

Simulation of the spark rate in a Micromegas detector with Geant4



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Outline

Introduction 1 – CLAS12 (and RD51)

Introduction 2 – existing data on sparks

Geant4 simulation of a MM in hadron beams

- *Highly Ionizing Particles (HIPs) production*
- *Deposited energy*

Spark rate estimate

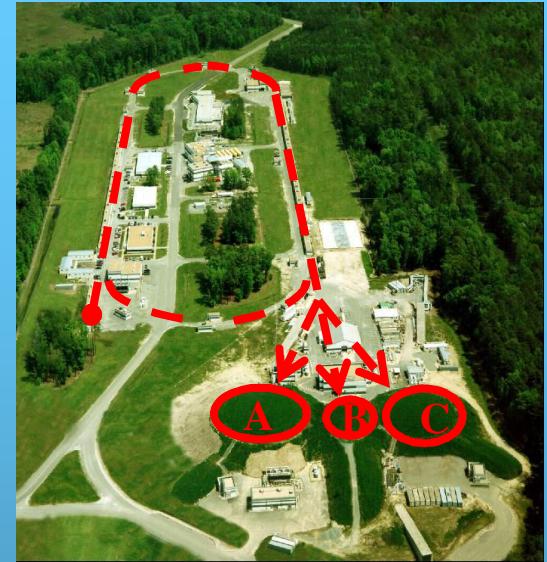
- *Normalized and real gains*
- *Comparison with data / effect of the gas mixture*
- *Systematics (production threshold, integration size)*

Predictions and conclusion

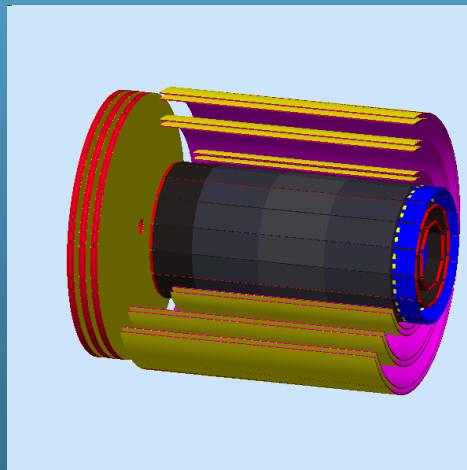
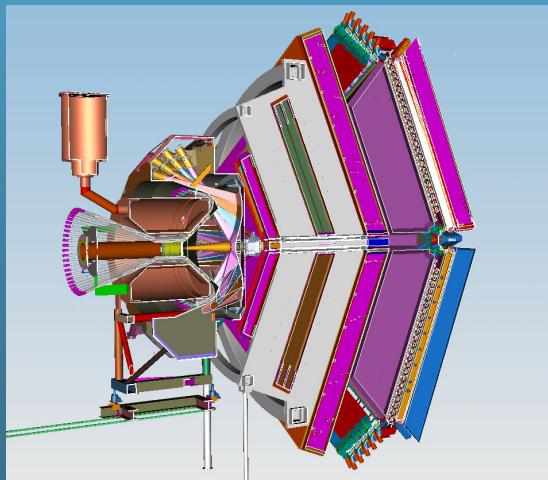
- *Bulk vs non bulk Micromegas*
- *Effect of the drift electrode material*
- *Applicability for CLAS12?*

CLAS12

→ CLAS = CEBAF Large Angle Spectrometer
(running experiment, Hall B) @ JLab



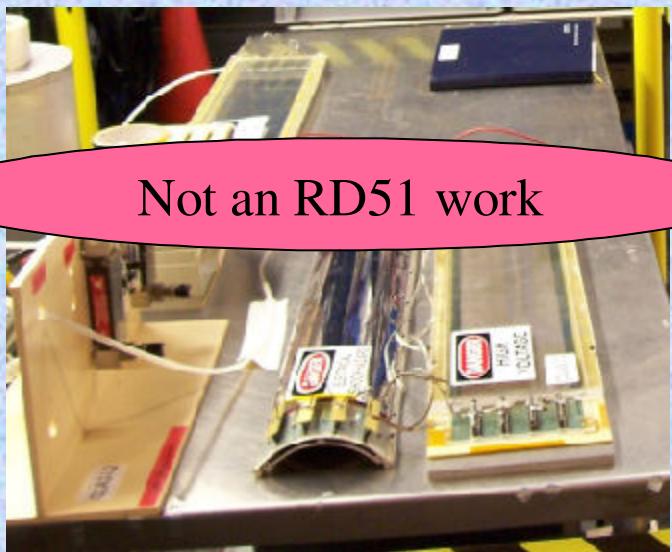
→ Will be upgraded for the energy increase of the accelerator (12 GeV) ~ 2014



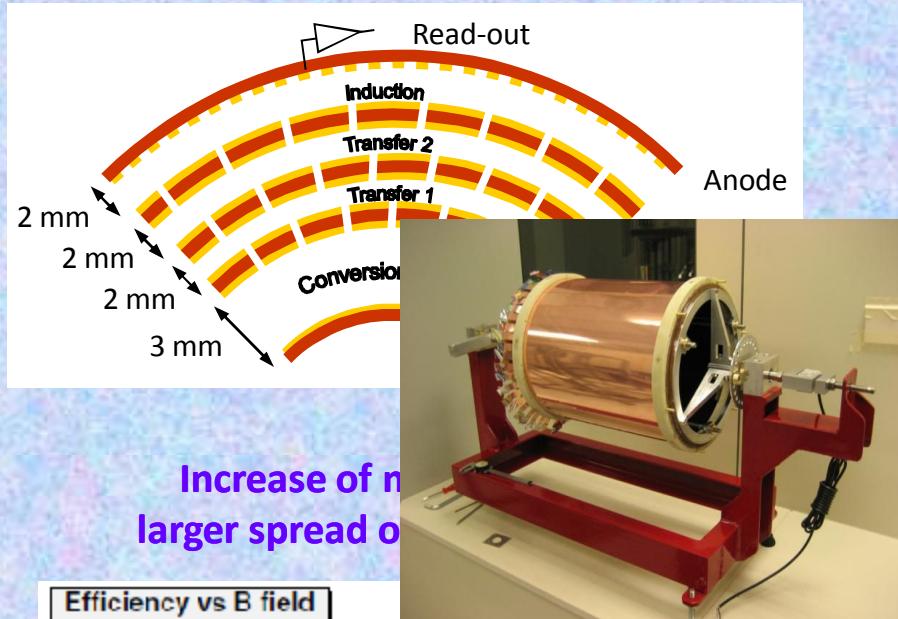
- 1st cylindrical MM
- 5 T transverse field
- 4 m² of MM

