Calorimeter for ILC

The Prototype Simulation of SDHCAL

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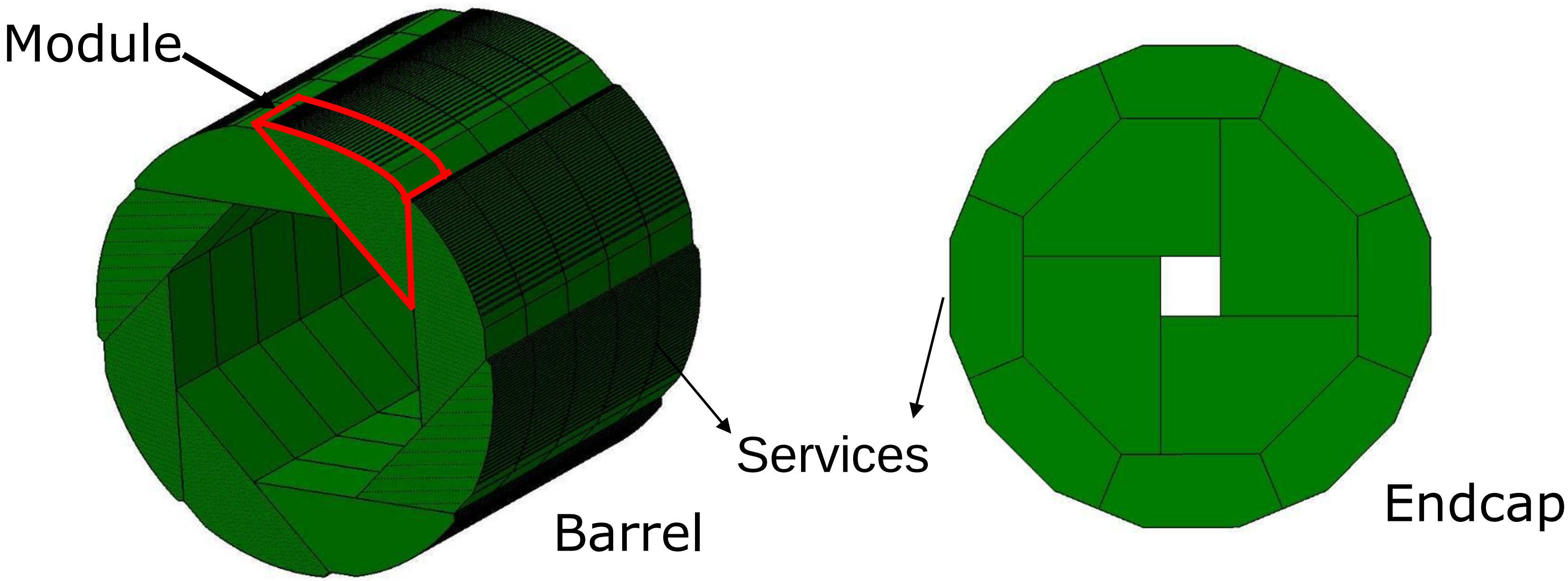
Outline

- **Introduction**: SDHCAL and Simulation motivation
- **Prototype simulation**: the structure of prototype and format of output file
- **Digitization**: the induced charge spectrum and the induced charge distribution (ICD) on pad
- **Comparison**: with small chamber and big chamber
- **Summary and Outlook**

SDHCAL Concept

Why: For future colliders, **jet energy resolution** will be a determinant factor of understanding high energy physics. To improve on the jet energy resolution **PFA** is a promising solution to reduce the confusion term. But PFA needs **high granularity Calorimeters**

How: Different solutions of such calorimeters are being followed within the CALICE international collaboration. The option we are investigating is the **S**emi-**D**igital **H**adronic **CAL**orimeter using GRPC as sensitive medium



SD-GRPC

From Vincent's ppt

Highly Granular GRPC Semi-Digital HCAL

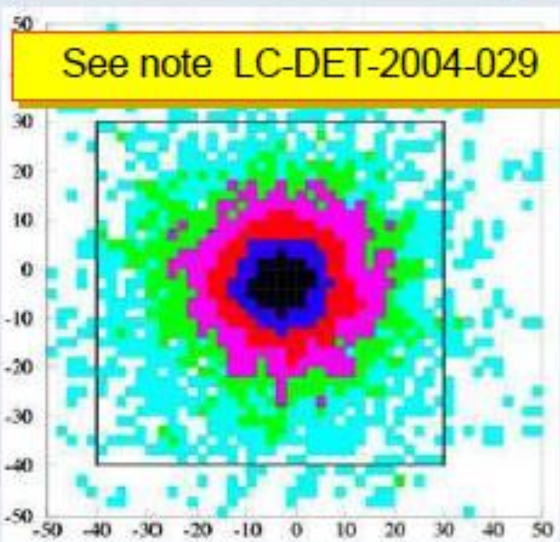
Particle Flow Based
- 1×1 cm² × 40 layers
- Imaging calorimety
  - Tracking in calorimeter
  - Energy loss recovery (see Henri's talk)

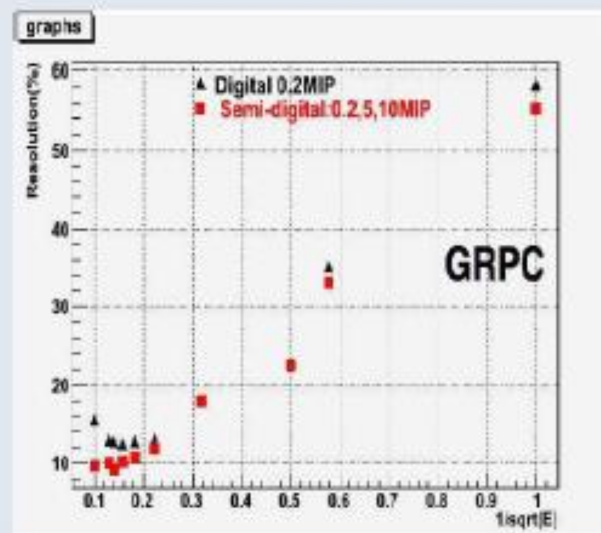
Gaseous calorimetry
- Lower sensitivity to *n*
  - Narrow showers (99% of 100 GeV π in 70×70cm²)
  - Less fluctuations (wrt H containing con

GRPC's
- Cheap
- Simple
- Reliable
- Large uniform surface (calibration of 70M ch.)

