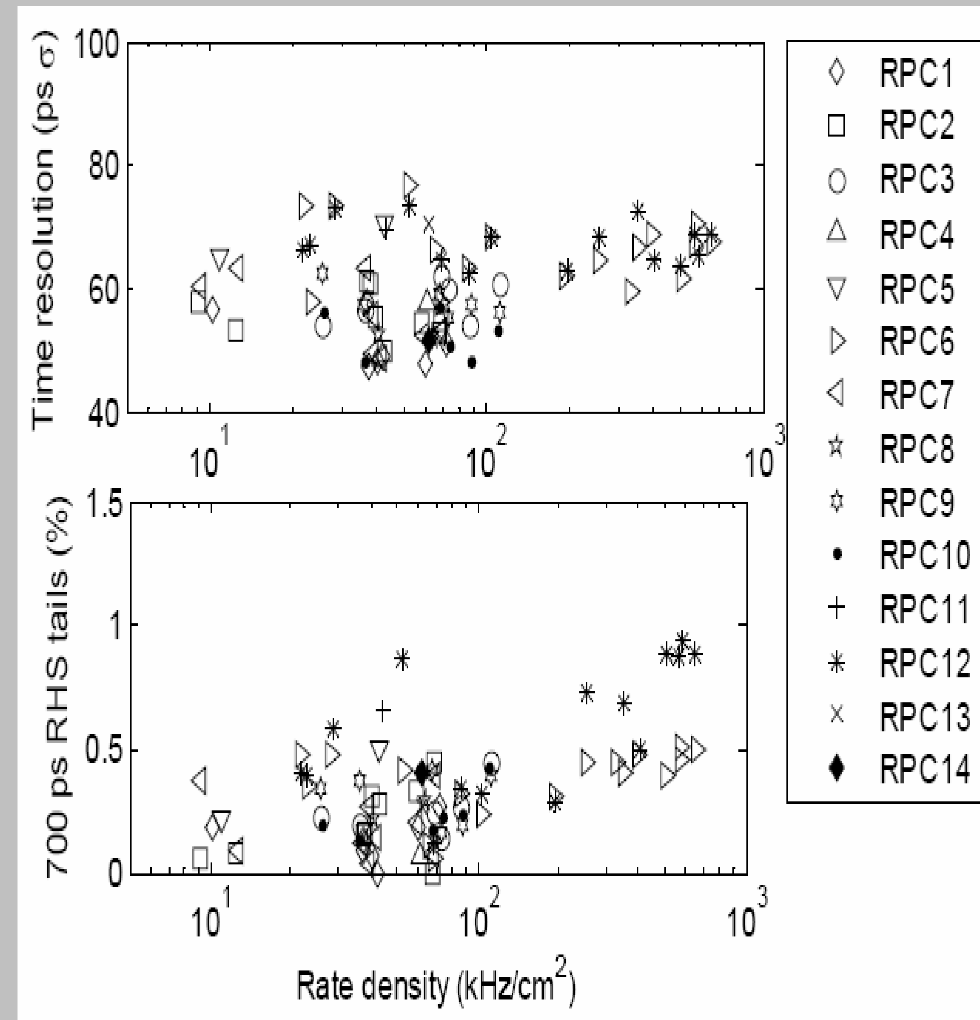


[1] H. Alvarez-Pol et al., NIM A, 535(2004)277, **[2]** V. Ammosov et al. NIM A, 576(2007)331, **[3]** R. Kotte et al. NIM A(2006)155, **[4]** L. Lopes et al., Nucl. Phys. B (Proc. Suppl.), 158(2006)66, **[5]** D. Gonzalez-Diaz et al., NIM A, 555(2005)72.

4. On-going efforts on large systems

HADES. Measurements with 28 channels (2005).





P. Fonte et al. PoS (HEP2005)376

D. Belver, A. Gil

HADES FEE (I).

DBO as in:

D. Belver et al. Nucl. Phys. (Proc. Suppl)158(2006)47-51

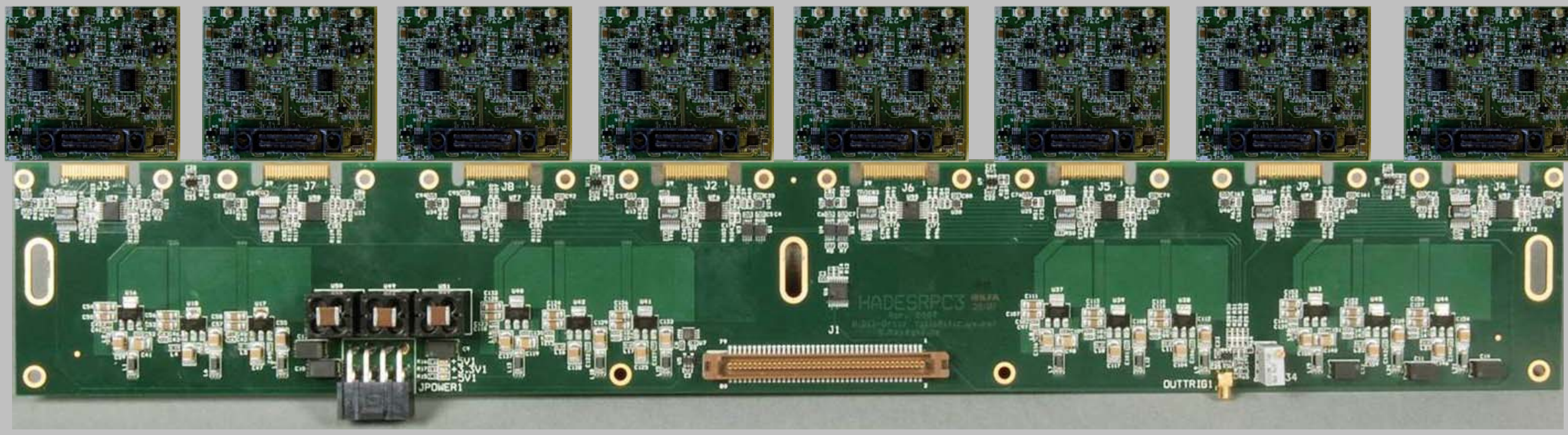
4 input channels, 2 GHz amplifiers, charge measured through ToT of integrated signal.

4.5 cm

5 cm

MBO (housing 8 DBOs):

-Distribution of pulser signal, thresholds, power.
-Rooting for readout of signals and T sensors.