RD51 WG3 - Curved Bulk Micromegas and Cylindrical GEMs

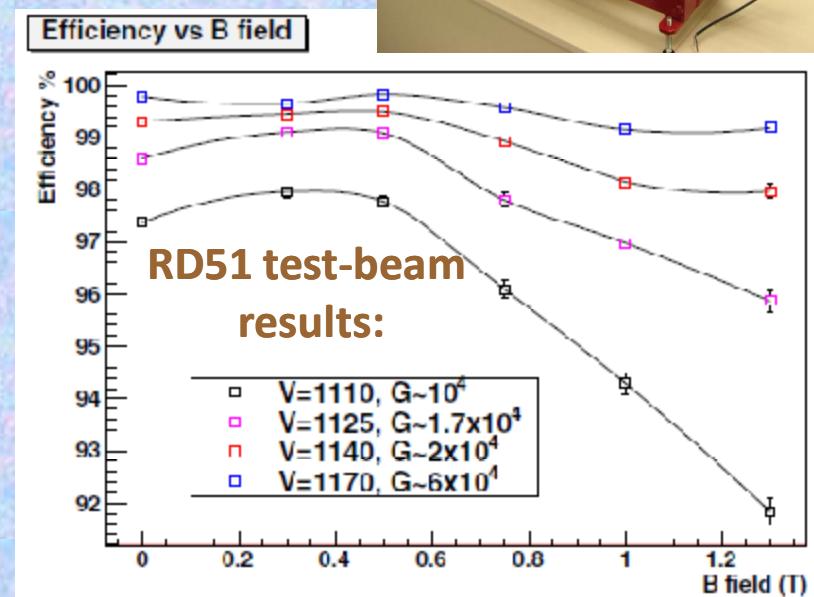
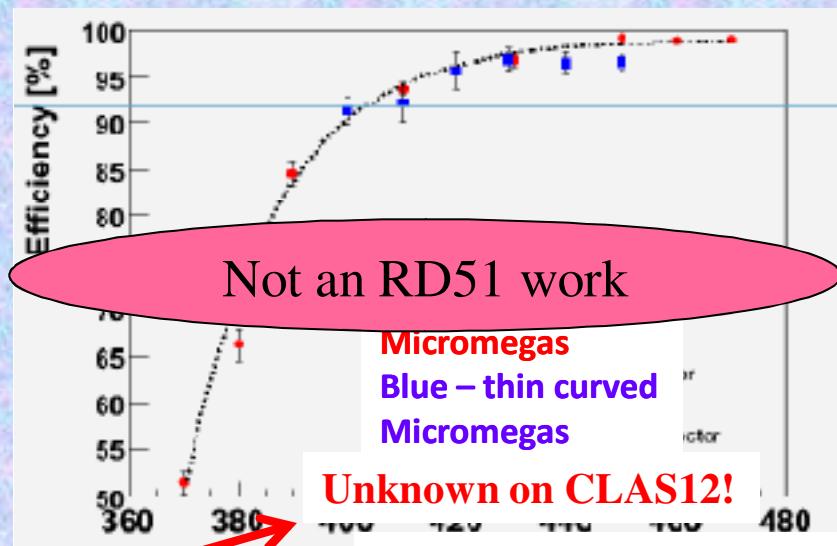
Thin Curved Micromegas for CLAS12



Cylindrical GEM for KLOE2 Inner Tracker:

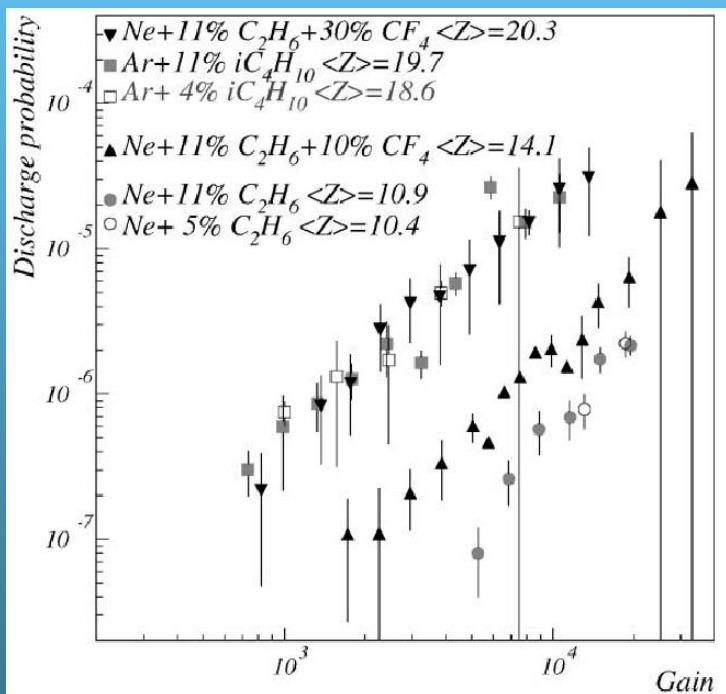


Increase of n
larger spread of



Sparks in Micromegas

- a spark/discharge is a rapid breakdown appearing in the amplification gap , visible in various experimental conditions (alpha source, hadron beams, etc...)
- pioneering work:
 - D. Thers et al., NIM A469 (2001), 133
 - A. Bay et al., NIM A 488 (2002), 162



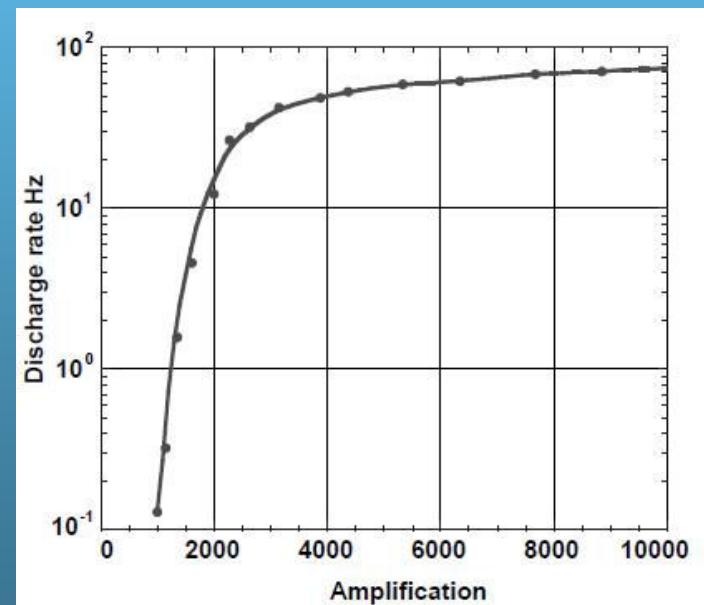
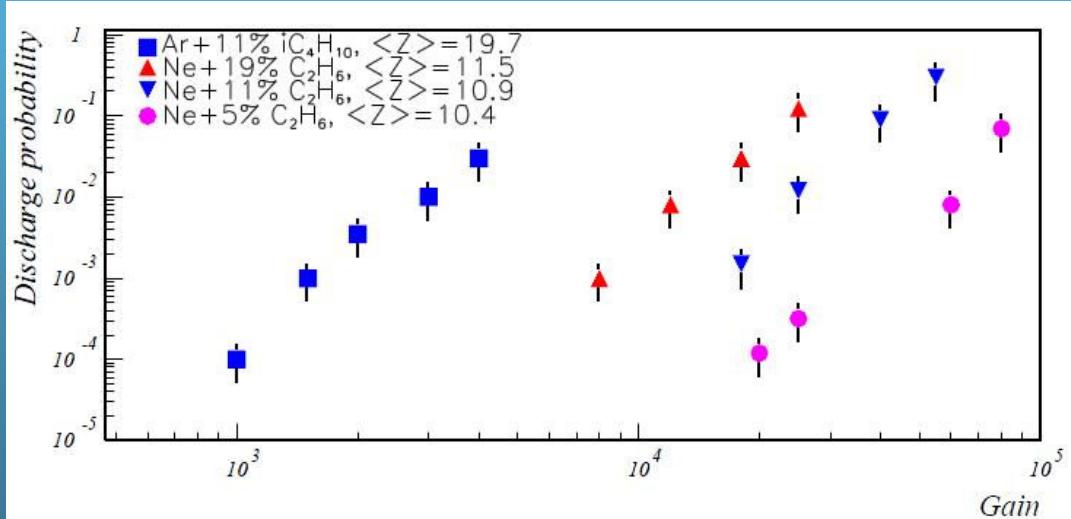
→ Spark rate is a power law of the gain
→ Strong dependence with Z (gas)

« A likely explanation is that a discharge is triggered when an energy of a few hundred keV is released in the detector conversion gap resulting in a large number of primary ions »

This behaviour was confirmed by several experiments
(+ additional studies with α sources...)