2 bits per cell
- Simplified electronics
  - reduced cost
  - less heat
- Improvement of energy rec. at High E.

See note LC-DET-2004-029

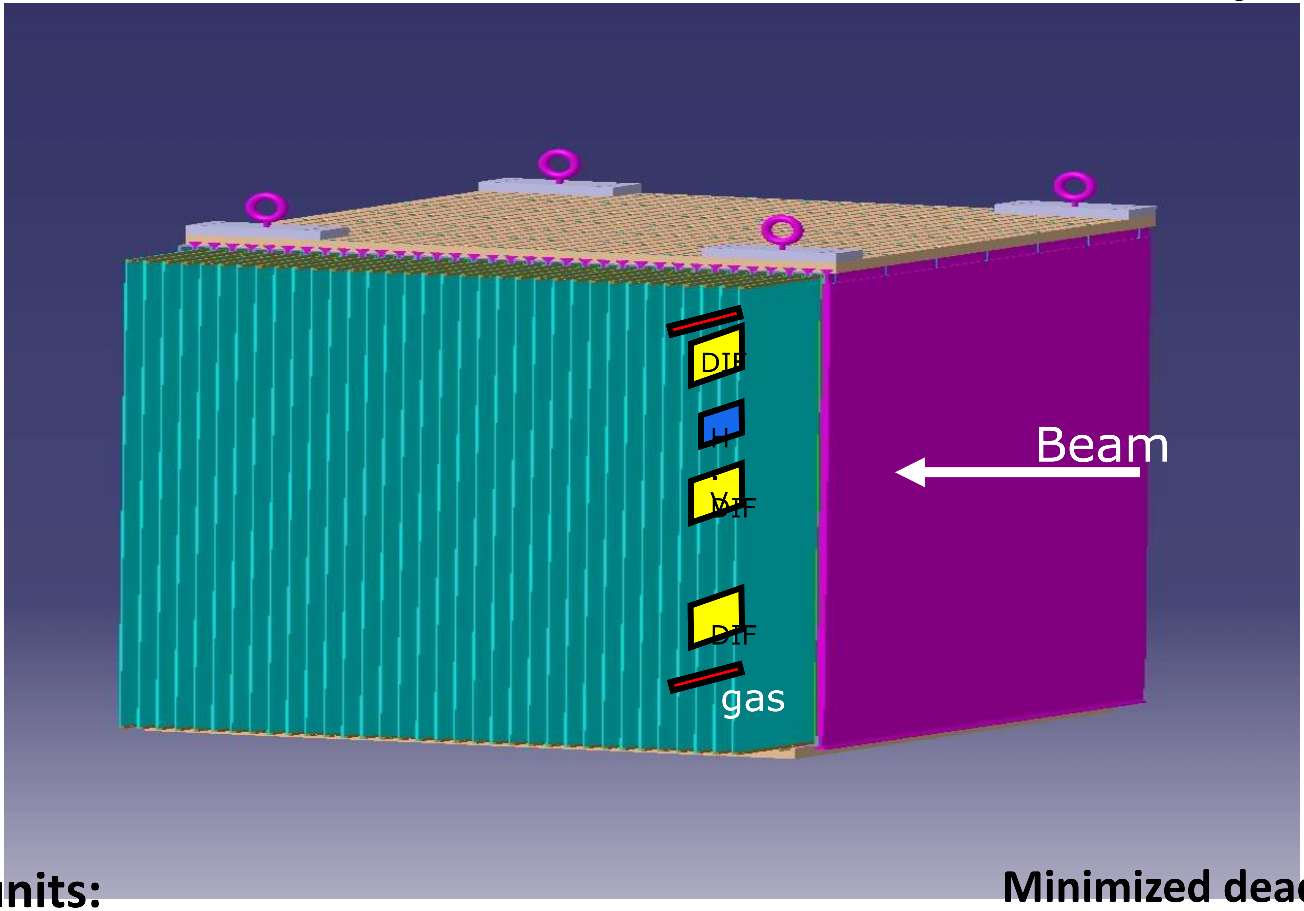




Prototype Building

We intend to validate the **SDHCAL concept** by building a prototype which is as close as possible to the proposed SDHCAL for ILD

From Imad's ppt



40 units:
→2 cm absorber+6mm sensitive medium
→1 cm² transversal granularity

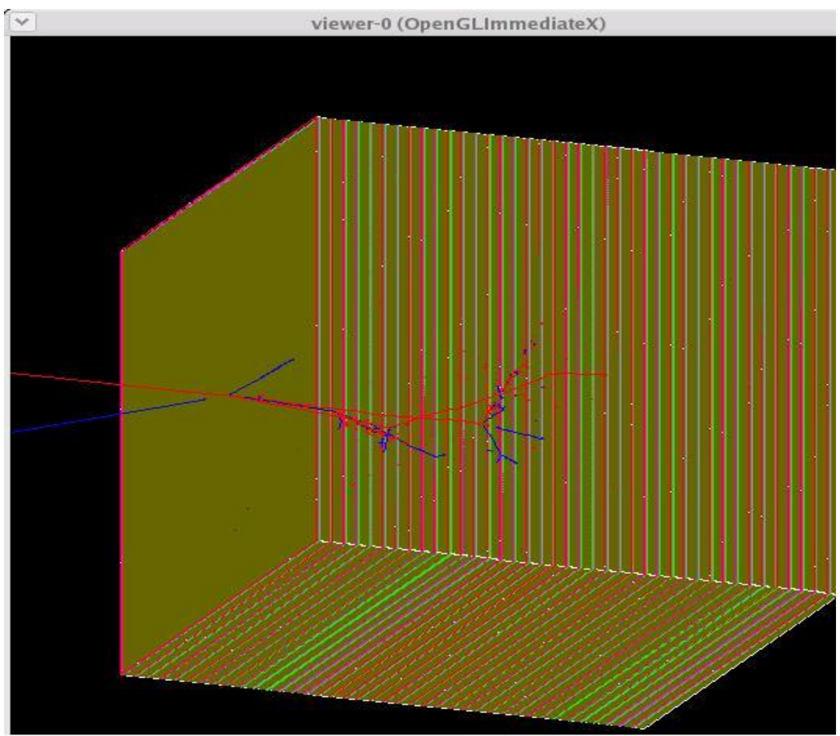
Minimized dead zone
Minimized thickness
Power pulsing

