Search for new GeV resonances in the dimuon mass spectrum

- Several theoretical arguments and some experimental results require an extension of the Standard Model (SM)
- In particular, the SM cannot explain the nature of the Dark Matter (DM)
- At present, the most popular hypothesis on the DM is that it is composed of **weakly interacting massive particle** (WIMPs)
- However the existence of massive WIMPs is strictly constrained by the recent LHC results

- On the other hand, in the last years the idea that DM could be light started to gain popularity (because of DAMA and CoGeNT results…)
  - In particular, the idea of light DM interacting with new O(1) GeV gauge bosons has been widely investigated[1]

[1] J.Phys.G30:279-286,2004
JHEP 1109:128,2011
JCAP 1008:018,2010

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- In addition to this new light (scalar) resonances are also expected in other scenarios like Two-Higgs-Doublet Models[2], etc…

[2] arXiv:1412.3385

- Although both high-mass and low-mass (< 1 GeV) new resonances are highly constrained, limits on new IMR resonances are looser[3]

[3] JHEP 0907:051,2009

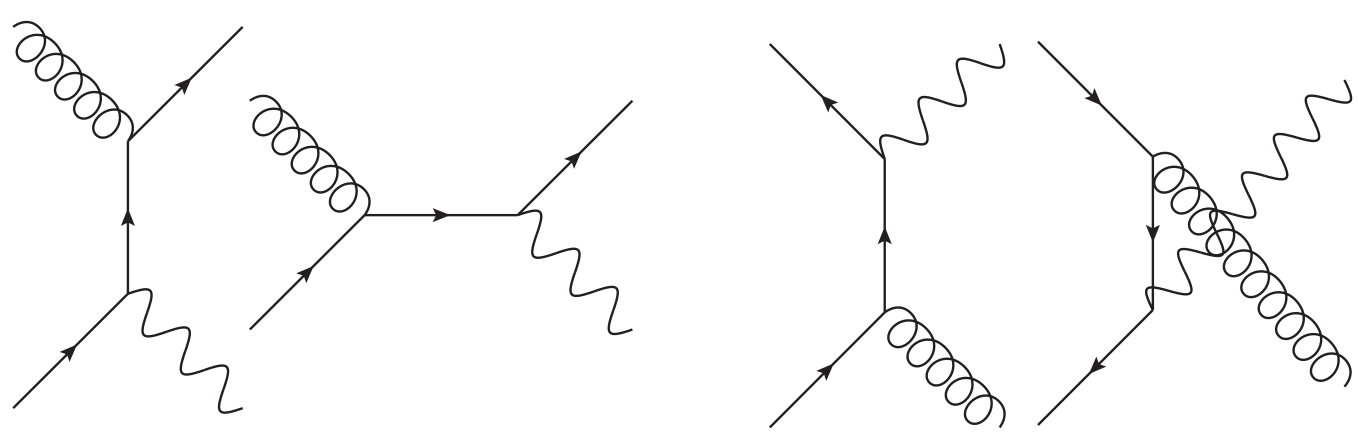
- The use of p-p collisions to look for new O(1) GeV gauge bosons could be disfavored w.r.t Pb-Pb collisions

Phys.Rev.C81:034911,2010

- For Pb-Pb collisions the QGP provides an additional thermal source of dileptons (much larger than that from non-thermal prompt production)

J.Phys. G38, 025105 (2011)

Phys.Rev. D54, 2399 (1996)



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- For these reasons a search for new O(1) gauge bosons decaying to muon pairs has been performed

- The strategy is to perform a **shape analysis** of the invariant mass distribution of opposite-sign muon pairs, in the mass range [1.5, 8.0] GeV/c^2

- Pb-Pb data at 5 TeV, collected in 2015, have been used

- Combinatorial background is estimated using the mixing technique and is subtracted from data