Some experimental discrepancy

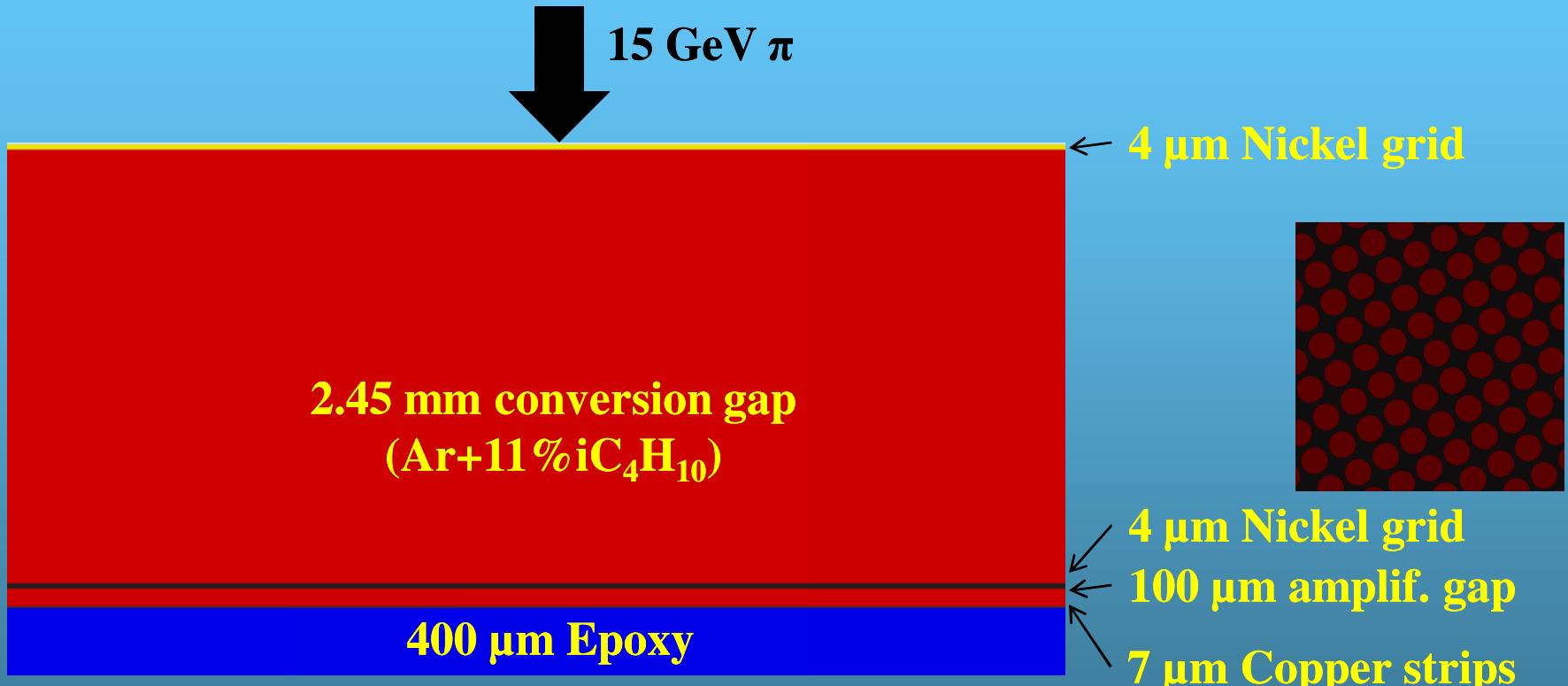
Author	Thers (PhD, 2001)	Bay (2002)
Drift gap	3 mm	3 mm
Amplification gap	0.1 mm	0.1 mm
Vdrift	700 V	600 V
Gas	Ar+iso (89-11)	Ar+iso (91-9)



?

Geant4 simulation of a MM

Simulation of the detector tested by Thers et al. in hadron beams

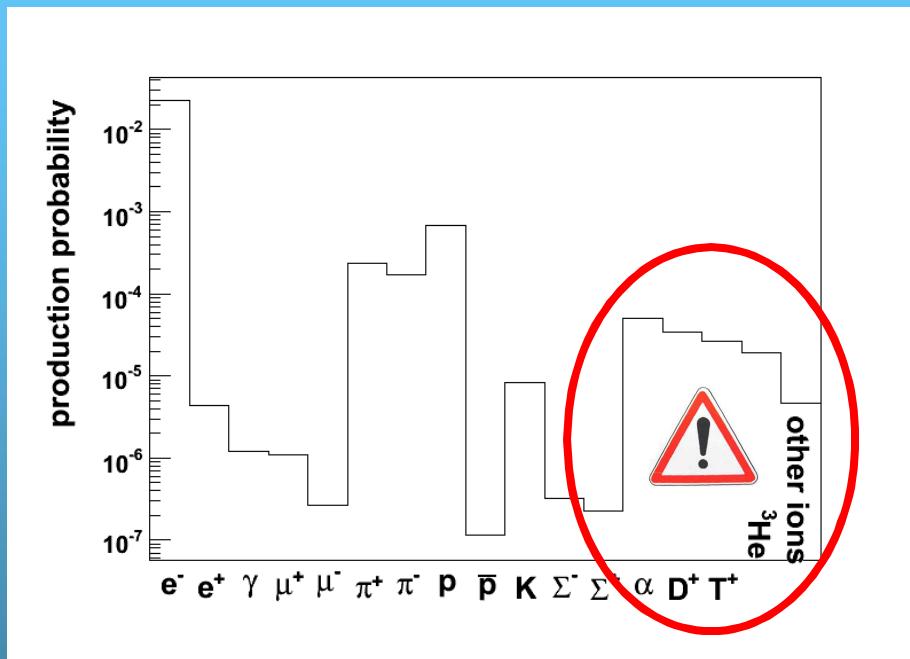


- Physics list: QGSC_BERT
- Integration of Edep in 300x300 μm^2
- Production threshold: 300 μm

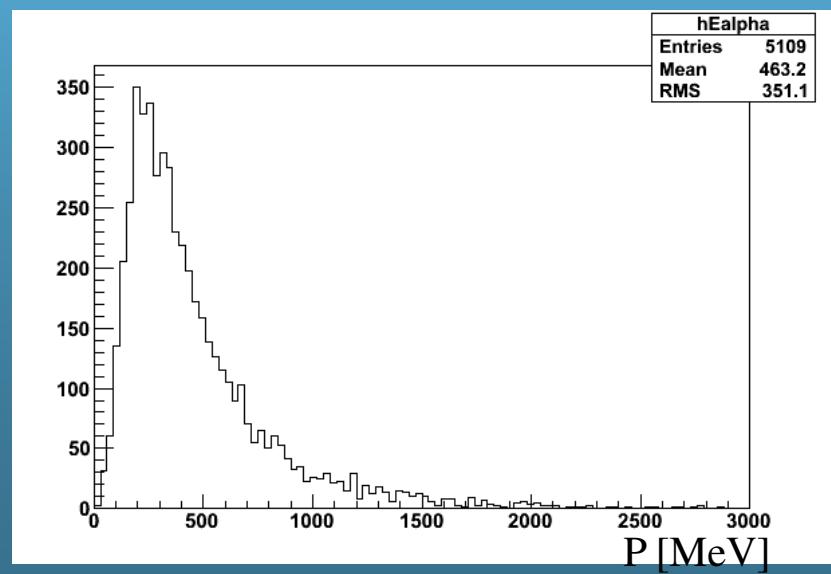
Requires large simulation
(rare processes, $\sim 10^{-6}$)

Secondary particles production

Many different types of secondary particles can be produced:

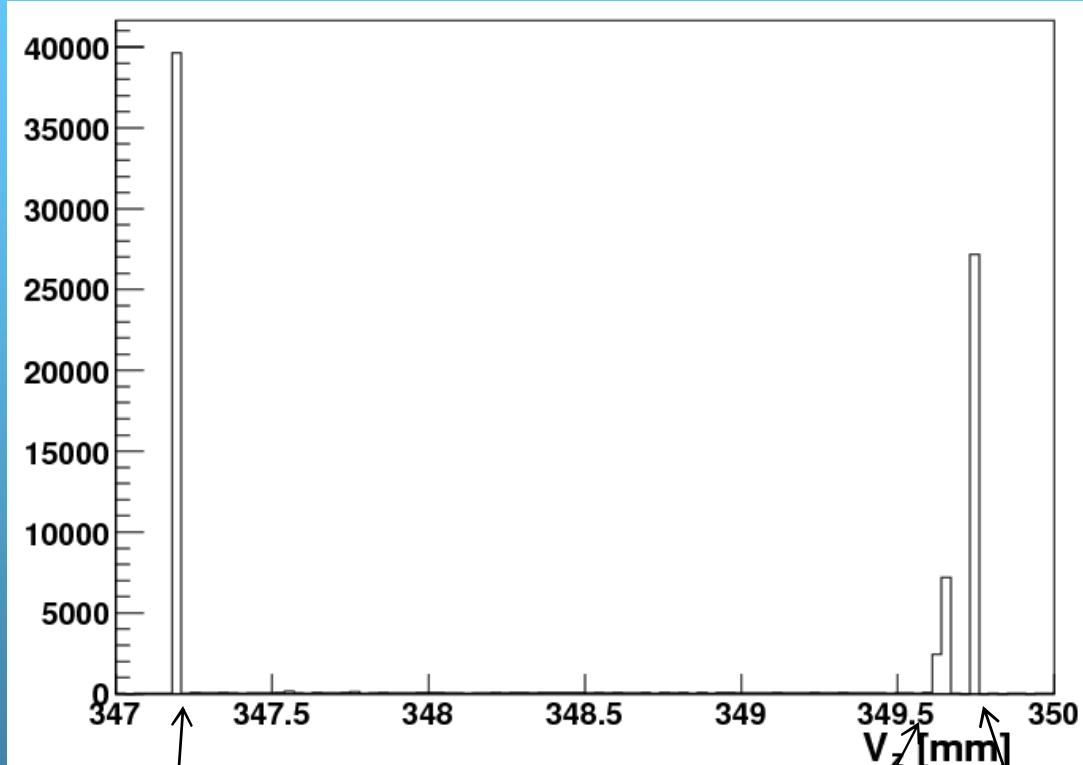


→ small probability to produce HIPs

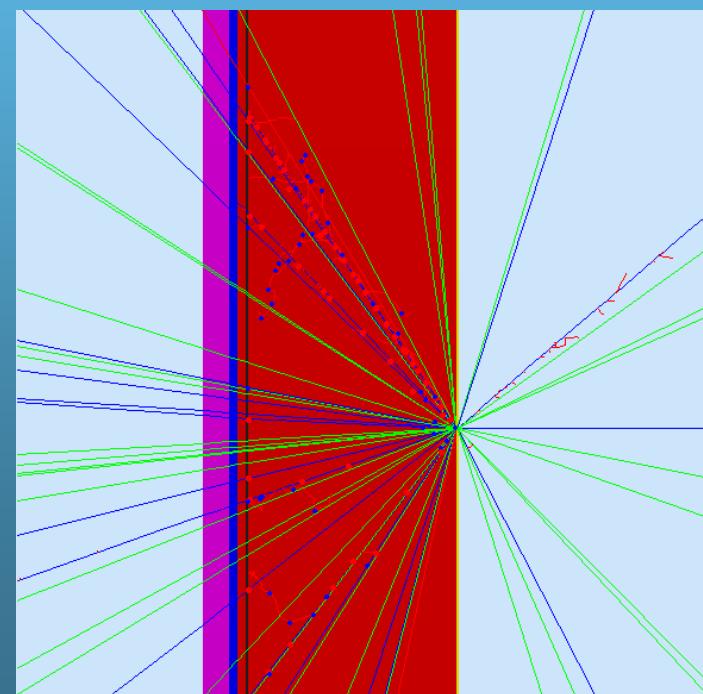


Origin of the HIPs

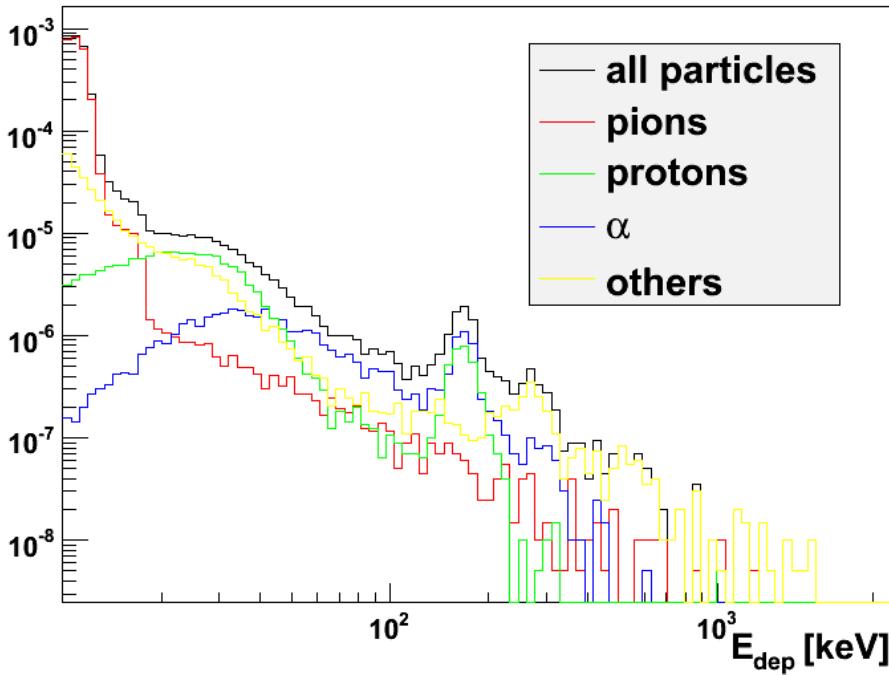
Origin of particles leaving at least 0.2 MeV in 300x300 μm^2 :



- 42% from the drift electrode
- 22% from the gas
- 10% from the micro-mesh
- 23% from the strips



Deposited energy distribution

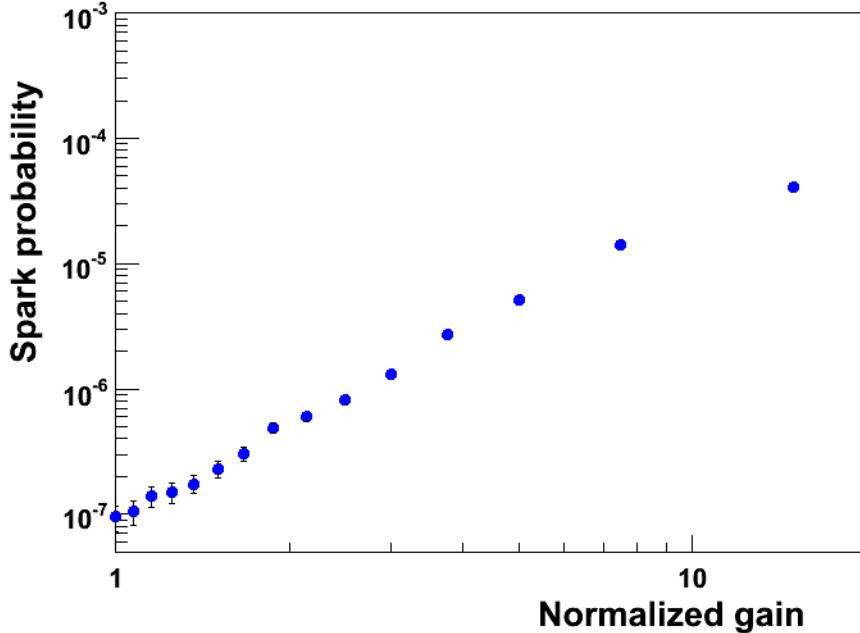


→ Energy above 1 MeV can be deposited! (~2000 times more than a MIP)

We will assume that :

- the number of primary electrons is proportional to E_{dep} ($N_p = E_{\text{dep}}/w_i$)
- if a deposited energy of 1 MeV produces a spark at a gain equals to unity (normalization), then a 500 keV deposit will produce a spark with a gain of 2