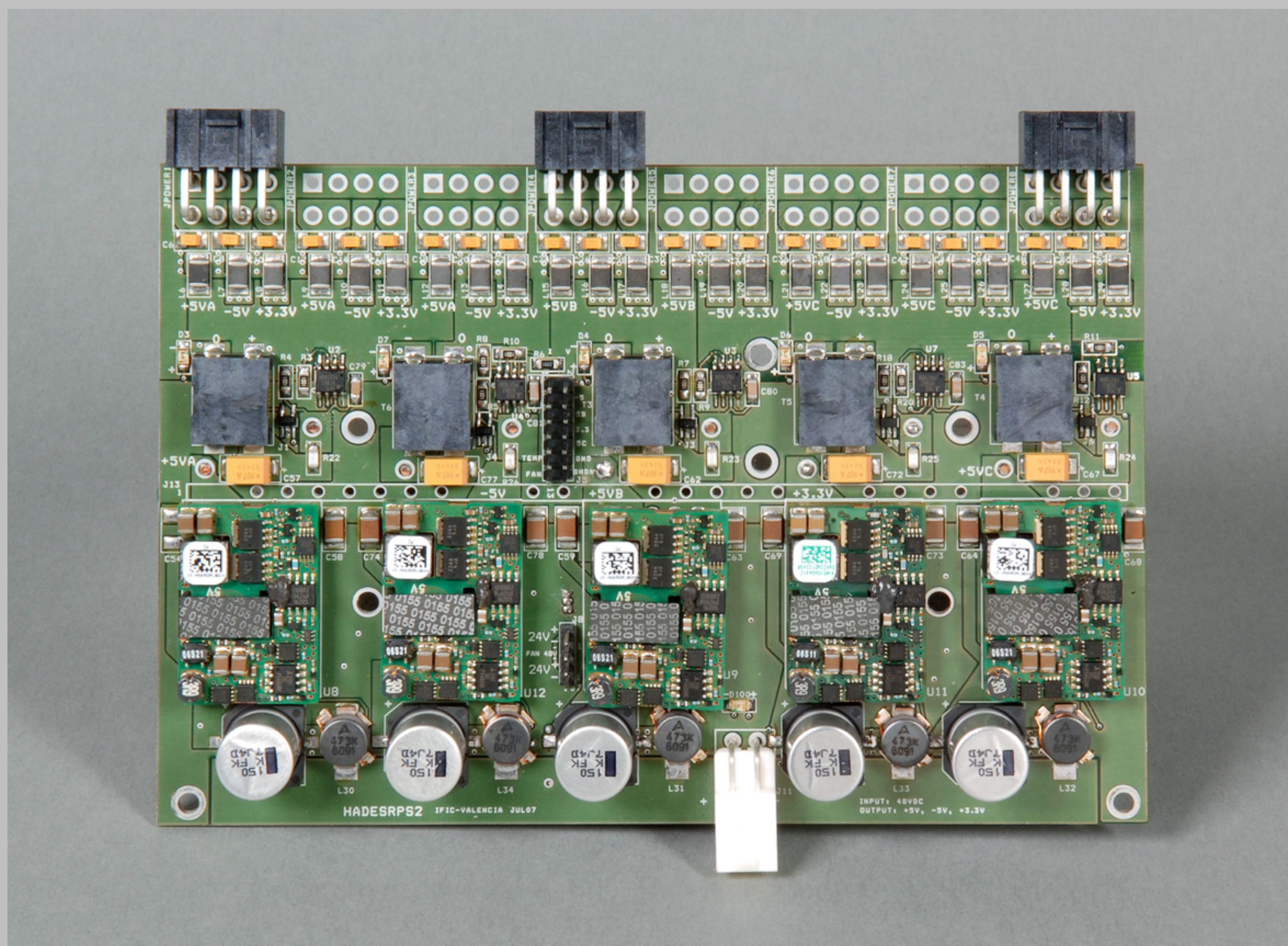


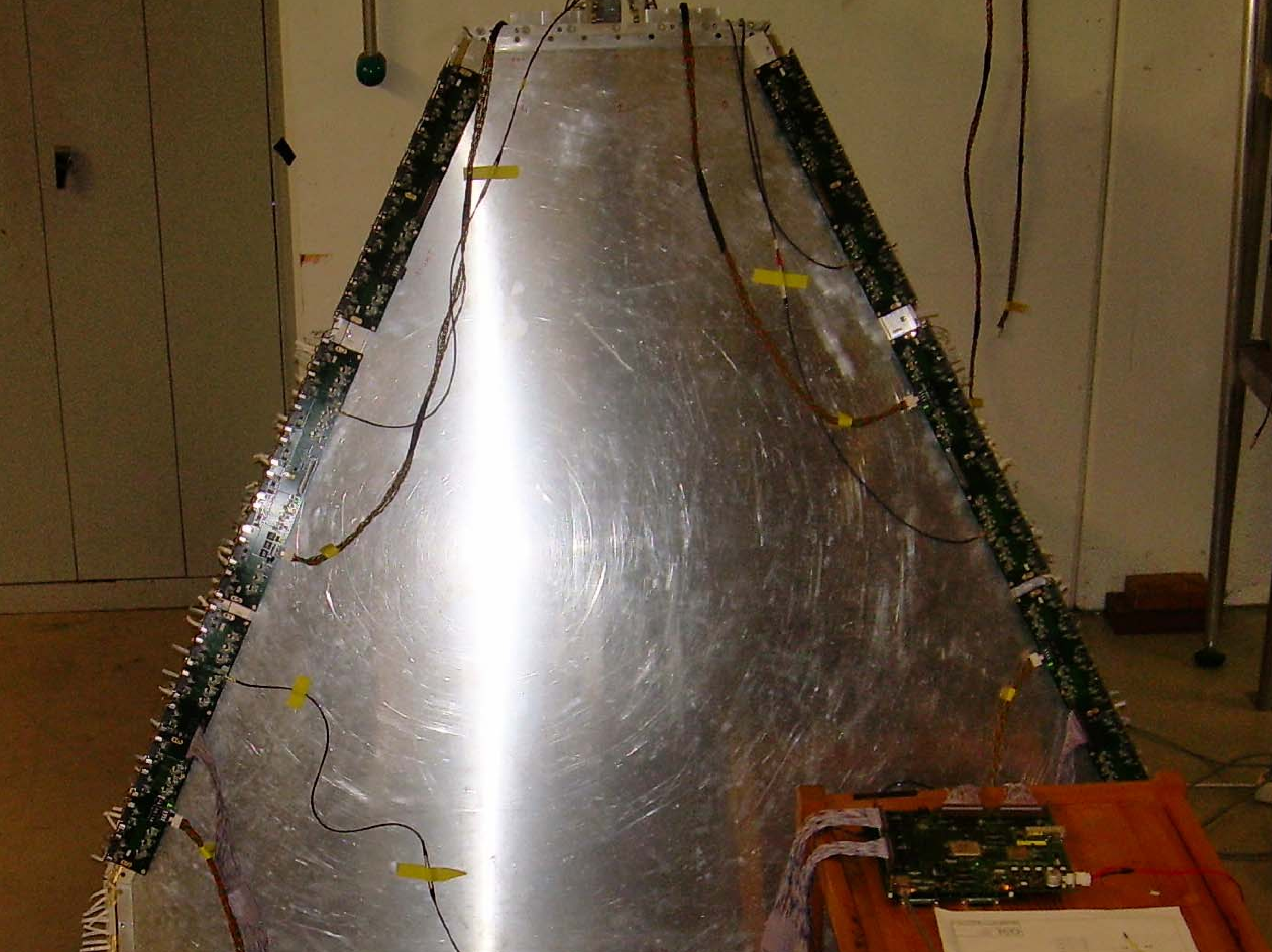
40 cm

A. Gil

HADES FEE (II).

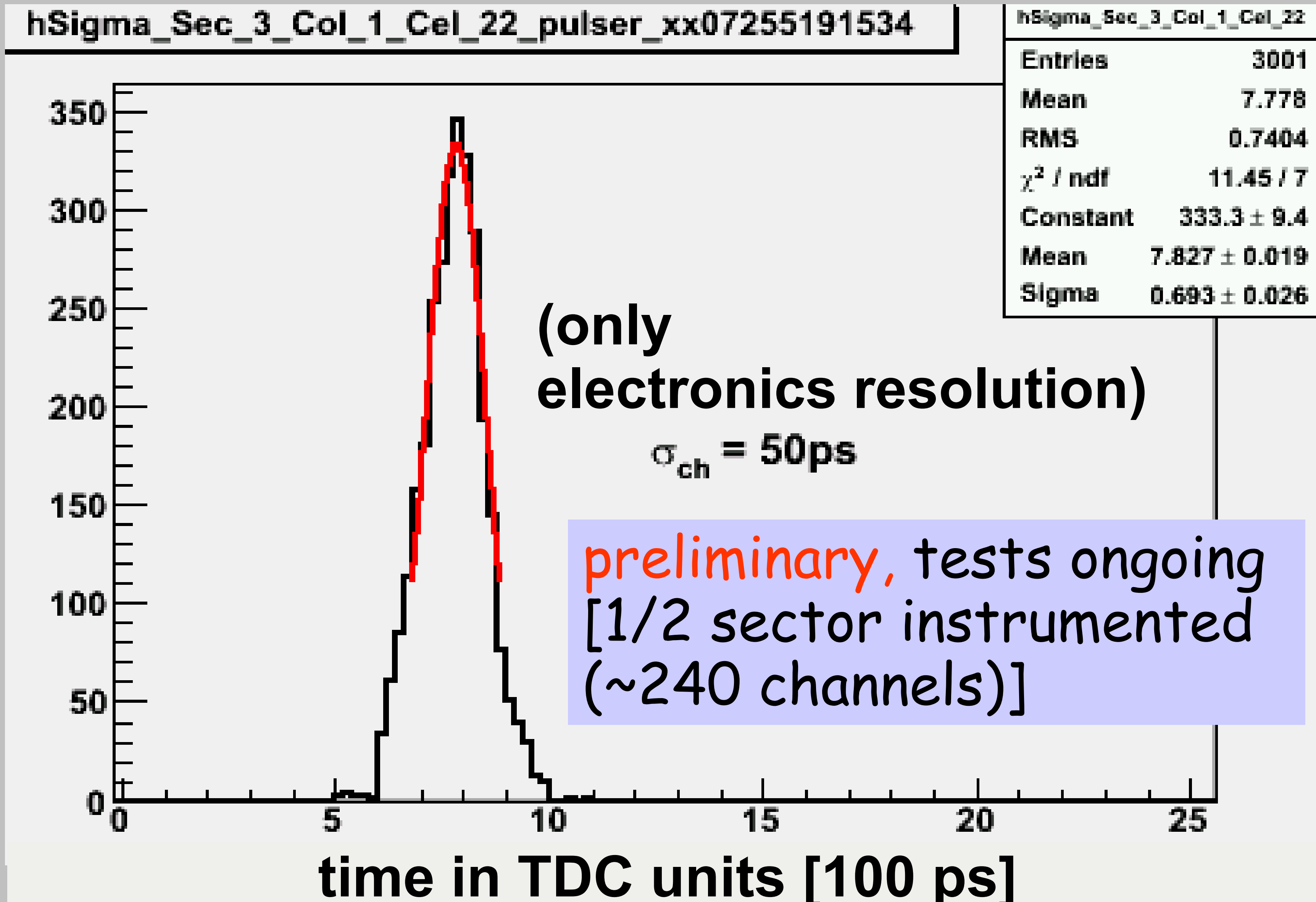
LV distribution based on switching power supplies integrated into custom made boards