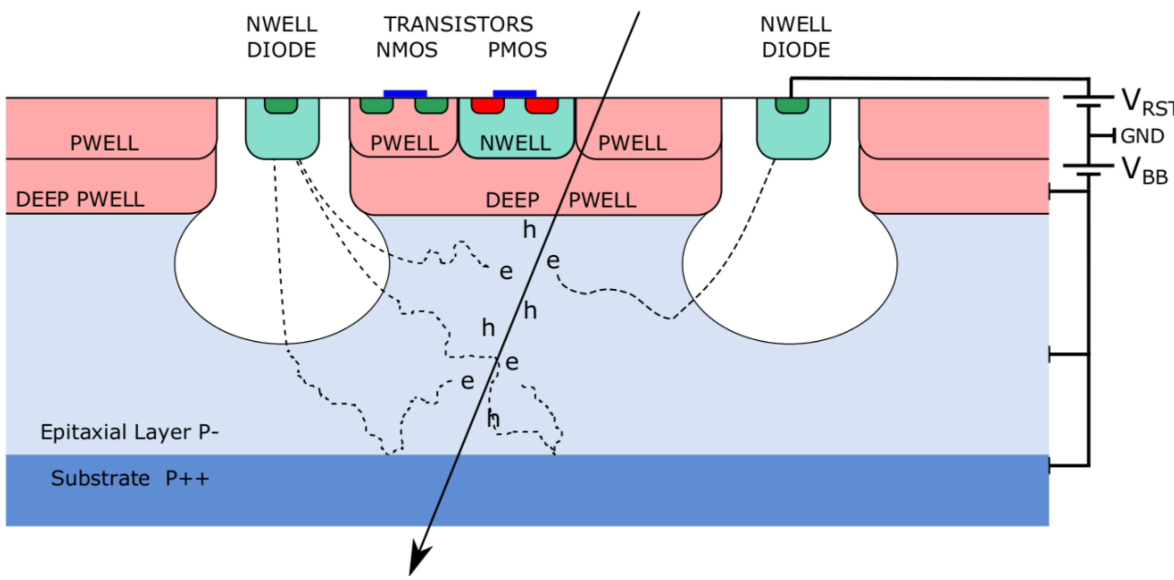
- The search is performed in different bins of centrality and dimuon pT

- **ALPIDE** chip is a CMOS Monolithic Active Pixel Sensor developed for the major upgrade of the Inner Tracking System (ITS) of ALICE

- It is implemented in a 180 nm CMOS Imaging Process

- chip size: 15 mm x 30 mm containing a matrix of 512 x 1024 pixels

- pixel size: 29.24 μm x 26.88 μm



- A charged particle crossing the sensor liberates free charge carriers in the material by ionization

- The electrons released in the epitaxial layer diffuse laterally while remain vertically confined by potential barriers

- The signal sensing elements are n-well diodes (~2 μm diameter)

- For the simulation of the ALPIDE chip, a **first** approach was to develop a fully parametrized simulation (mainly because of the unknown analog response of the chip)

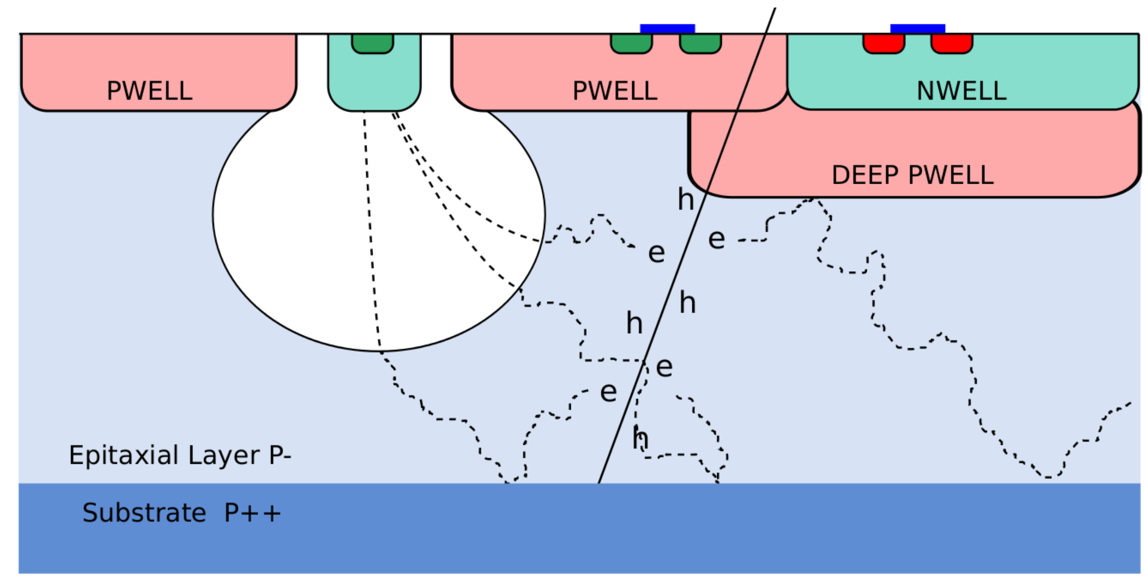
- In this context, two contributions were considered:

  - A contribution from physics to take into account the dependancy of average cluster size (**ACS**) on the energy deposited in the chip (ACS as a function of *βγ* was parametrised as below)

$$A \cdot \frac{1+x^2}{x^2}\left[\frac{1}{2}\cdot\ln(B\cdot x^2) - \frac{x^2}{1+x^2} - C\cdot\ln(x)\right]\cdot\frac{1}{\cos\theta}$$

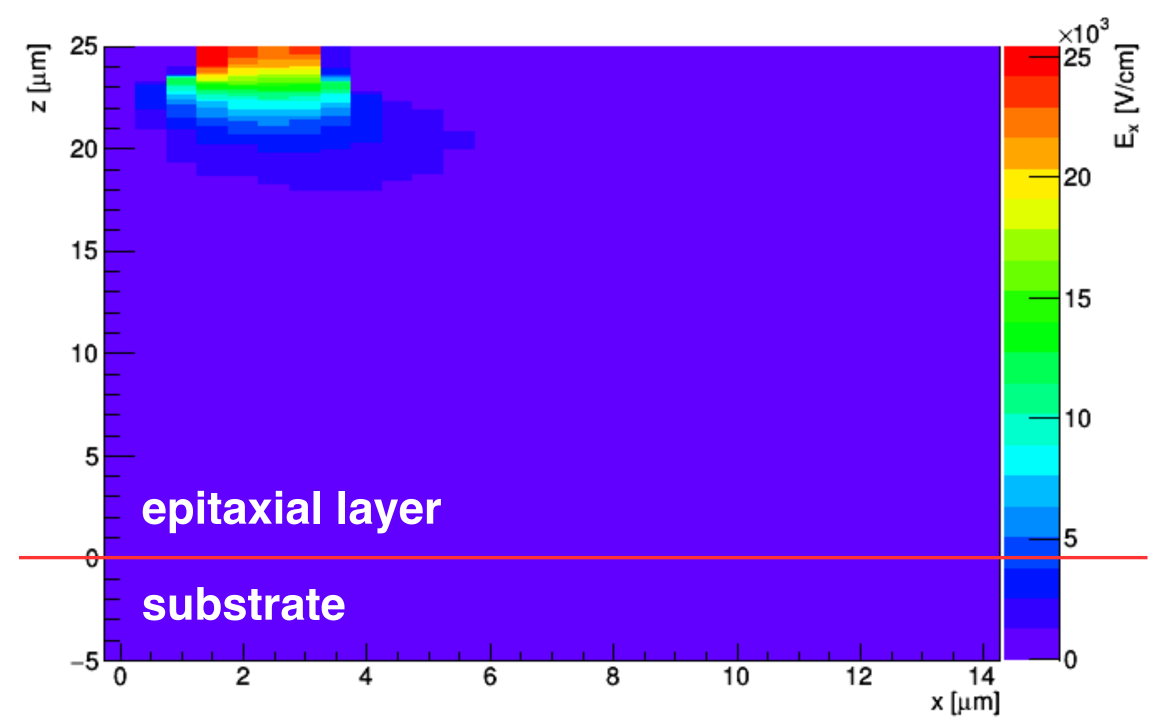
  - A detector contribution to take into account the dependency of the ACS on detector-based parameters like the particle crossing position, the threshold, Vbb, etc…