Spark rate estimate



$$S(G_n(E_{dep})) = \int_{E_{dep}}^{\infty} f(X)dX$$

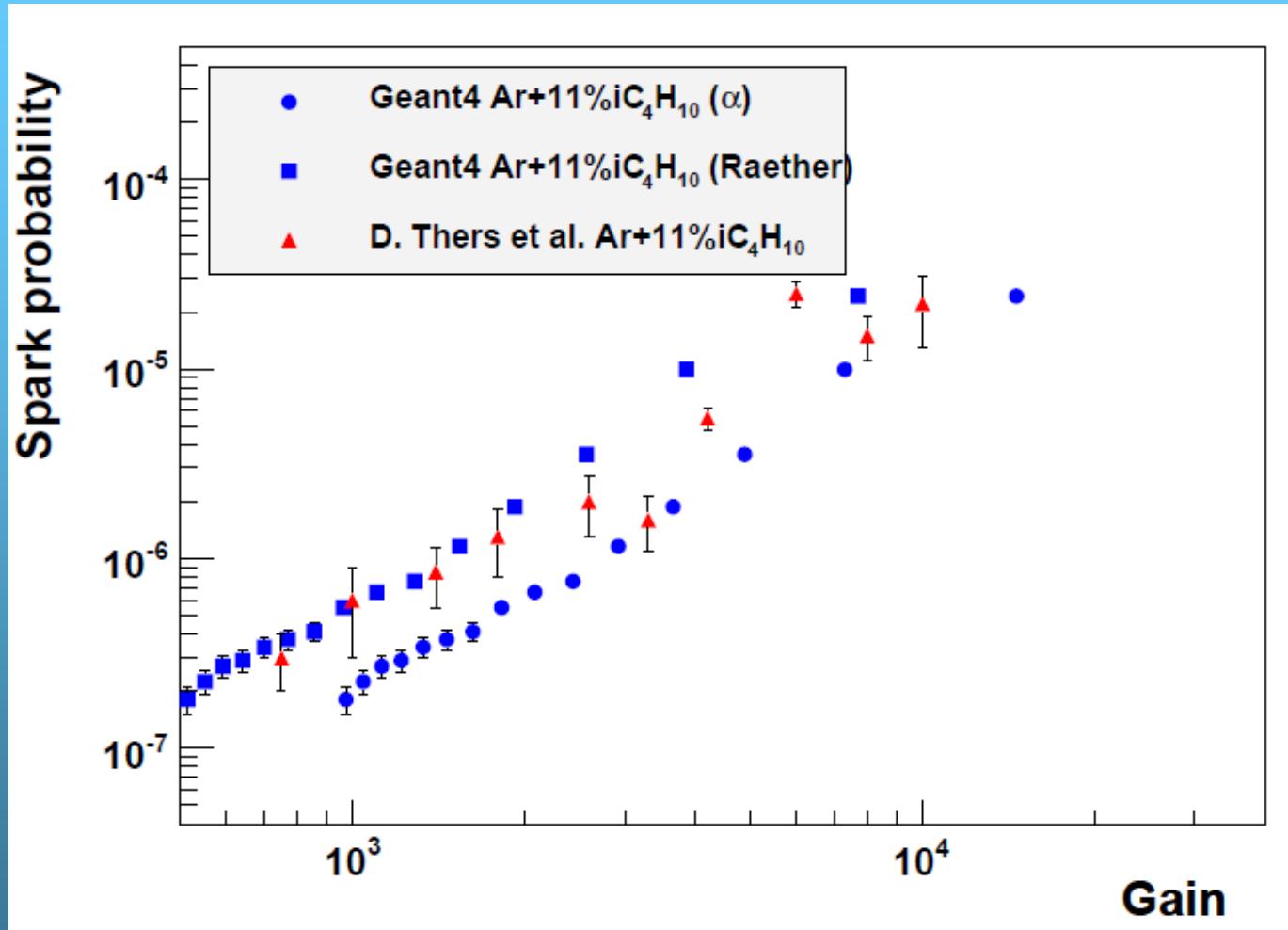
$$G_n(E_{dep}) = \frac{1 \text{ MeV}}{E_{dep}}$$

→ Power law dependence is clearly observed, as in the data

How to relate the « normalized » gain (from simulation) to the real one?

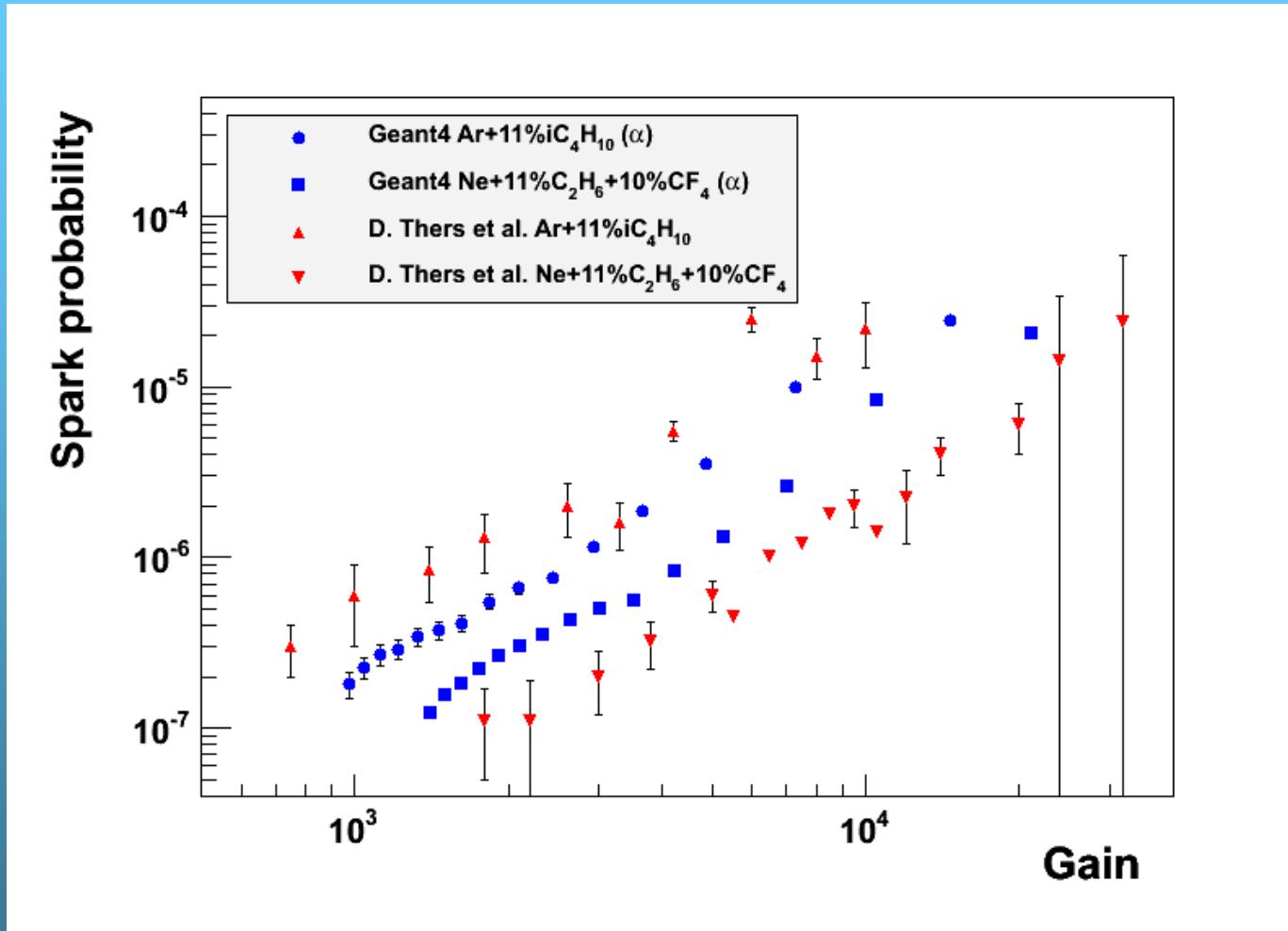
- 1) Make use of the Raether's limit (spark if $N_p \times G \sim 2 \times 10^7$)
- 2) Relate the spark rate with a α source and deposited energy