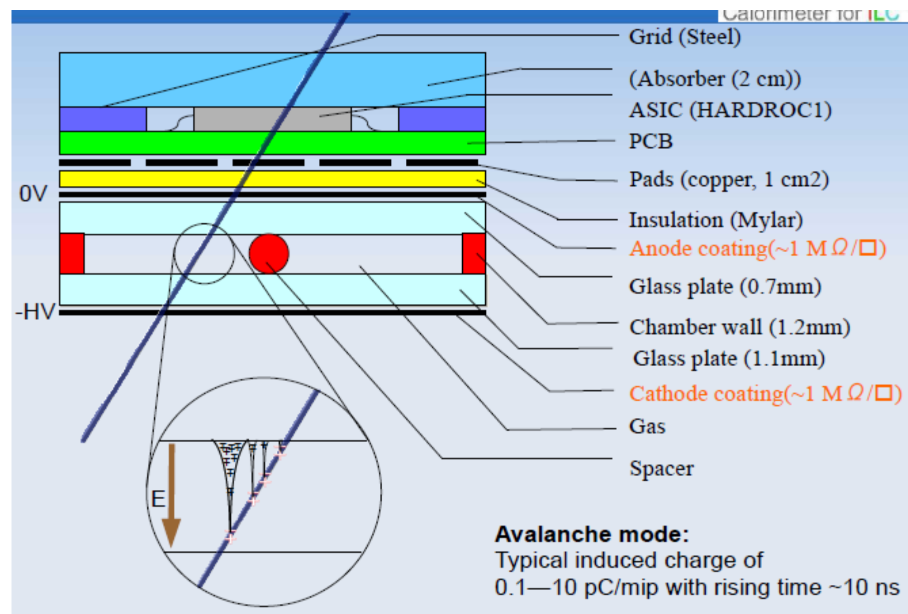
Geant4 Based Prototype Simulation

- **Why**

1) Simulate the performance of the SDHCAL GRPC and validate using beam test data (Including dead zones and edge effects, Obtaining the same efficiency and multiplicity as for data)
2) Perform the digitization of SDHCAL in Mokka model
3) Prepare adding the prototype model to ILC software

- **Structure**





LCIO Format Output

Laurent Mirabito

```
evt_->setRunNumber(runNum);
evt_->setEventNumber(evtNum);
evt_->setTimeStamp(0);
evt_->setDetectorName("SimuLyonPrototype");
evt_->setWeight(0);
evt_->addCollection(this->createRawCalorimeterHits(),srhcol);
```

```
=======================================================
     Event  : 1 - run:  0 - timestamp 0 - weight 1
=======================================================
 date:      01.01.1970  00:00:00.000000000
 detector : SimuLyonPrototype
 event parameters:
 parameter _weight [float]: 0,

 collection name : DHCALRawHits
 parameters:
```

```
    ------------------------------------------

[   id   ] |  cellId0 ( M, S, I, J, K) | cellId1   |amplitude |  time
[00000006] | 00001e01 | 00000000 |           2 |        0
       id-fields: (M:1,S-1:0,I:120,J:0,K-1:0)
[00000007] | 00001f01 | 00000000 |           2 |        0
       id-fields: (M:1,S-1:0,I:124,J:0,K-1:0)
```

Digitization

Why

Geant4 hasn't avalanche process! In order to understand GRPC performance and achieve better comparison with data, the avalanche growth and induced charge distribution need to be simulated

How

1: Simulate RPC physics process ….

2: Get from data , **extract parameters in Polya function from Data**

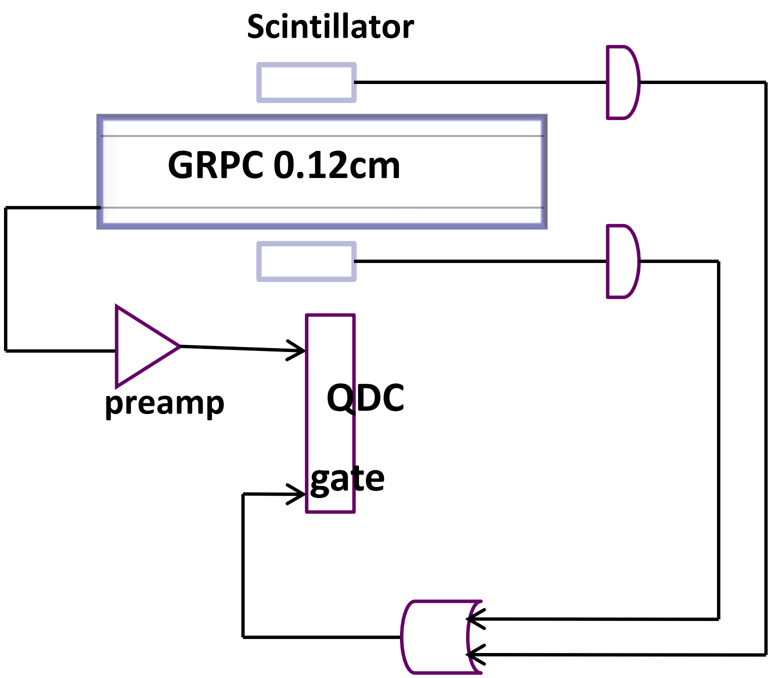
The induced charge spectrum of RPC in avalanche mode can be described by a Polya function : *F.Suli, Gas Detectors,2009*

$$Q = c\frac{(b+1)^{(b+1)}}{b!}\left(\frac{x}{a}\right)^{b} e^{\left(-(b+1)\frac{x}{a}\right)}$$