P. Cabanelas, D. Belver

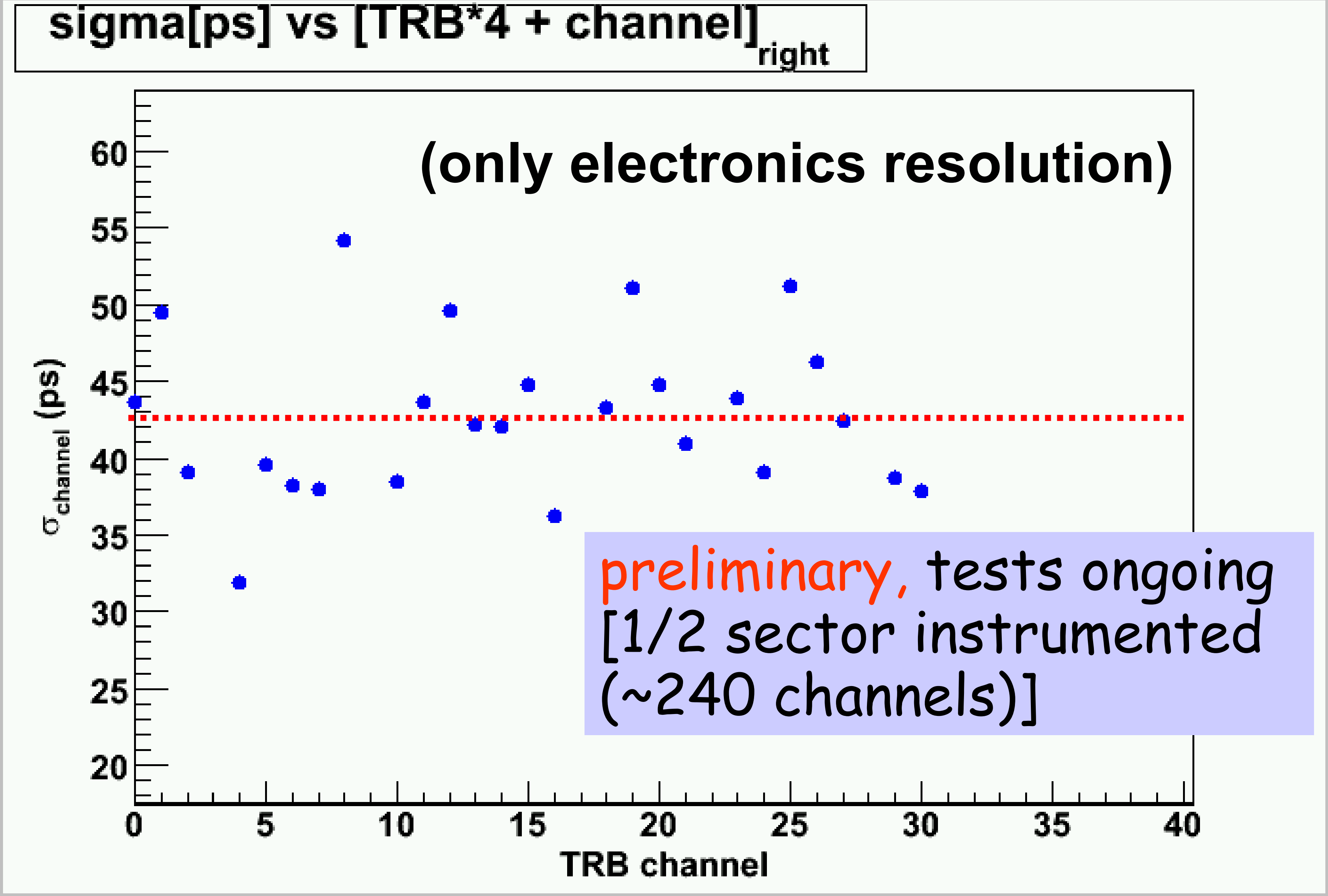
HADES FEE (III).



preliminary, tests ongoing
[1/2 sector instrumented
(~240 channels)]