Comparison with data



- 1) Correct order of magnitude
- 2) Similar slope

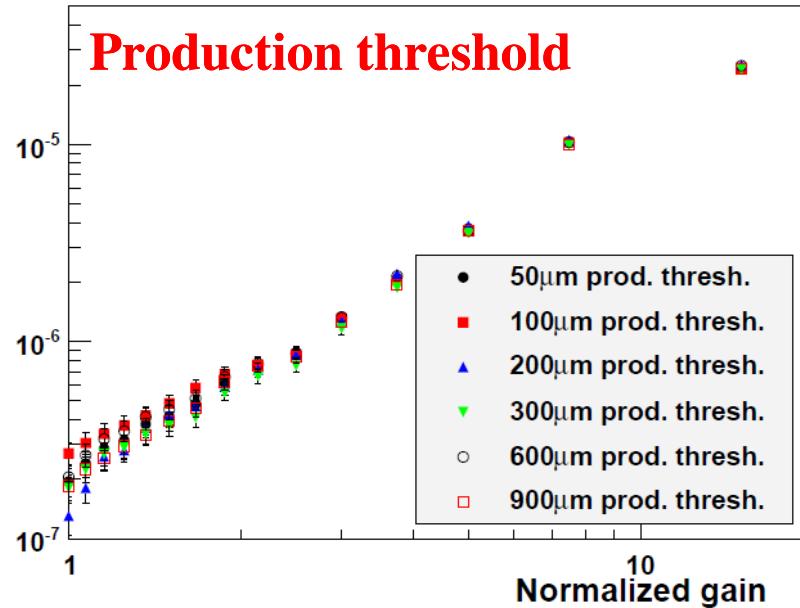
Effect of the gas mixture



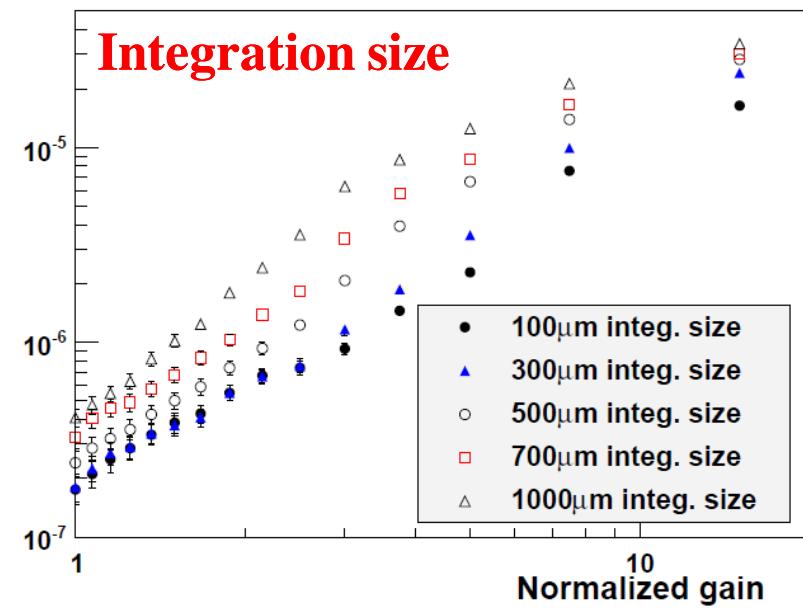
Simulated spark rate also grows with weight of the gas

Some systematics

Spark probability



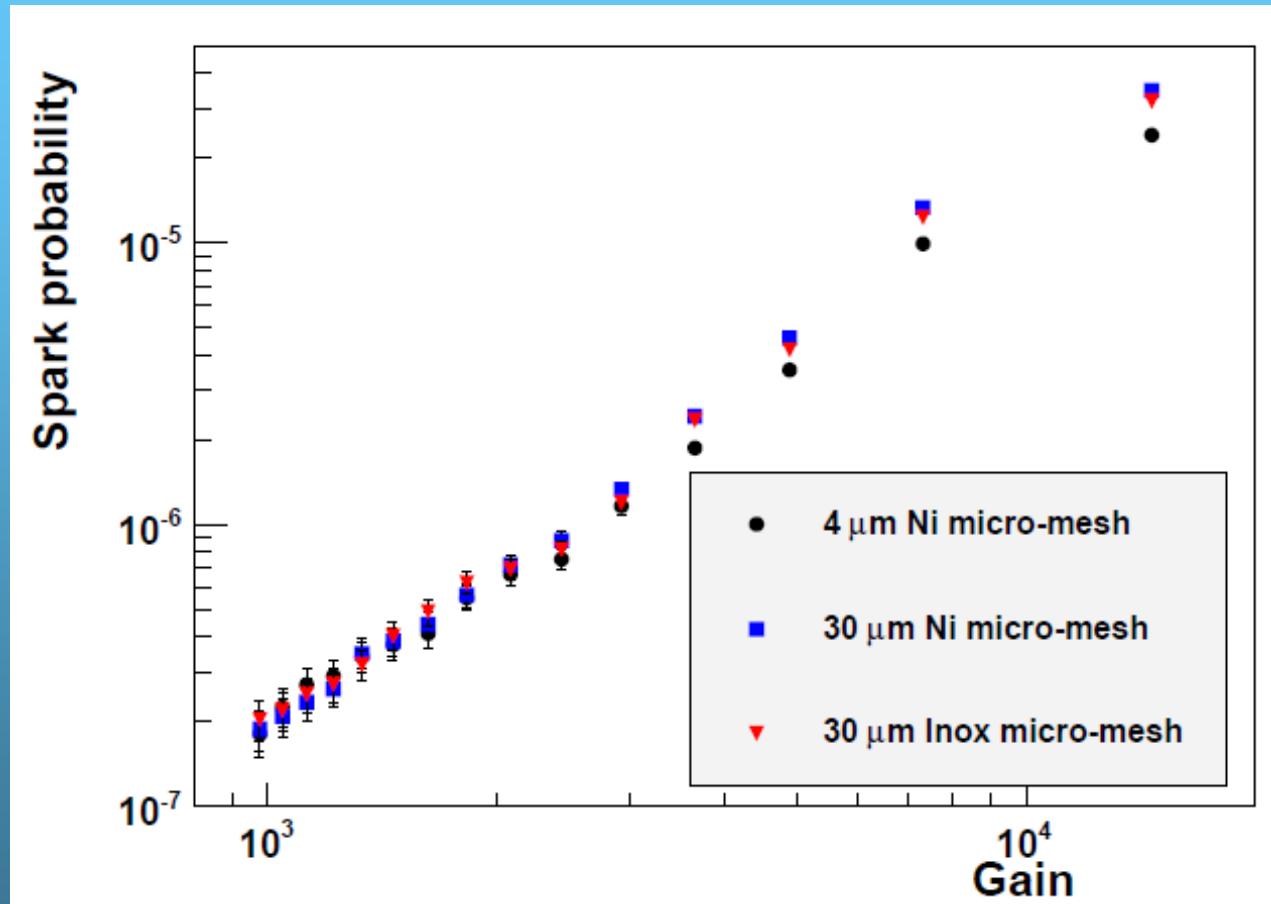
Spark probability



→ Dependence only on the integration size (should be close to transverse diffusion size)