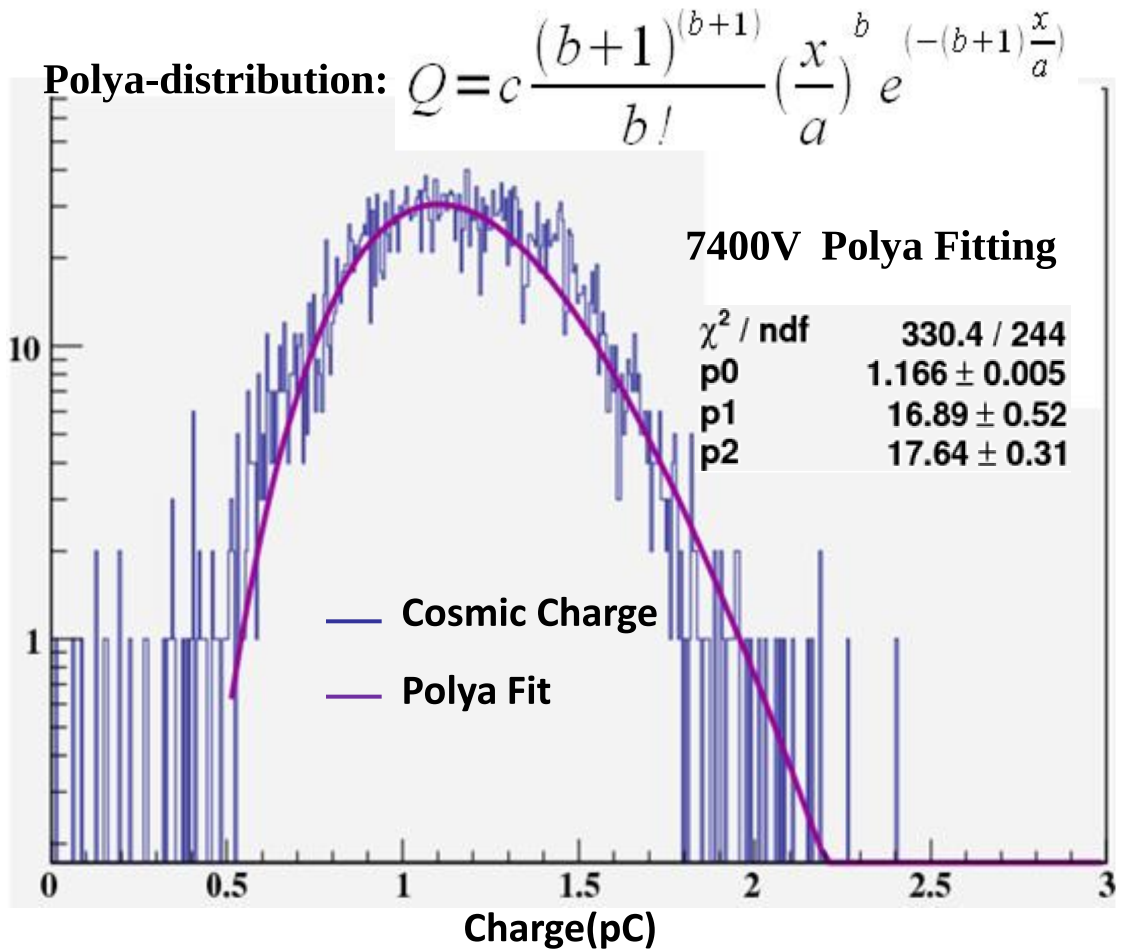
$$a = e^{\alpha s}$$

a is average multiplication factor on the gap s ,
b is an integer to determine the shape
c is a normalization factor.

Cosmic Ray Charge Spectrum



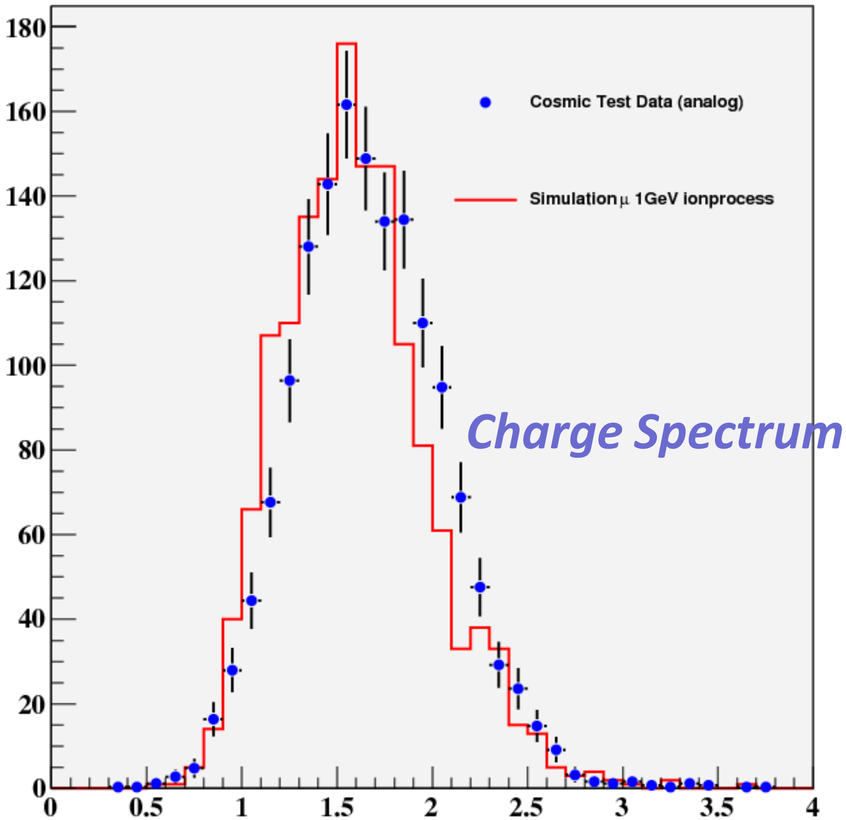
Charge Spectrum Cosmic Test Set Up
64 Channels, trigger area < Channel area
Analog readout