- On May, Miljenko Šuljić and Jacobus W. van Hoorne presented a new “microscopic” simulations of MAPS



- Carrier transportation in MAPS sensitive volume is due to both diffusion and drift

- The diffusion was simulated as a random walk of each individual electron



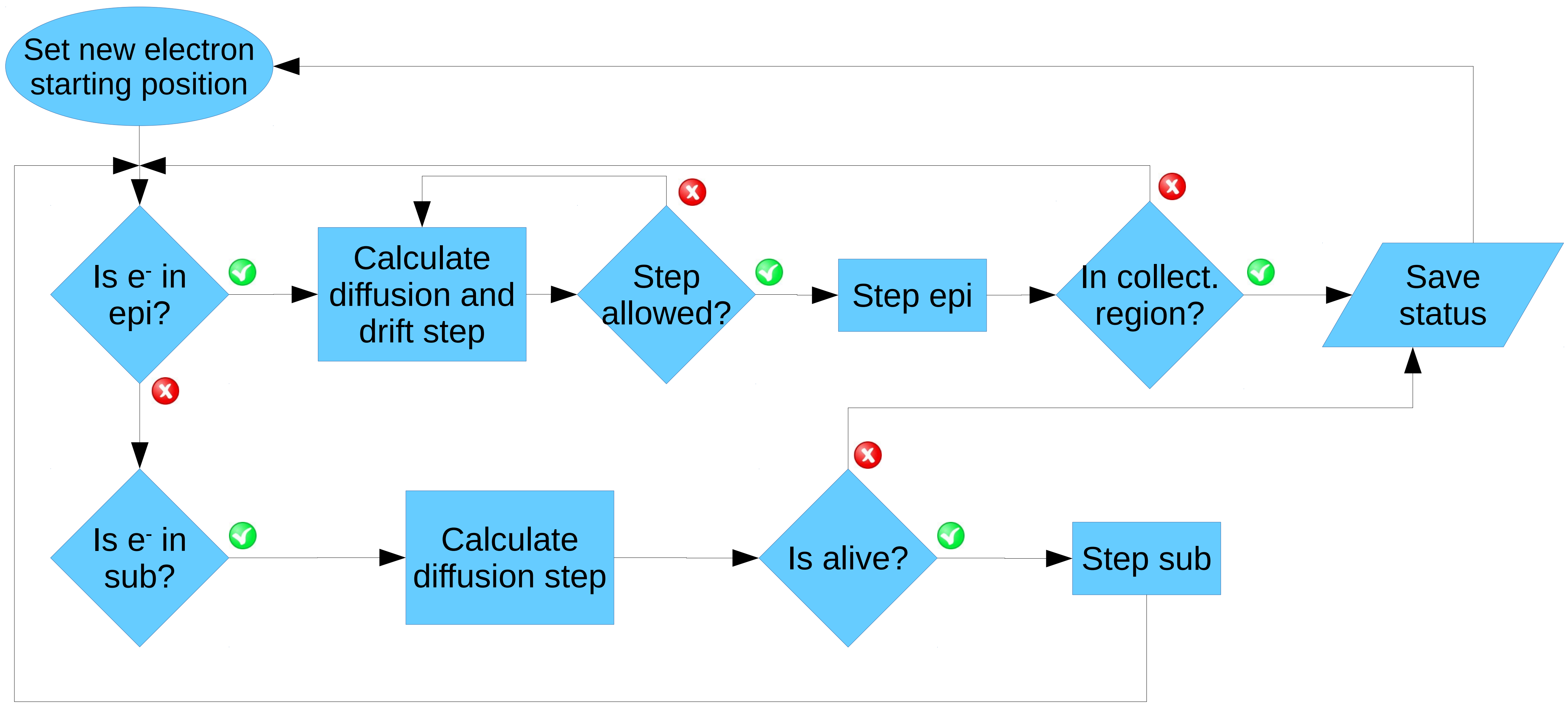
- The drift was simulated using the electric field maps extracted from a TCAD simulation