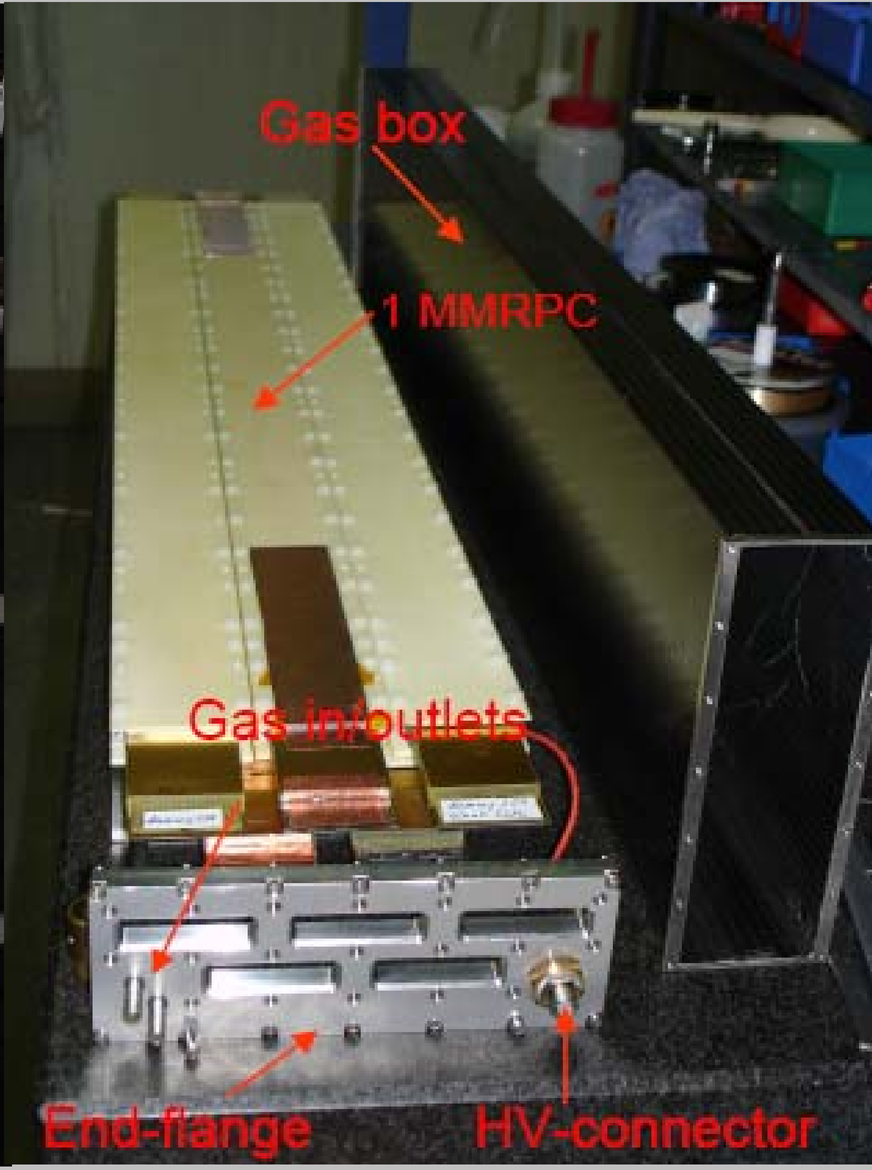
P. Cabanelas, D. Belver

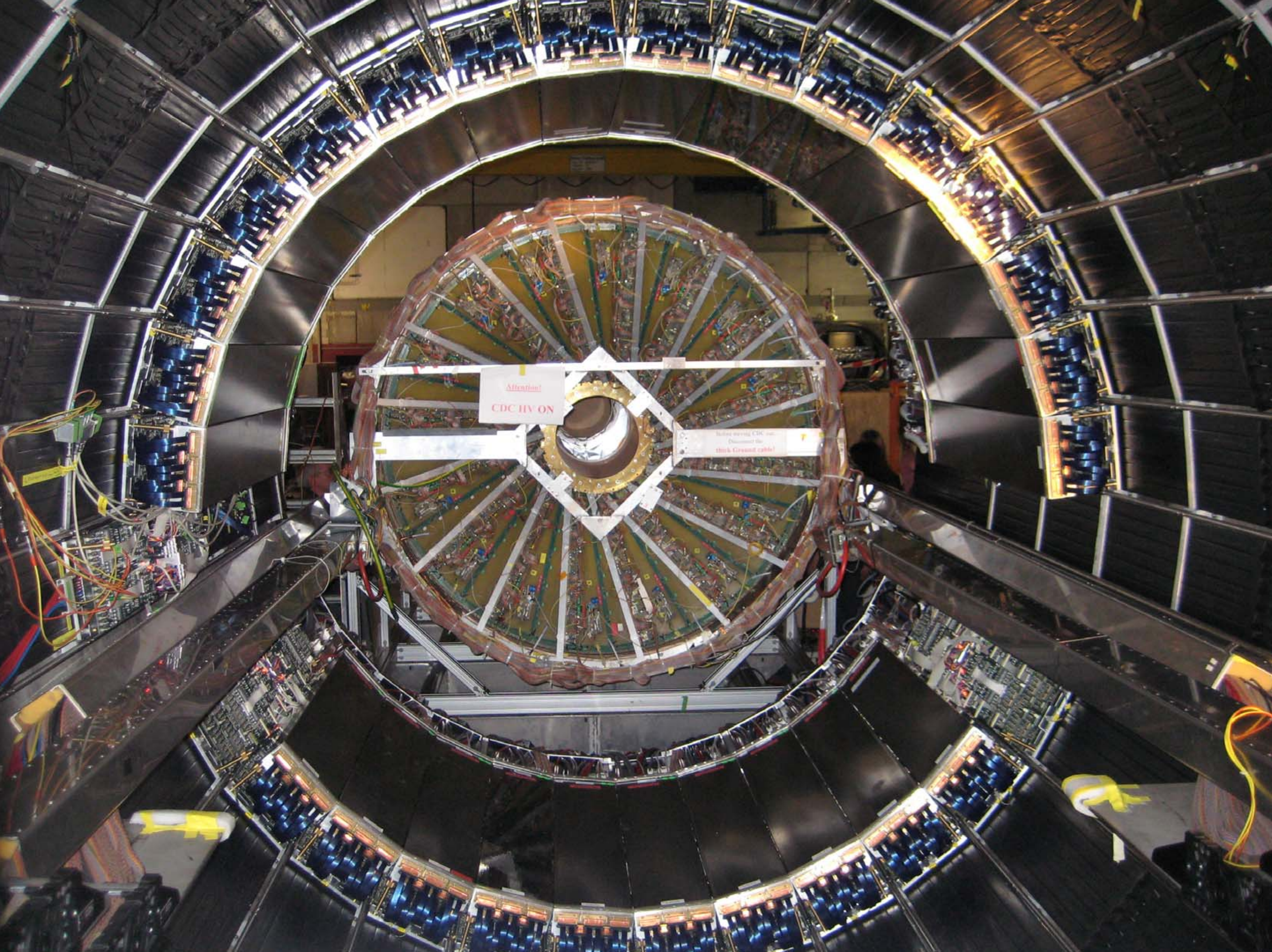
HADES FEE (IV).



A. Schuettauf

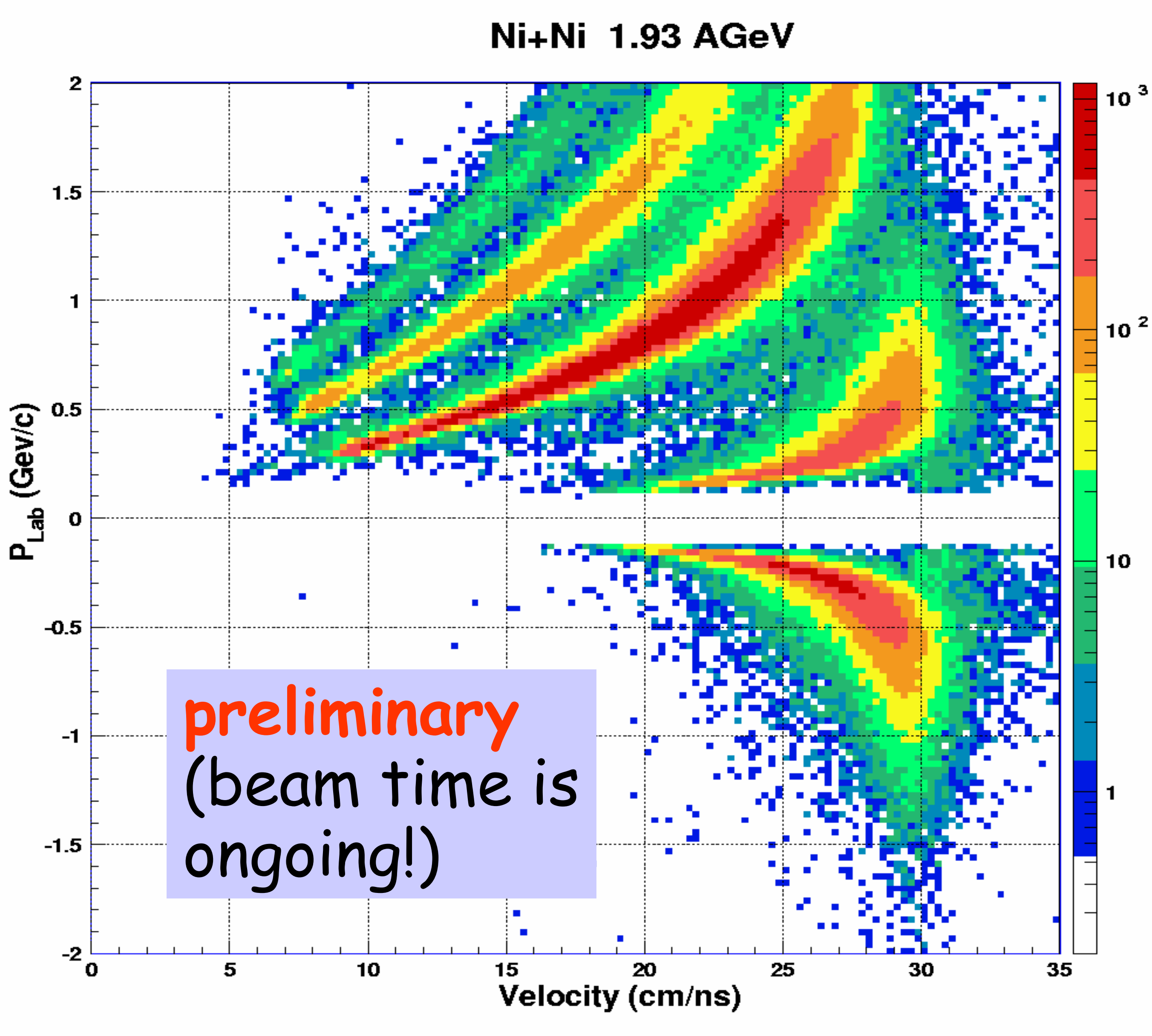
FOPI. Full system measurements (I).