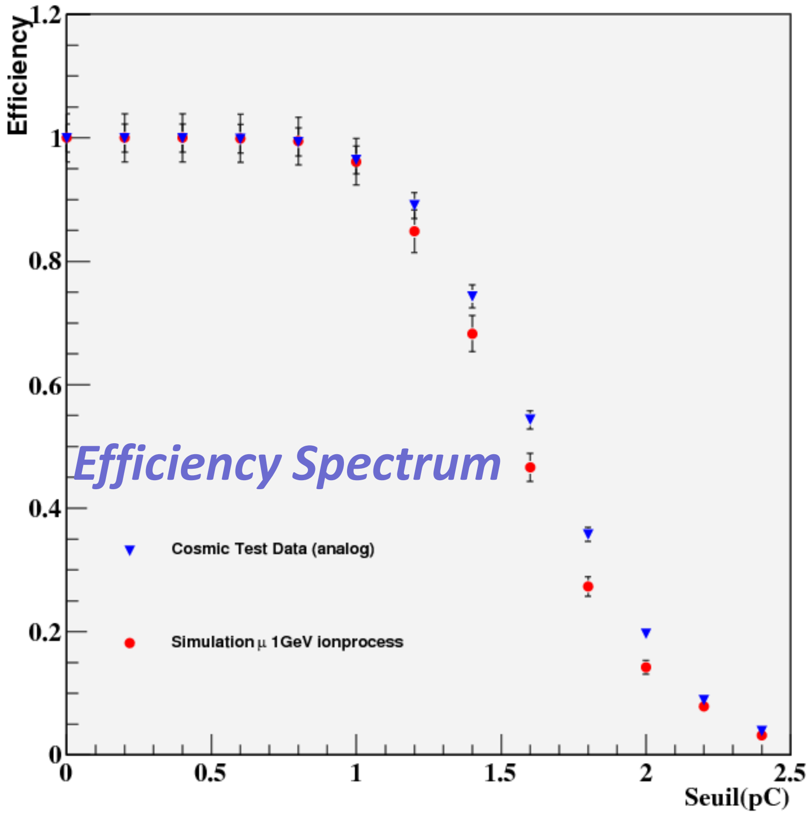


Avalanche signal charge spectrum (Cosmic Ray)

Simulation Charge Spectrum

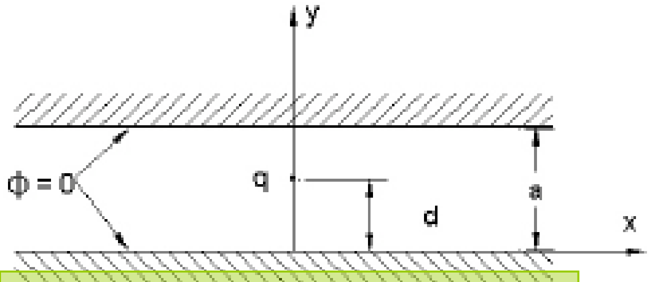
In prototype simulation : 10GeV mu, the parameters are got from Polya fitting





Notice! Plot show the average induced charge spectrum for all pads, it is more important to know the induced charge distribution on each pad, especially for pad multiplicity calculation.

Induced Charge Density Distribution



Model to calculate ICD

a; the gas gap,

q; the total charge getting from polya function we take it as point charge

d ; the location of q.

The potential in gap can be expressed

$$\Phi(x,y)=4q\sum\frac{1}{n}\sin\left(\frac{n\pi d}{a}\right)\sin\left(\frac{n\pi y}{a}\right)\exp\left(\mp\left(\frac{n\pi x}{a}\right)\right)$$

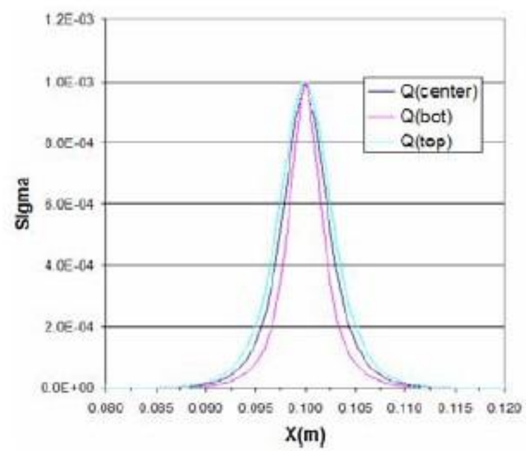
from this lecture: http://puhep1.princeton.edu/~mcdonald/examples/ph501/ph501lecture4