- Simulation step is the sum of the diffusion and drift steps

- Collection region is defined by n-well volume + 1⁄2 spacing and 2 μm thick "high field" region directly below

Miljenko Šuljić

Algorithm

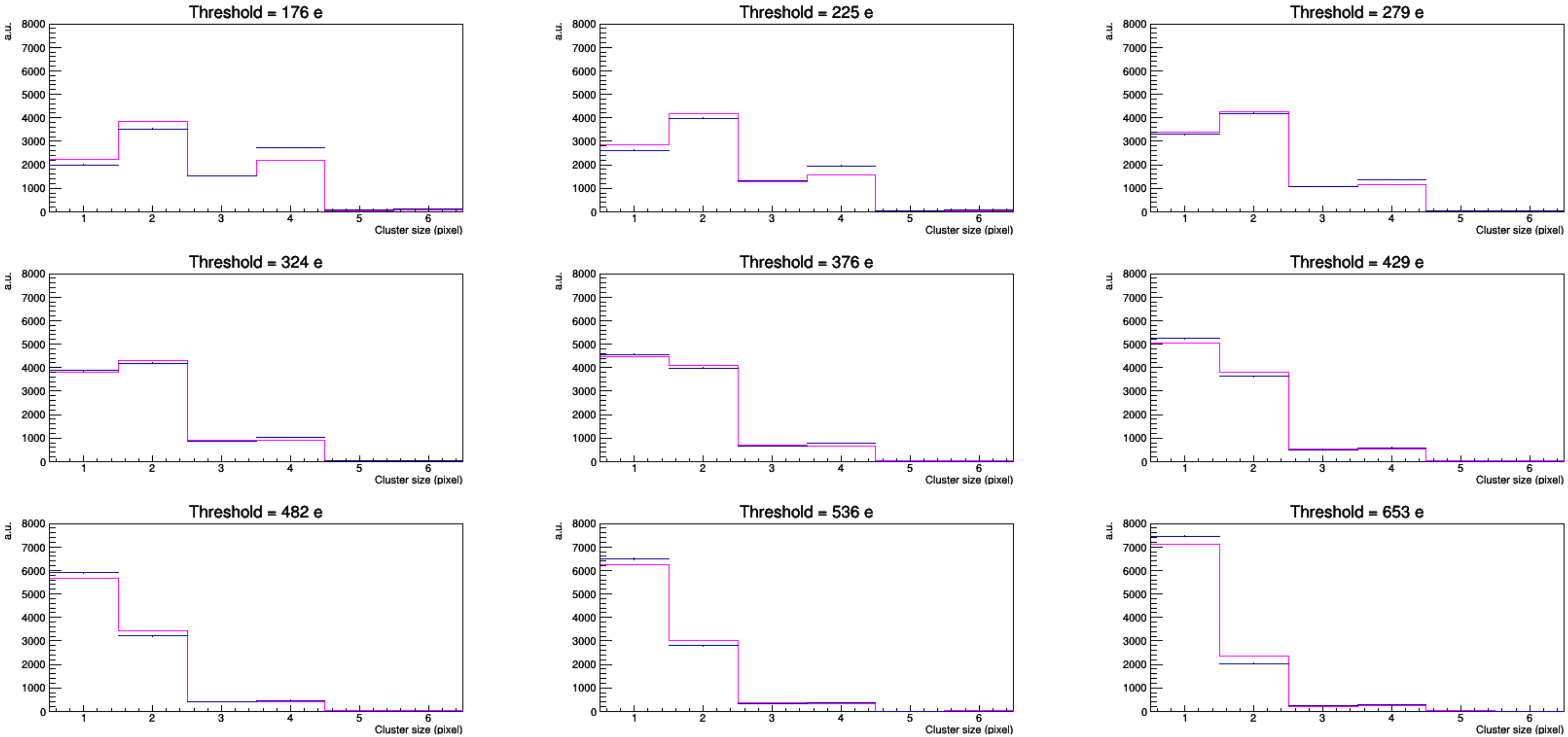