Attention!
CDC HV ON
thick Ground cable!

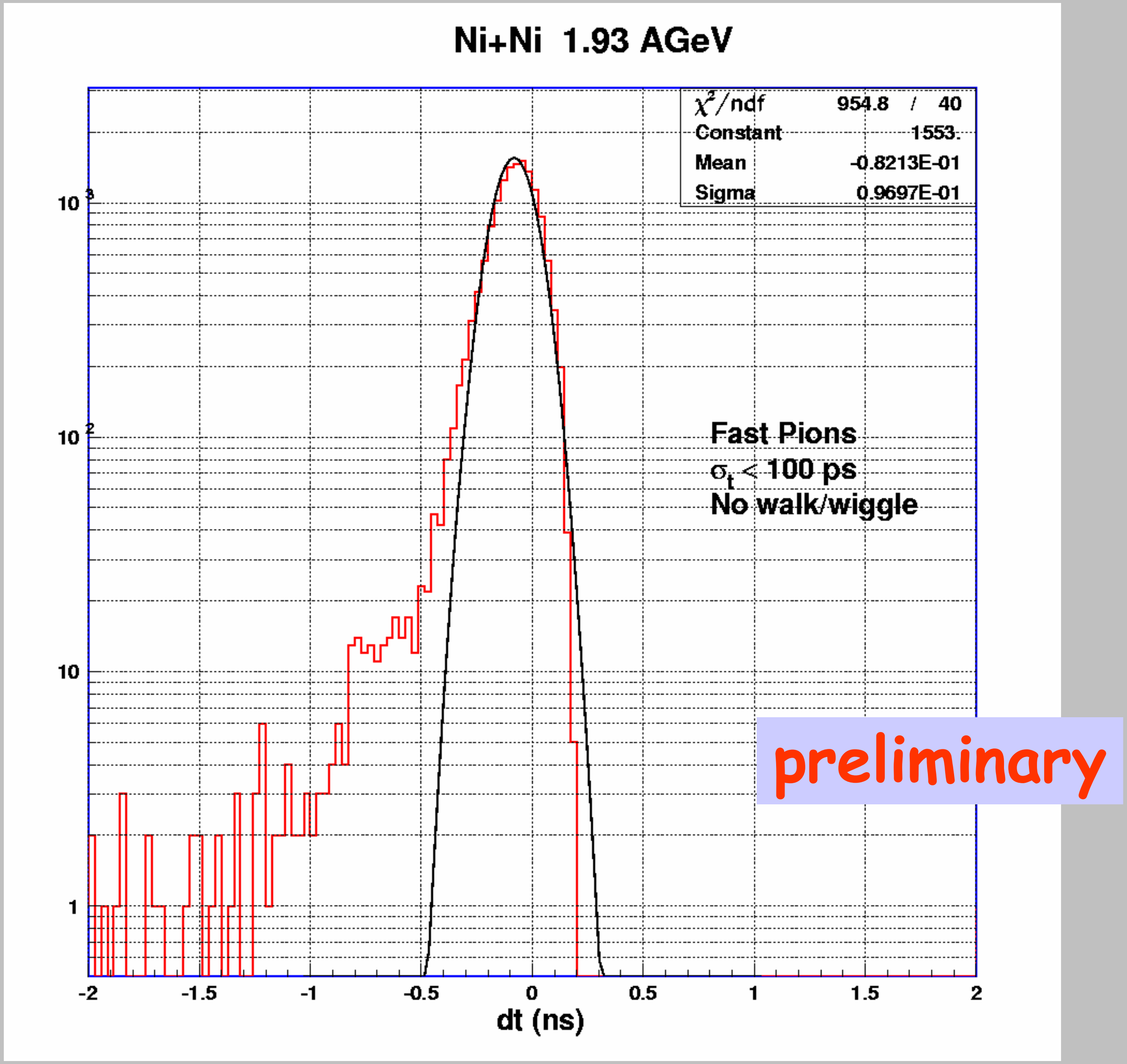
A. Schuettauf

FOPI. Full system measurements (II).



A. Schuettauf

FOPI. Full system measurements (III).



Outlook.

- A fast and simple algorithm for describing the avalanche process has been developed and used for creating RPC hits within the cbmroot framework.

- The influence of the comparator threshold, the local production of secondary particles, track inclination, energy loss, number of gaps crossed and multiple tracks in the same (electrically independent) cell is automatically taken into account by the developed algorithm.

- The mechanical concept is progressing. Further advances must be driven by information coming from simulation.

- There are several technologies available that deliver good detector performances at the rates required by CBM. However, none of these technologies has been tested yet in a medium-size realistic prototype.

- HADES and FOPI started to deliver promising data on full system performances. Preliminary HADES data show single channel electronic jitter at levels of **40-50 ps** for 240 channels, while FOPI preliminary analysis shows full system **detector resolutions below 100 ps** (without walk and wiggle corrections) in NiNi reactions at 1.93 AGeV.

Backup slides

Some simple analytical formulas

produced δ-electrons

$$\frac{d^2N}{dT\,dx} = \frac{1}{2} K z^2 \frac{Z}{A} \frac{1}{\beta^2} \frac{F(T)}{T^2}$$

emitted δ-electrons

$$\left.\frac{dN}{dT}\right|_{emitted} = \frac{d^2N}{dT\,dx} R(T)\theta_H(l - R(T)) + \frac{d^2N}{dT\,dx} l\theta_H(R(T) - l)$$