The ICDD along X axis

$$\sigma(x)=\frac{-q}{2a}\frac{\sin\left(\pi\frac{d}{a}\right)}{\cosh\left(\pi\frac{x}{a}\right)-\cos\left(\pi\frac{d}{a}\right)}$$

and $\int_{-\infty}^{\infty}\sigma(x)\,dx\equiv q$

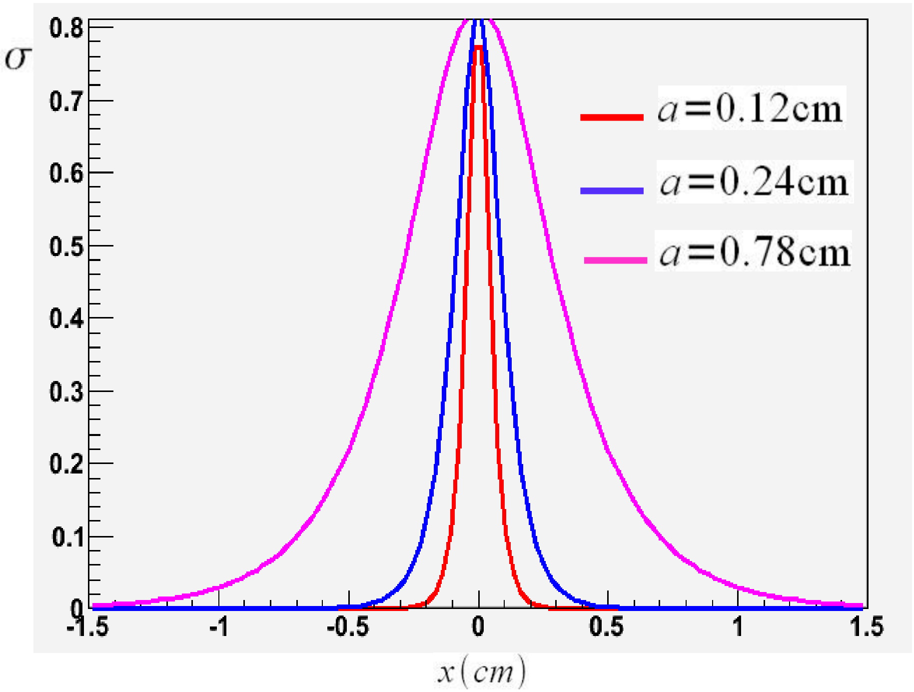
No big difference of q position



In the case a=2d

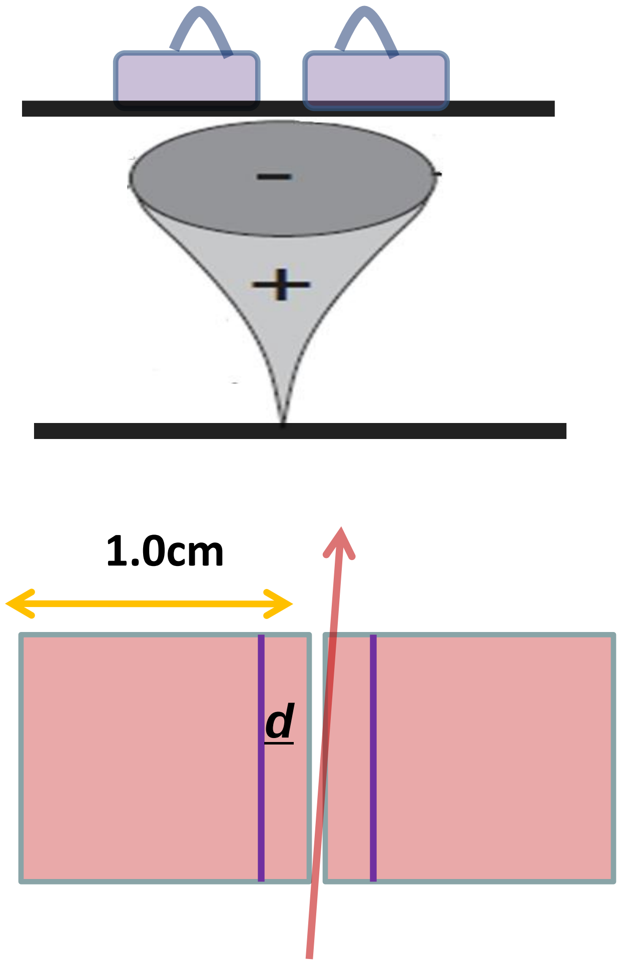
$$\sigma(x)=c\frac{-q}{2a}\frac{1}{\cosh\left(\pi\frac{x}{a}\right)}$$

1D ICDD on pickup pad



Induced charge density distribution along x axis at different gas gap a

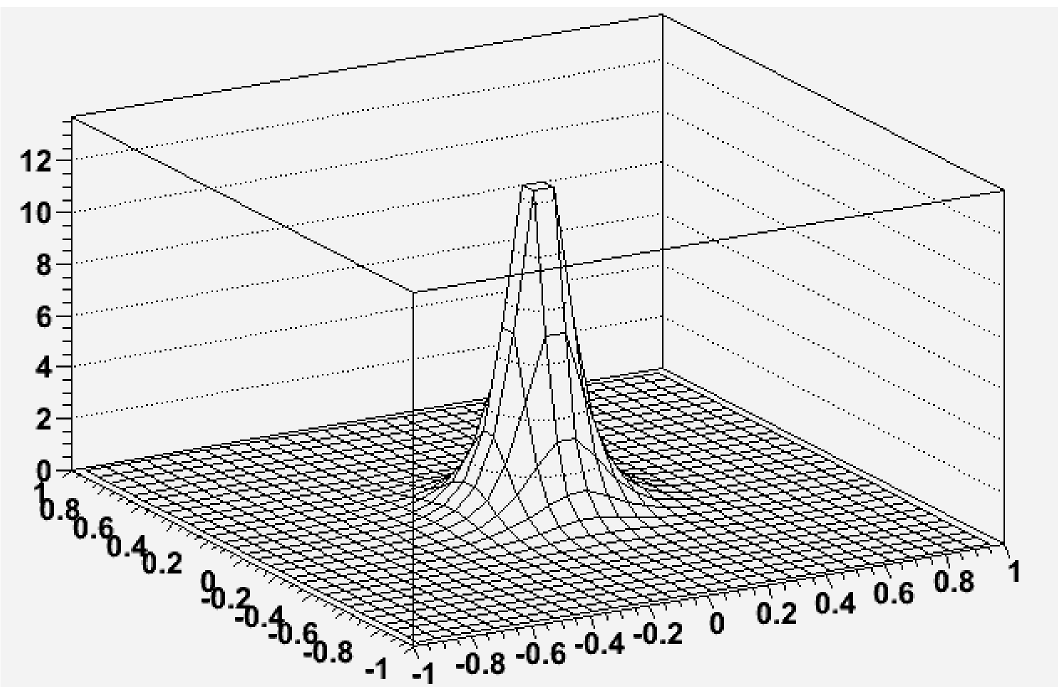
The explanation of left plot



a=0.12cm → d~0.25

2D ICDD on Pickup Pad

$$\sigma(x,y)=c\frac{-q}{2a}\frac{1}{\cosh\left(\pi\frac{\sqrt{(x-x_0)^2+(y-y_0)^2}}{a}\right)}$$