Spark rate predictions

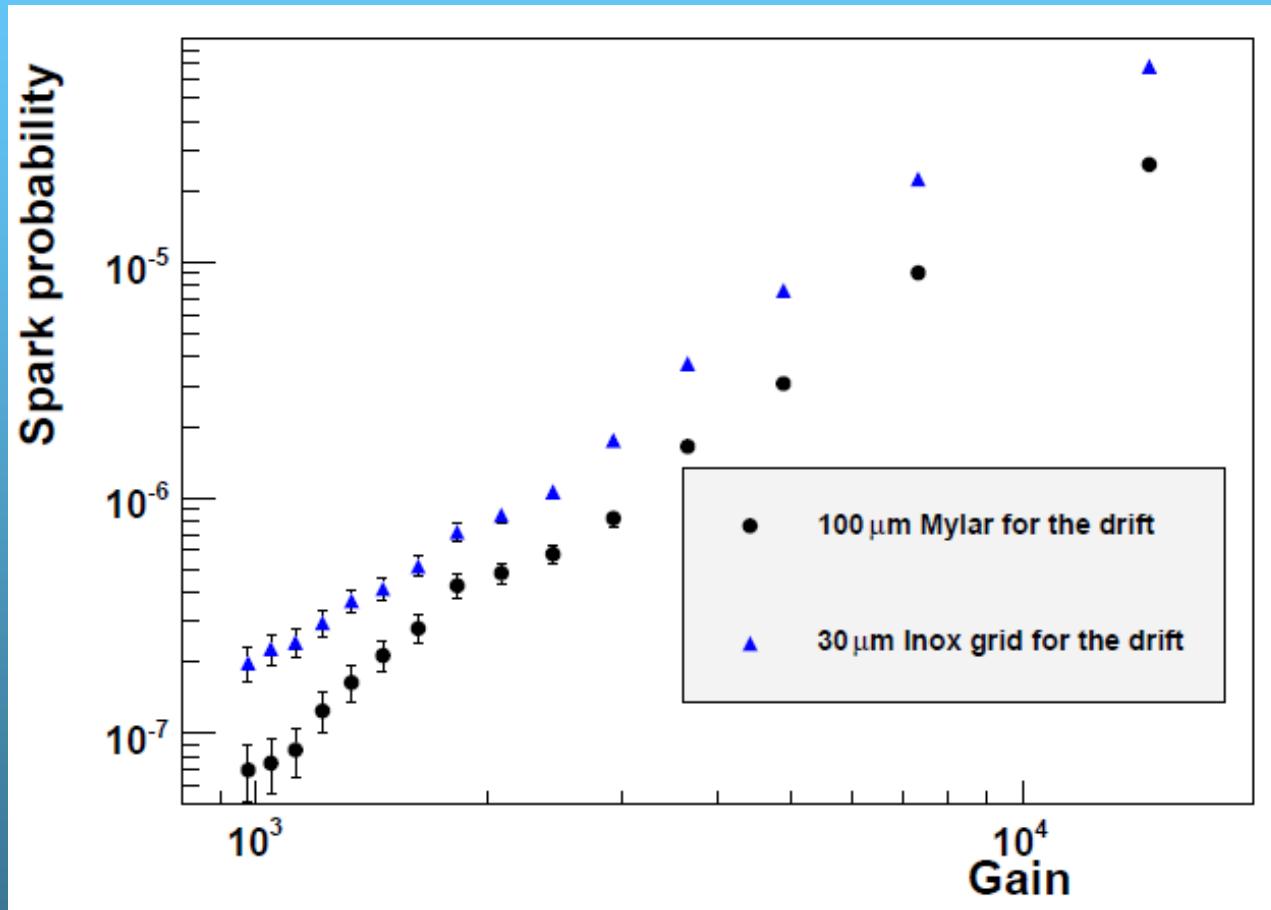
1) Bulk (woven, thick mesh) vs non bulk (electroformed, thin grid):



→ Expect similar spark rate for the 2 types of detectors

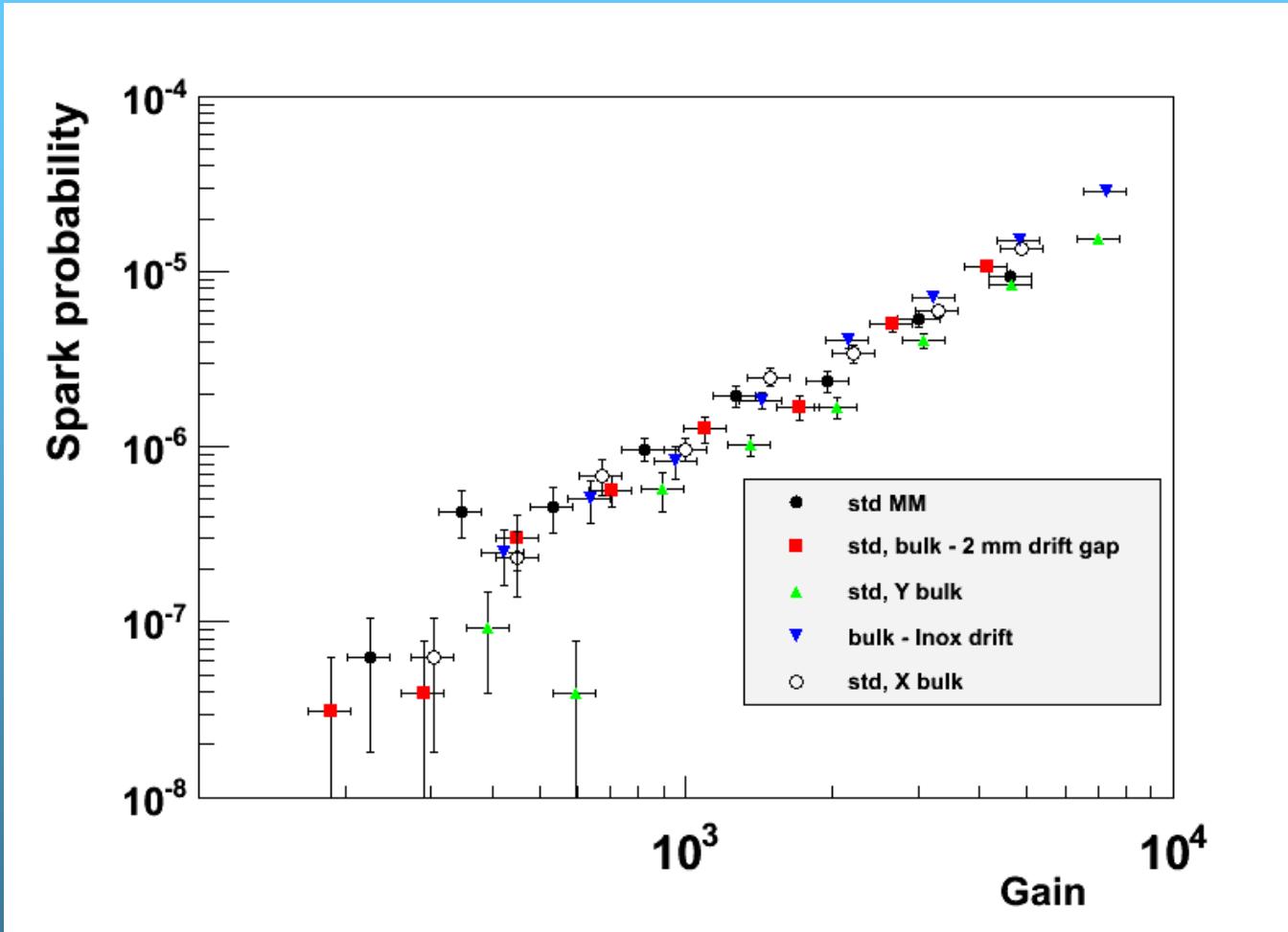
Spark rate predictions

2) Aluminized mylar vs woven Inox drift electrode:



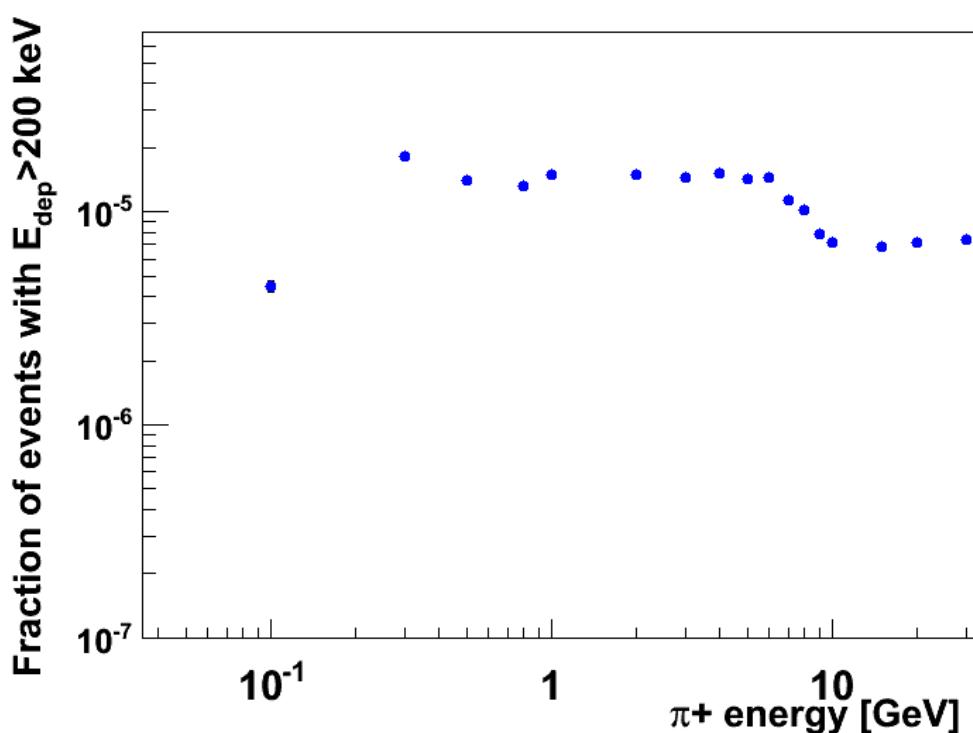
→ Spark rate ~2 times larger with the Inox drift