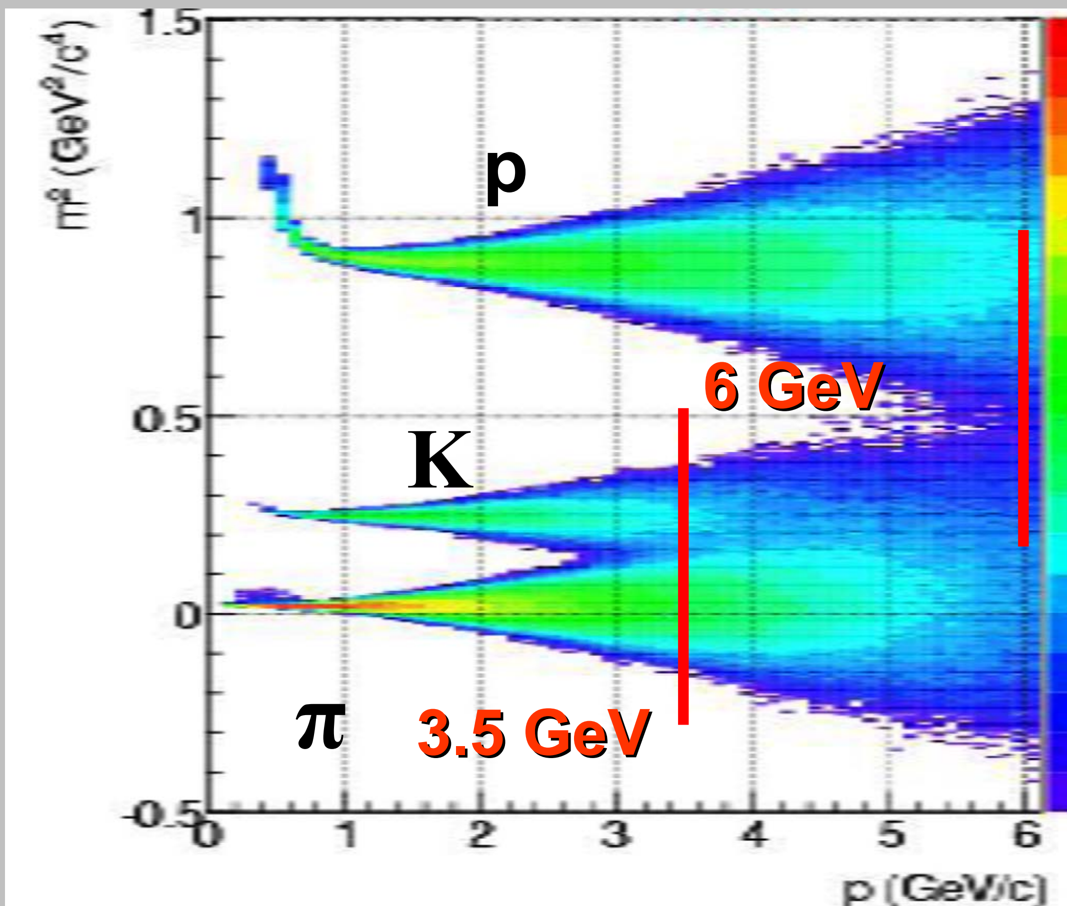
$$R = R_0 T^\alpha$$

$$n_\delta(T_{prim}) = \int_{T_{min}}^{T_{max}} \left.\frac{dN}{dT}\right|_{emitted} dT$$

PID capabilities

The TOF wall is the only detector providing hadron identification in CBM.

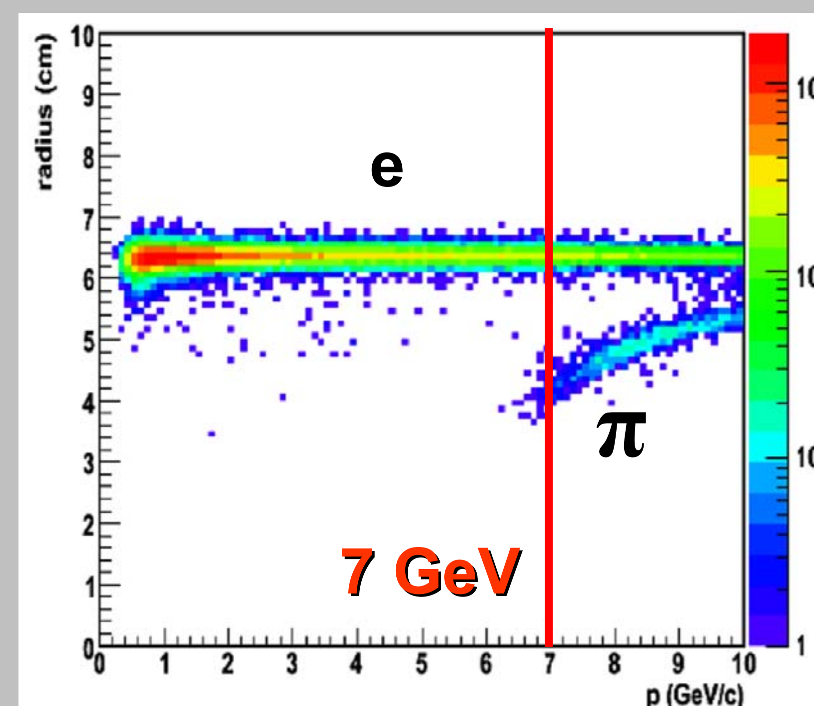
(RICH also provides hadron identification, but its optimization is driven by electron detection, resulting in hadron identification only at very high momenta, **p>7 GeV)**



Ideal reconstructed mass (from eq. [1])

reconstructed mass

$$m^2 = p^2\left(\frac{1}{\beta^2} - 1\right), \quad \sigma_{m^2} = \frac{2p^2}{\beta^2}\frac{\sigma_T}{t} \quad [1]$$

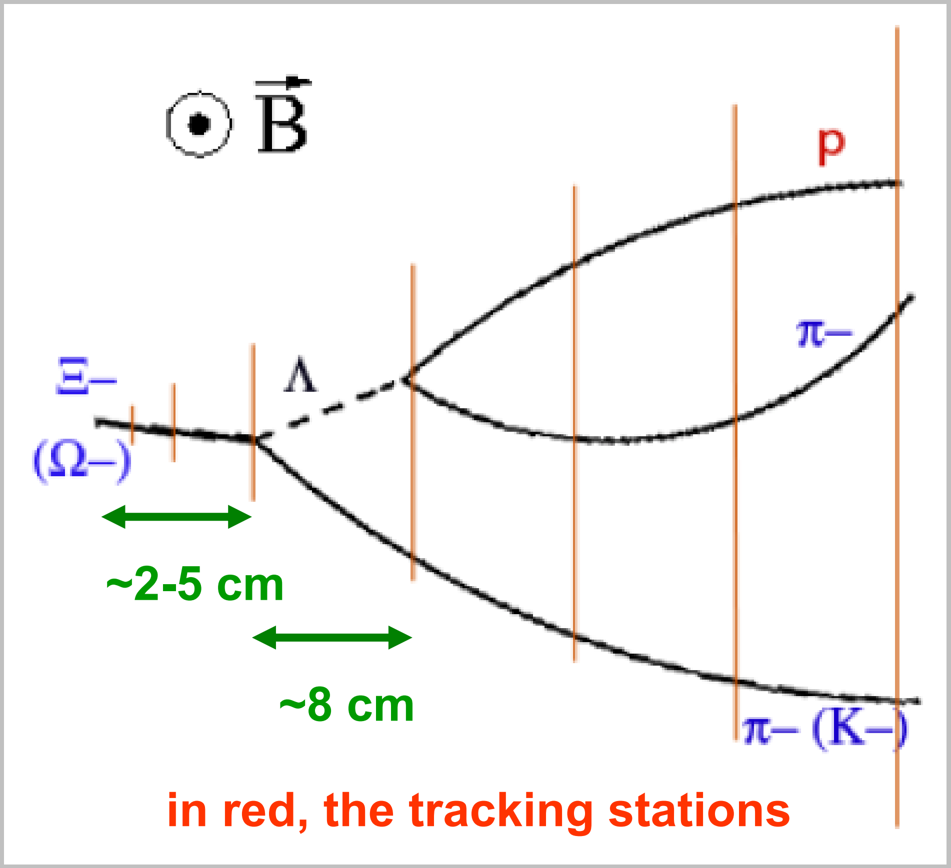


The CBM-TOF wall. Design requirements.

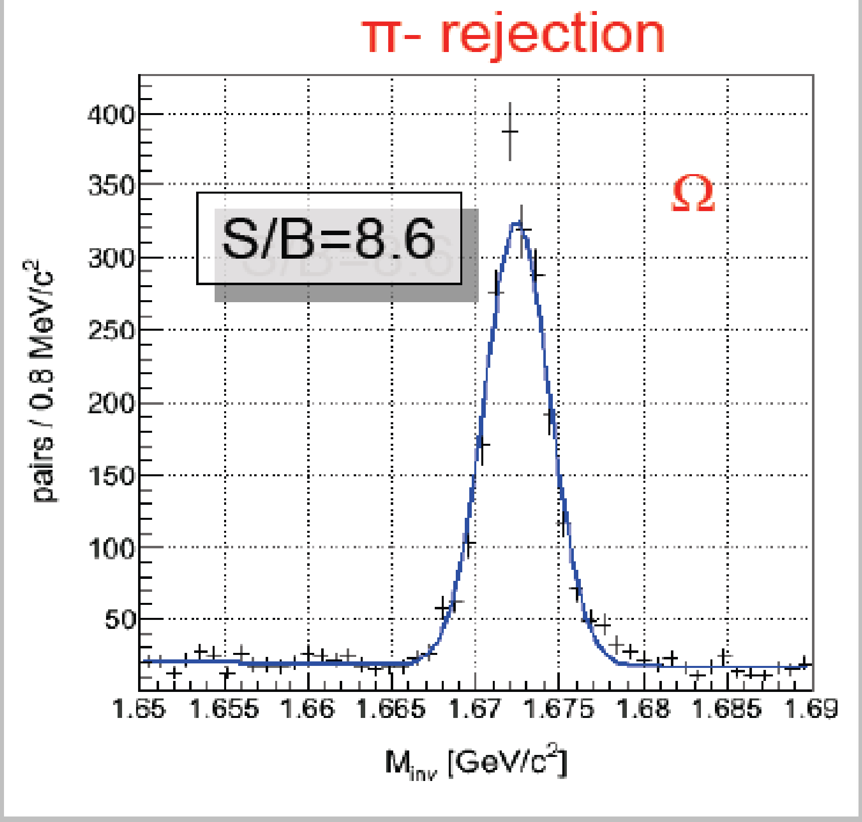
- Overall time resolution σ_T = 80 ps.
- Occupancy < 5 % for Au-Au central collisions at E=25 GeV/A.
- Space resolution ≤ 5 mm x 5 mm.
- Efficiency > 95 %.
- Pile-up < 5%.
- Rate capability > 20 kHz/cm^2.
- Multi-hit capability (low cross-talk).
- Compact and low consuming electronics (~65.000 electronic channels).