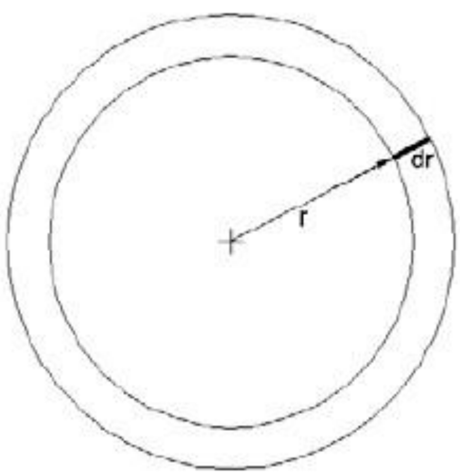


The ICDD along x and y axis, x_0,y_0 is the original position of q at x and y axis.

Integral the upper equation to the full size of the pad . will get induced charge in each pad

Painting Effect

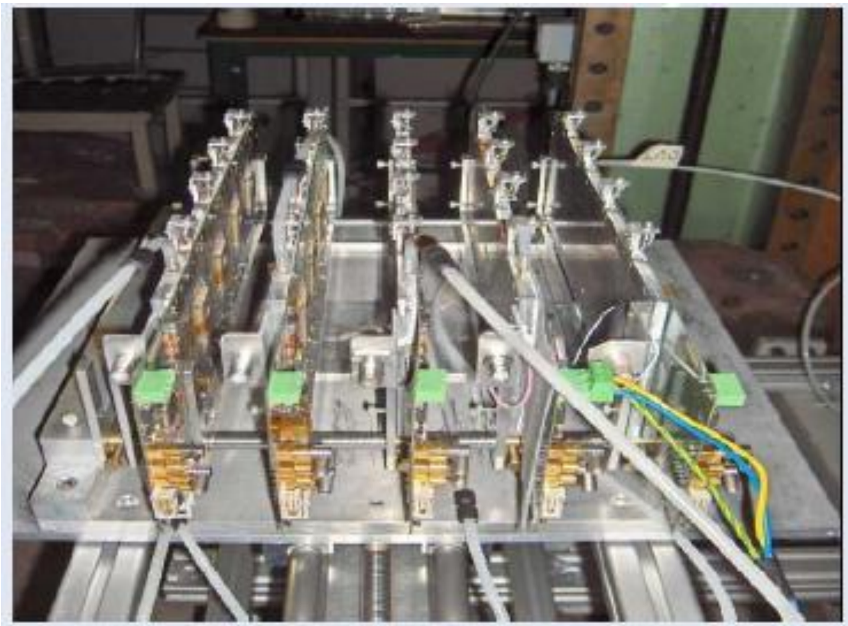
- If only spatial effect is considered, the cluster size of GRPC pad readout should be 1~2, but in reality, this is not always true.
- One additional consideration is that the induced charge distribution is smeared by graphite coating.
- Between RPC gap and the pickup pad plane there is a graphite coating layer. Depending upon the value of the resistivity of this coating layer, the distribution of the induced charge on the pickup plane the smearing effect can be more or less large.