- Total simulated volume: 5x5 pixels

- The agreement between simulation and data is really amazing

Miljenko Šuljić

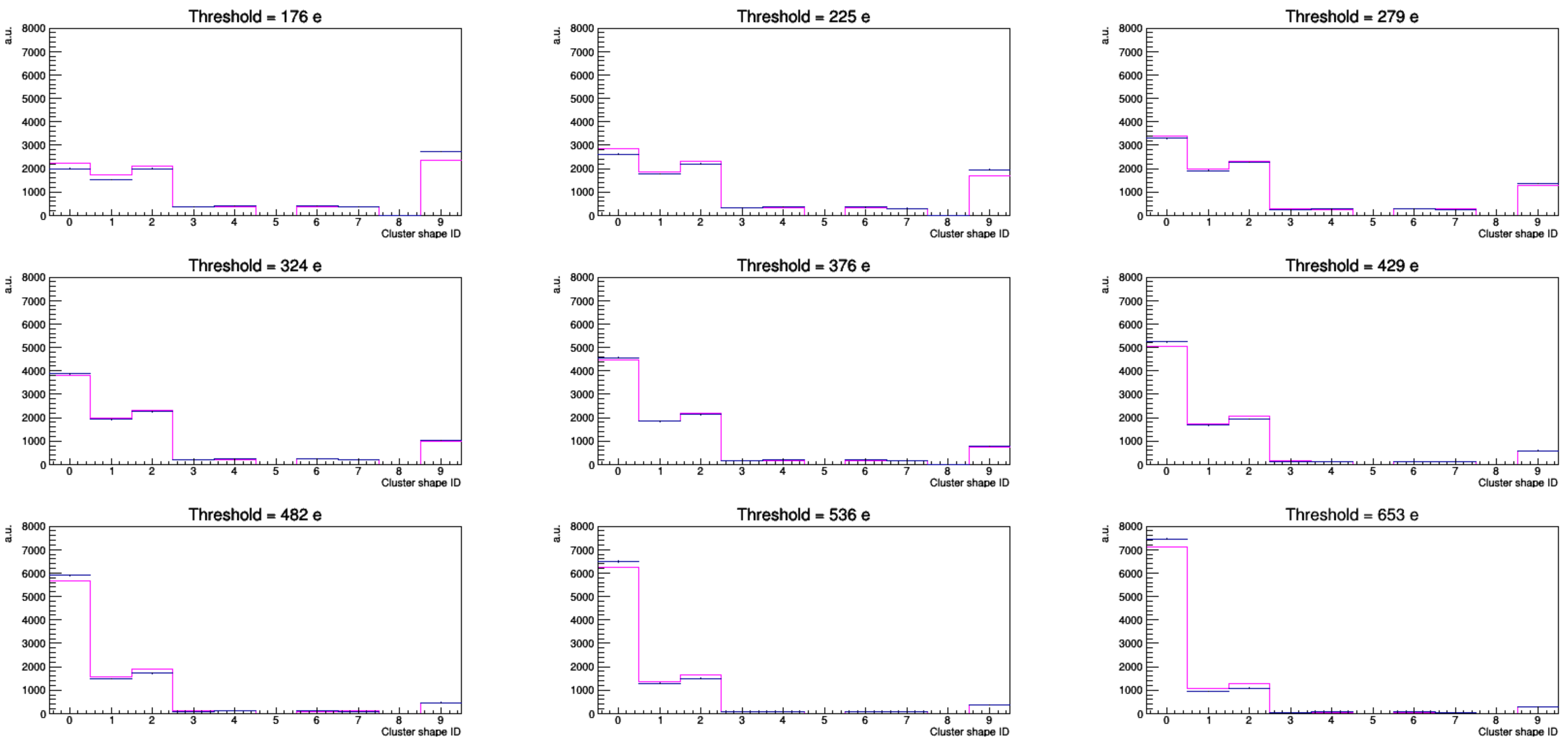
Cluster size at different thresholds (scaled)