E. Kryshen

Physics case (II). Hyperon reconstruction

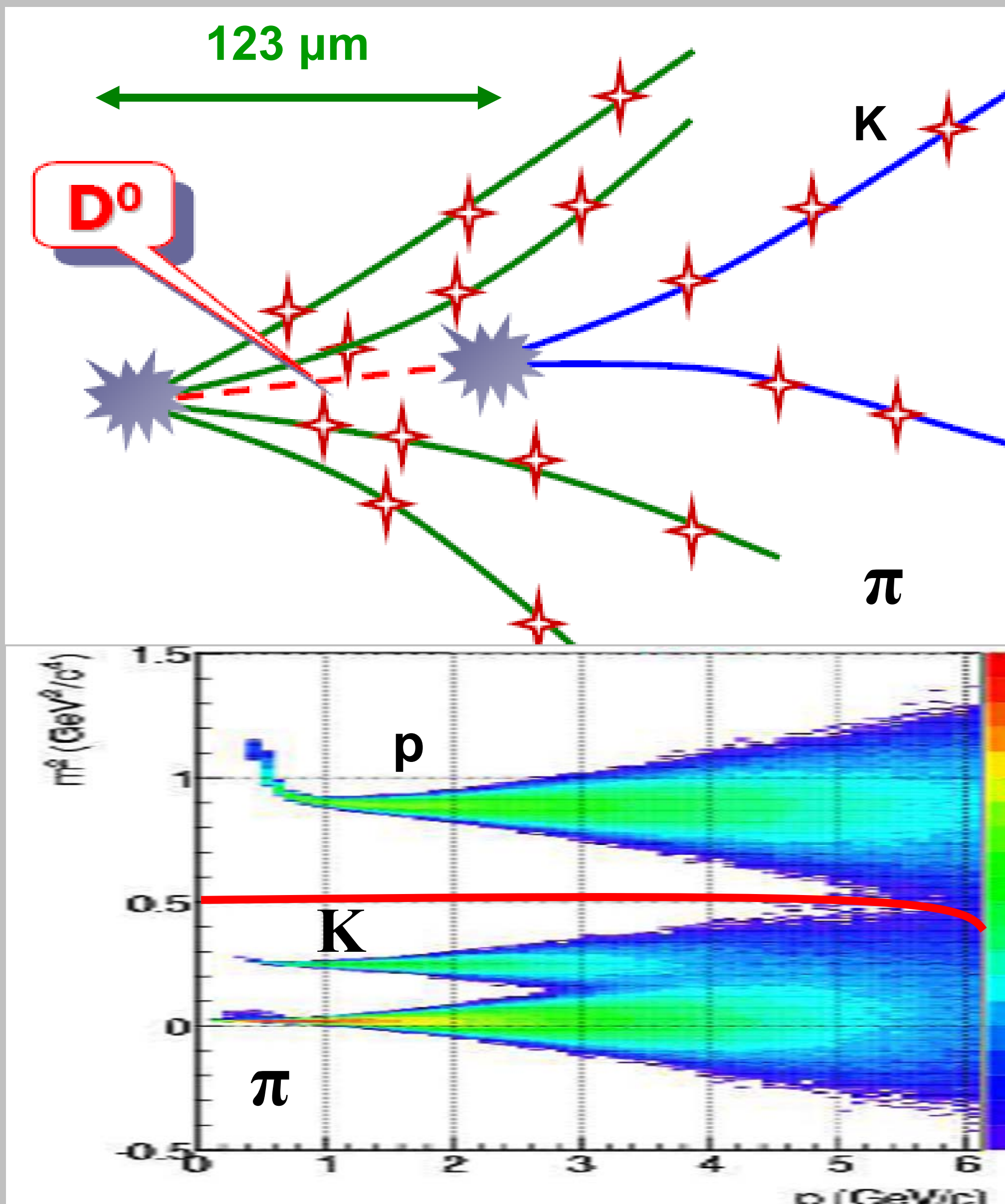


For production close to threshold, the use of topological cuts must be complemented with PId, mostly for suppression of **π background.**



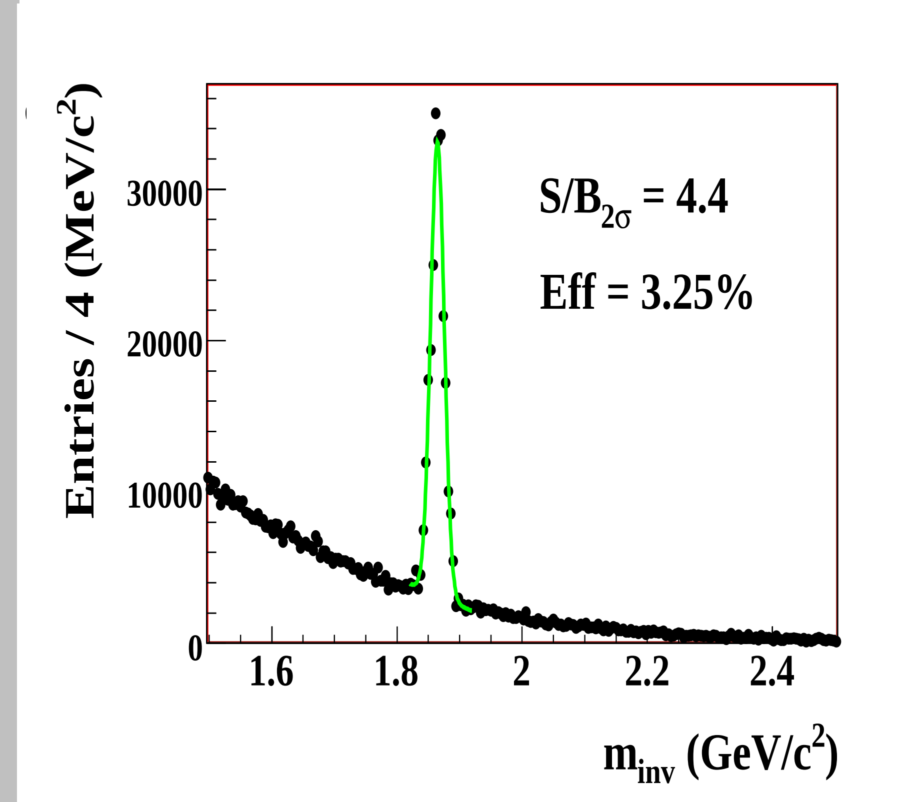
Simulated central Au-Au collisions at sqrt(s)=3.35 GeV/AA [E=6 GeV/A]