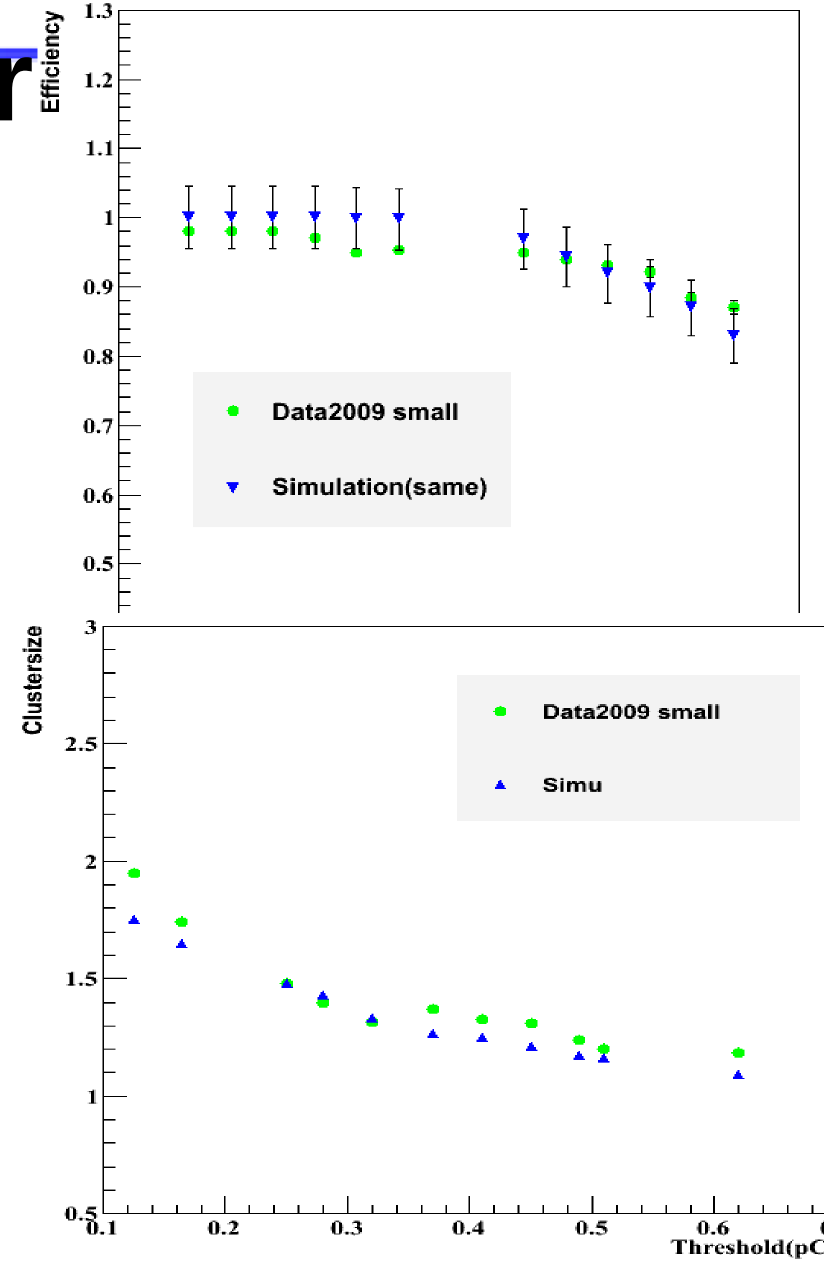


Models to get the smearing effect.
start from radius r, increases dr to r+dr
For this moment we take this effect
from a=0.12cm to a=0.24cm
means from d=0.25cm to d=0.4cm

ongoing study

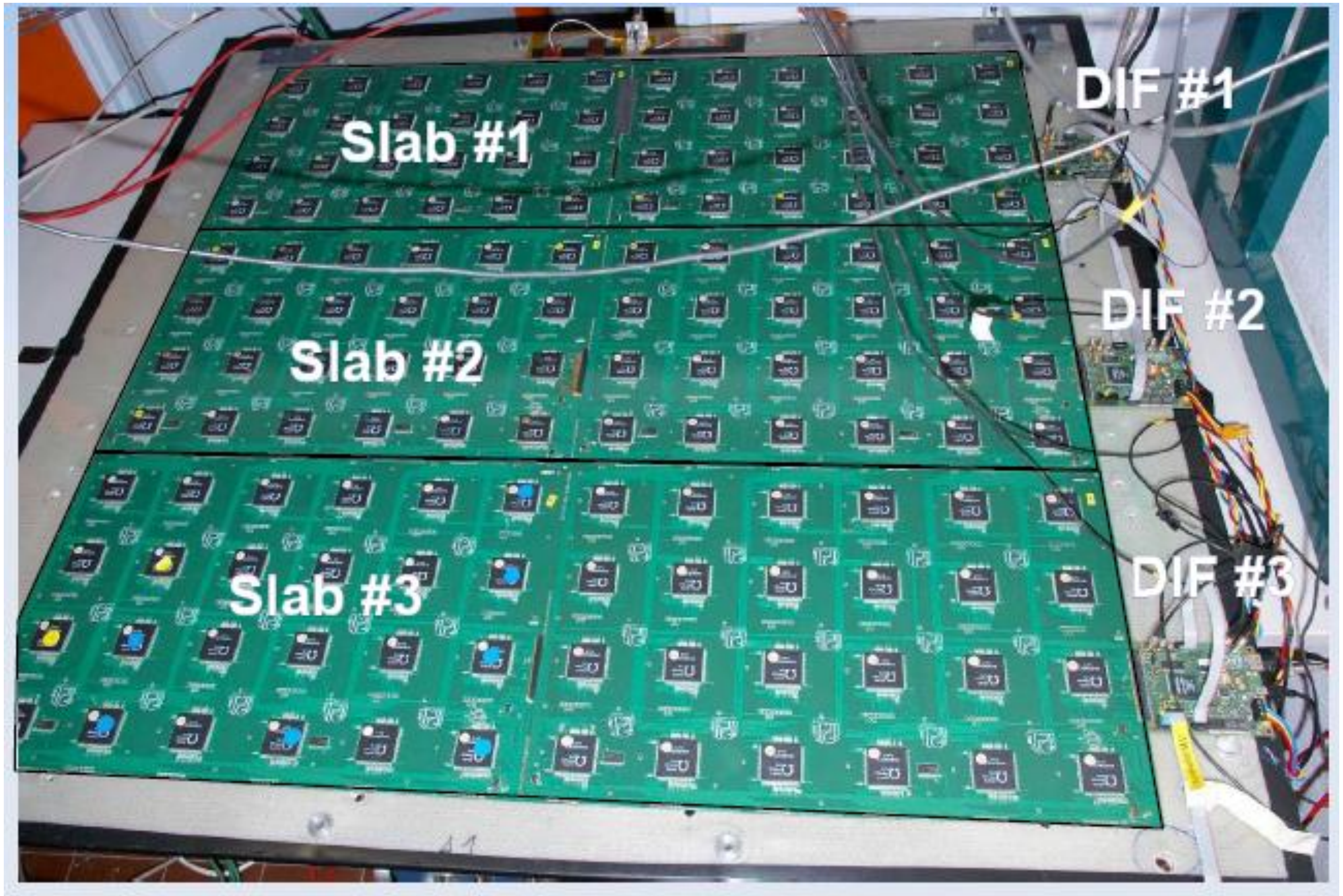
Comparsion with small chamber





Efficiency =triggerd event/totevent
Triggrered event= at least one pad in this event beyond the threshold
Multiplicity = see how much pad be fired in this one pad

Comparision with big chamber



Ongoing study, have TB next month and do full study after that

Summary and Outlook

Summary

Why need to do digitization

How to do digitization (induced charge spectrum and induced charge distribution on pick up pad)

Comparison with data

Outlook

Painting effect on pad multiplicity

Add the digitization to Mokka (need hit position information)

Add the prototype simulation to ILC soft