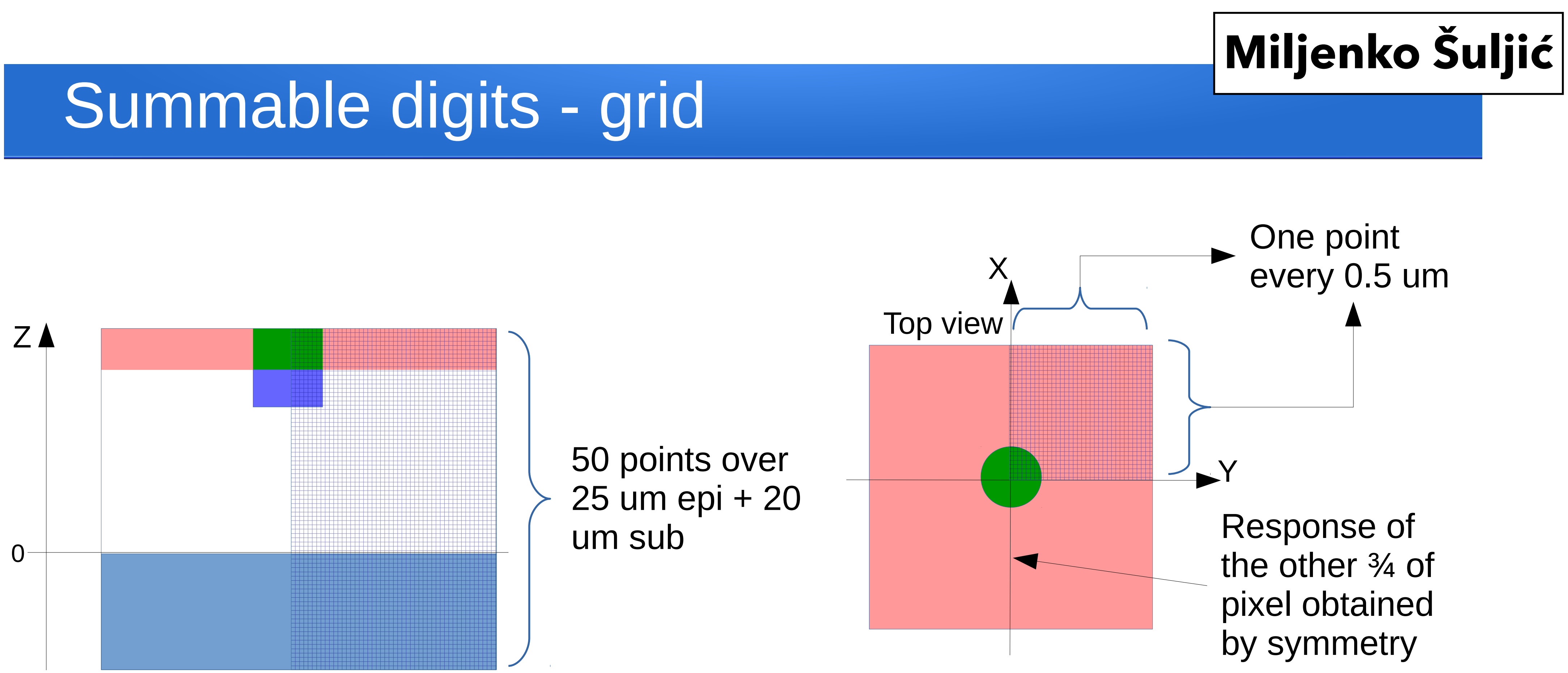
- The agreement between simulation and data is really amazing