Physics case (III). D° reconstruction

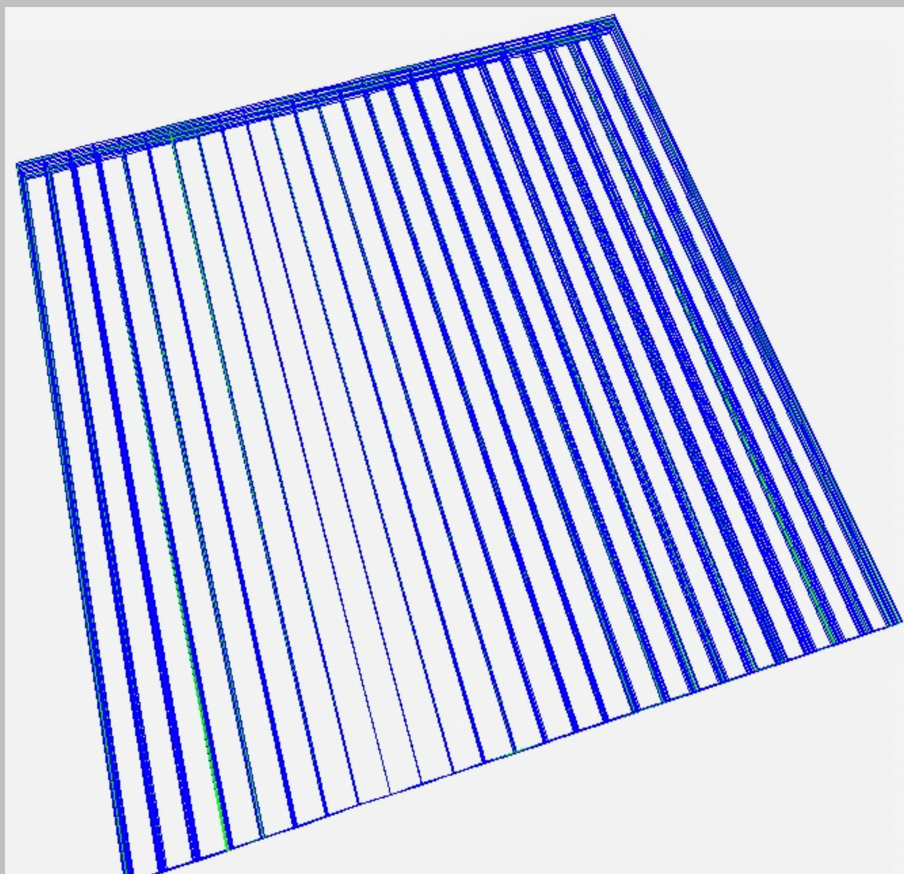


Proton suppression for reducing background from hyperon decays is crucial

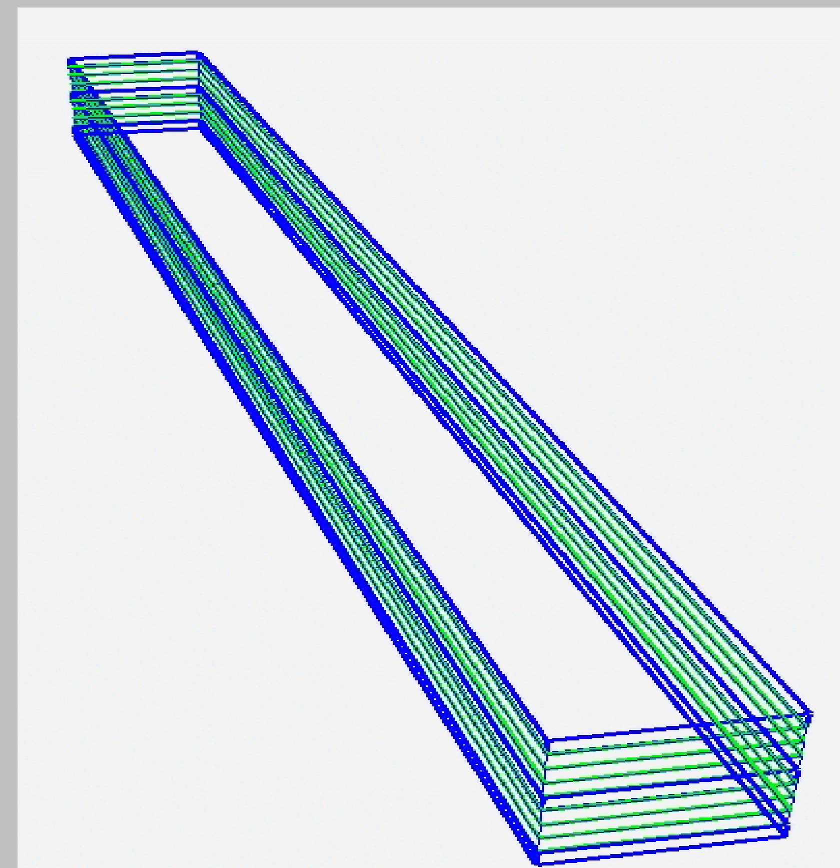
Simulated central Au-Au collisions at E=25 GeV/A



RPC response (I)



module

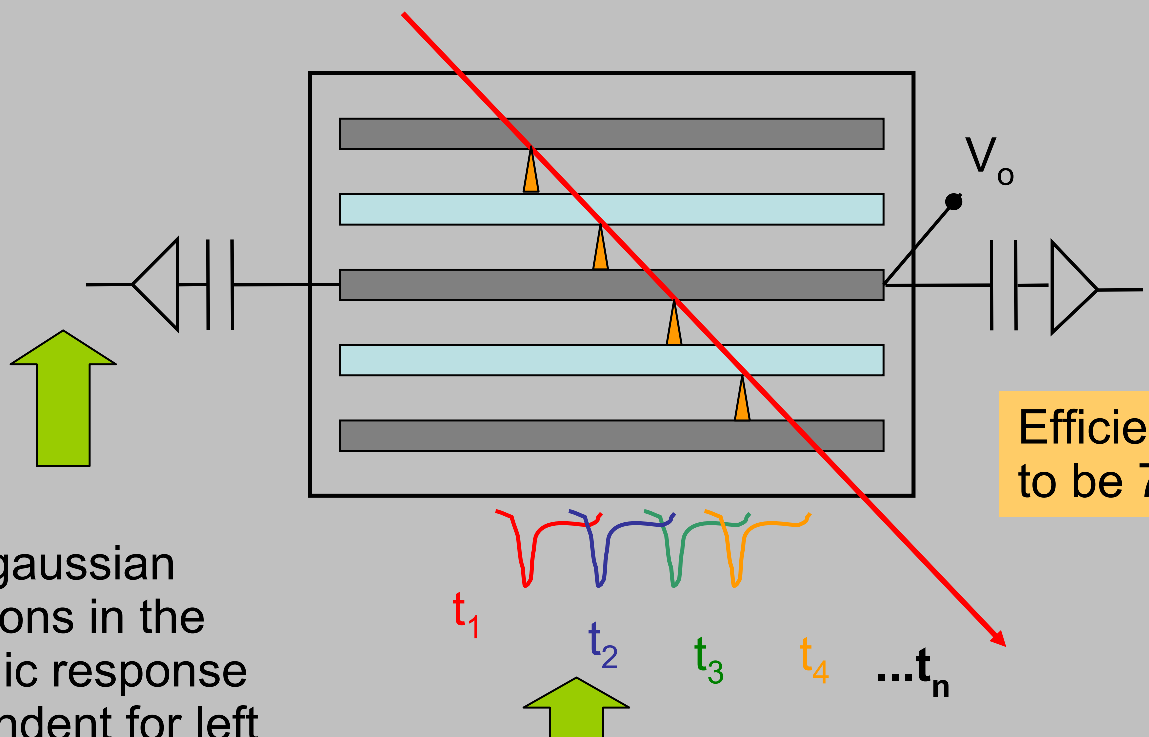


strip

The MonteCarlo information in each gap is used to generate a time response and efficiency that depends on the number of gaps crossed.

RPC response (II)

Structure of the first TOFHitProducer (version 1.1)



particles produced locally (4 cm) are disregarded

Efficiency per gap is assumed to be 75% [300 μm gap]

2. Add gaussian fluctuations in the electronic response (independent for left and right)

1. Add gaussian fluctuations due to detector response (same for left and right)

For simplicity, in this version the gaps are treated as if they were independent

Prescription: the fastest hit in the left and right is stored !