CERN RD51 tests (150 GeV, 10/2009)



→ Bulk~non bulk; Inox drift>~ mylar drift (but large dispersion)

Towards a SR estimate for CLAS12



→ Looks suspiciously stable
down to 300 MeV

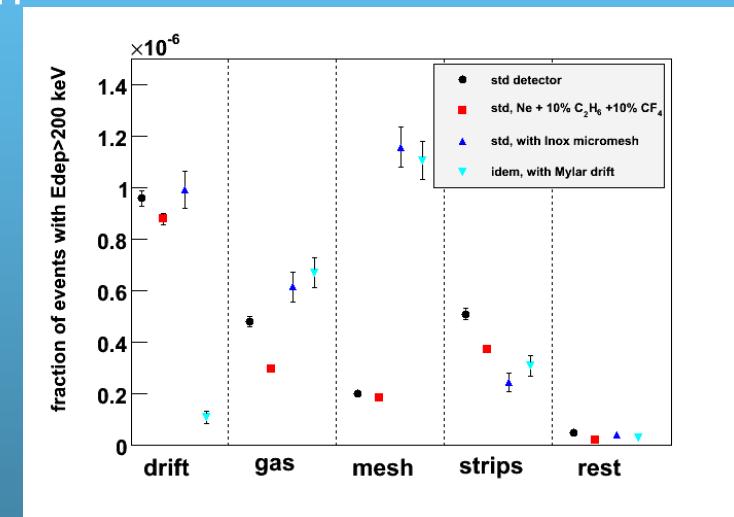
It would be really useful to experimentally investigate the SR at energies below 2 GeV (CERN PS beam request in 2010)

Conclusion

- Better understanding of sparks? (HIPs production)
- May be just a coincidence, but the simulation predicts:
 - 1) the correct amplitude of the spark rate
 - 2) the correct slope as a function of the gain
 - 3) a smaller rate for lighter gas

⇒ Can use it to optimize the detector design
(material, mesh segmentation)

- Work recently submitted to NIM A



- Still doubts on the reliability of the simulation at CLAS12 energies
- ⇒ Tests at PS soon

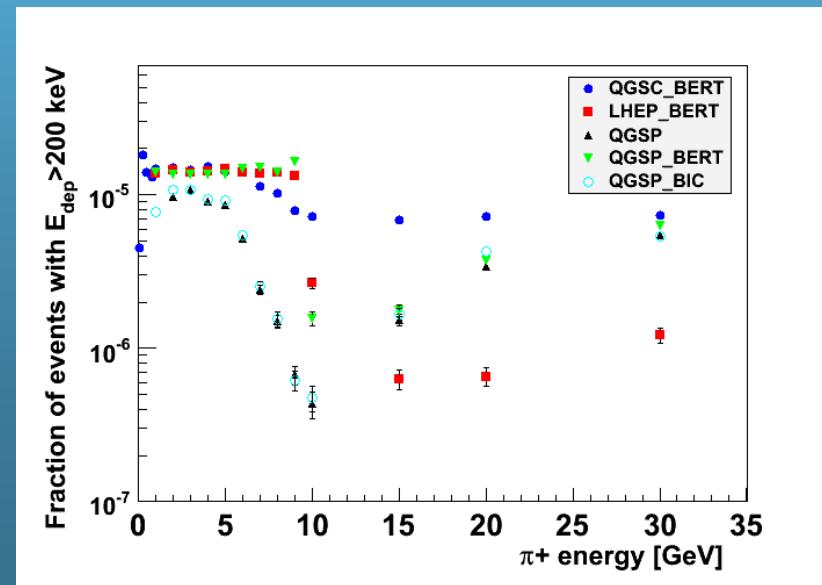
Backup

Physics lists - 1

→ Many physics lists available in Geant4:

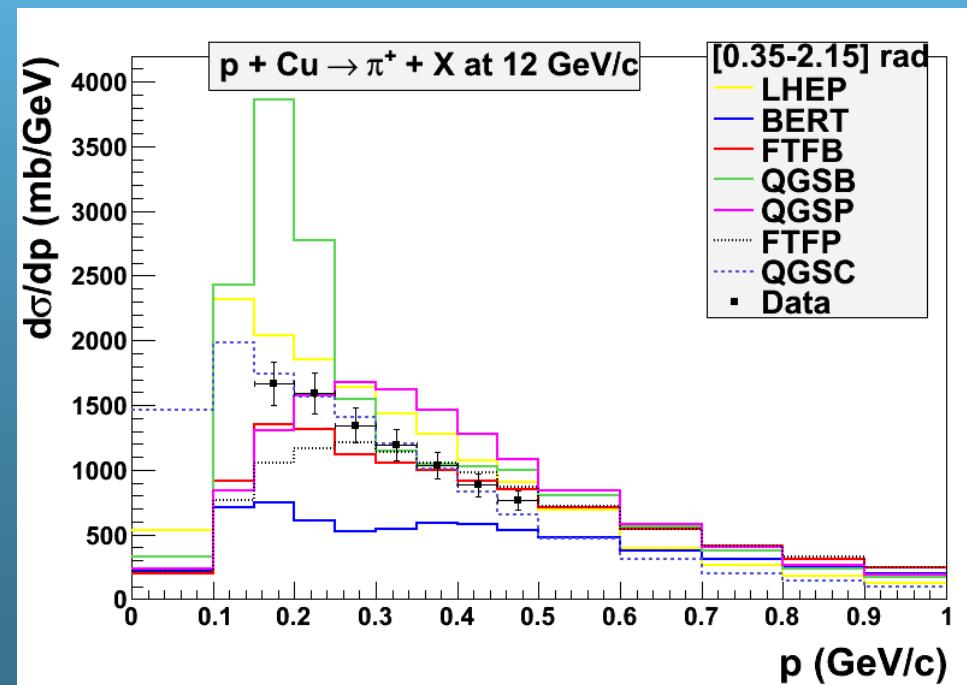
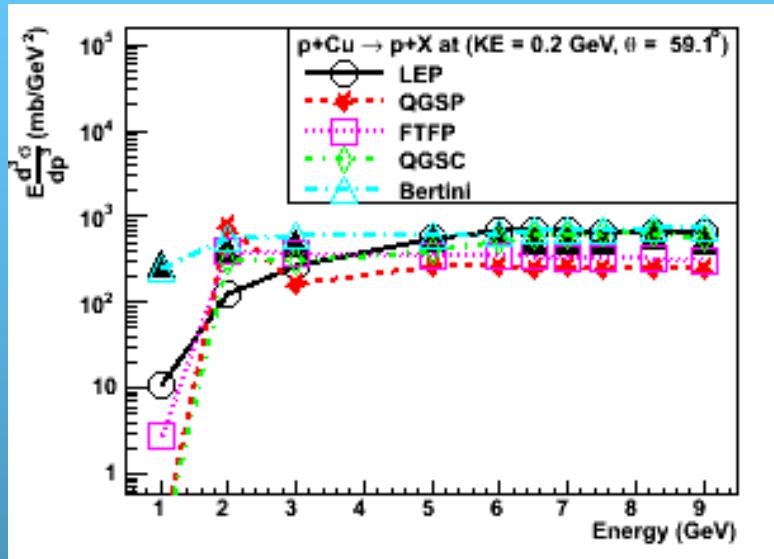
- QGSP (>12 GeV)
- QGSC (>12 GeV)
- Bertini (< 9 GeV)
- Binary (<5 GeV)
- LEP (<12-25 GeV)
- FTF (>4 GeV)
- Combinations of some, e.g. QGSP_BERT, to cover larger ranges
- ...

→ Can give very different results!



Physics lists - 2

→ Existing data



→ QGSC best in the range 7-12 GeV,
and predicts correct momentum
distribution of secondaries
(but time consuming!)