Miljenko Šuljić

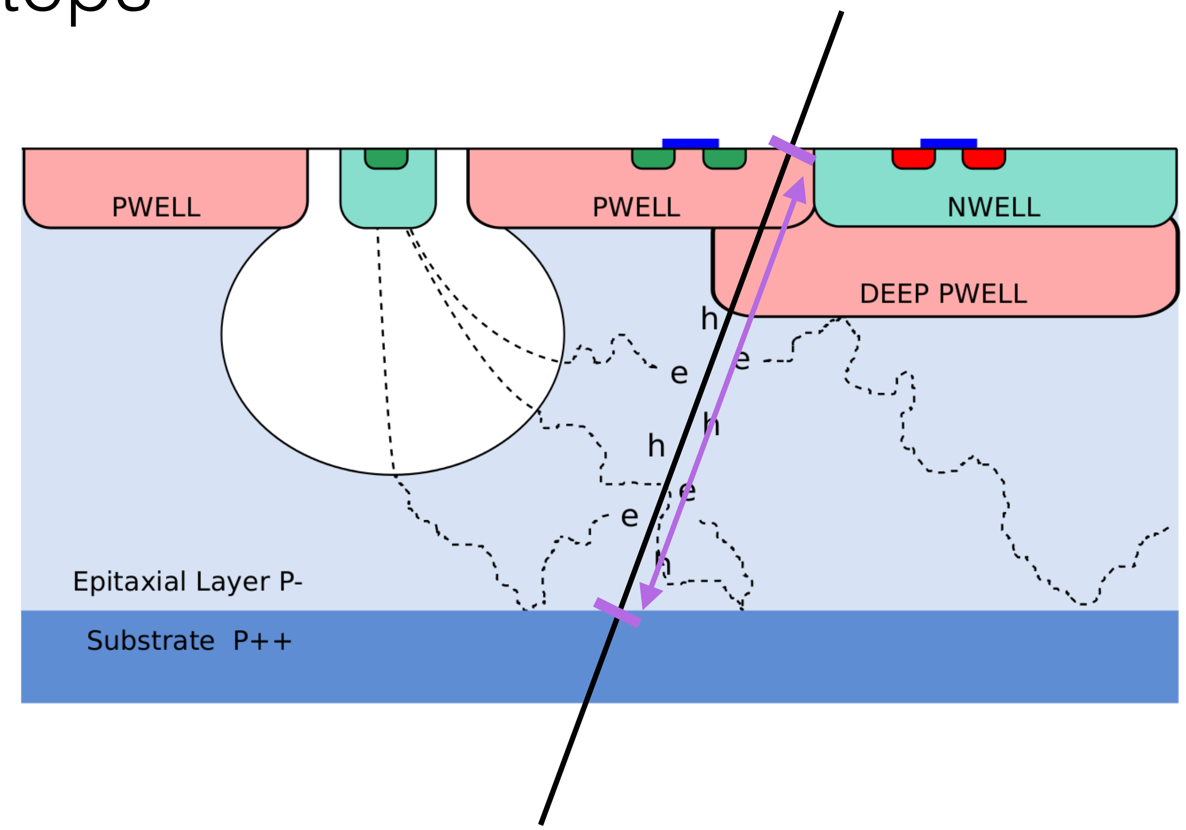
Cluster shape ID at different thresholds (scaled)



- Because of these impressive results we all decided to stop the development of the parametrized simulation and to port the new microscopic simulation to O2
- Miko’s simulation could not be ported to O2 as “it is”
- We decided instead to use the simulation to produce a detector response table to be loaded and used in O2



- When we have a hit in a pixel, we divide the path of the crossing particle in the epitaxial layer into N_{step} steps



- The energy loss of the track in the chip is converted to N_{ele}
- For each step N_{ele}/N_{step} electrons are assumed to be generated at the step position (pixel reference frame)
- Using the simulation grid from Miko the (normalised) response matrix is obtained
- The N_{step} response matrices from each step are summed up and multiplied by N_{ele}/N_{step} which gives the distribution of the N_{ele} electrons in the 5x5 pixels centred around the crossing position