FAMOS :
a FAst MOnte-Carlo Simulation for CMS

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Need for FAMOS

- The CMS detailed simulation, OSCAR, is based on Geant4
  (Object oriented Simulation for CMS Analysis and Reconstruction)
- Digitization is made by the reconstruction program : ORCA
  (Object-oriented Reconstruction for CMS Analysis)
- The timing of the full simulation is typically between
  4 minutes ($Z \rightarrow e^+e^-$) and 10 minutes ($Z \rightarrow q\bar{q}$) (1GHz)

- CMS will publish its *Physics Technical Design Report* in 2005
  - high need for a tool able to generate quickly (<1s/event) large and reliable simulated samples : FAMOS
    - it must be fully ORCA compatible to allow the comparisons and the transition between ORCA and FAMOS to be made easily
- A particular effort has been set on this tool since November 03

Structure

Generation

Pythia
Particle Gun

or

External file

Detector	*Simulation method*	*Output*	*Reconstructed objects*
Tracker	Smearing	Tracks	Heavy Flavors
ECAL* Preshower	Shower Simulation*	Hits } Towers	Clusters
HCAL	Smearing (→Shower Simulation)	Hits } Towers	Jets, MET†
Muon system	Smearing	Muons	Isolated Muons

†Missing Transverse Energy

*I will focus on these items in this presentation

Material effects

- Before simulating the calorimeter, the tracks have to be extrapolated and the material effects in the tracker properly simulated
  - bremmstrahlung
  - photon conversions
  - dE/dx
  - multiple scattering

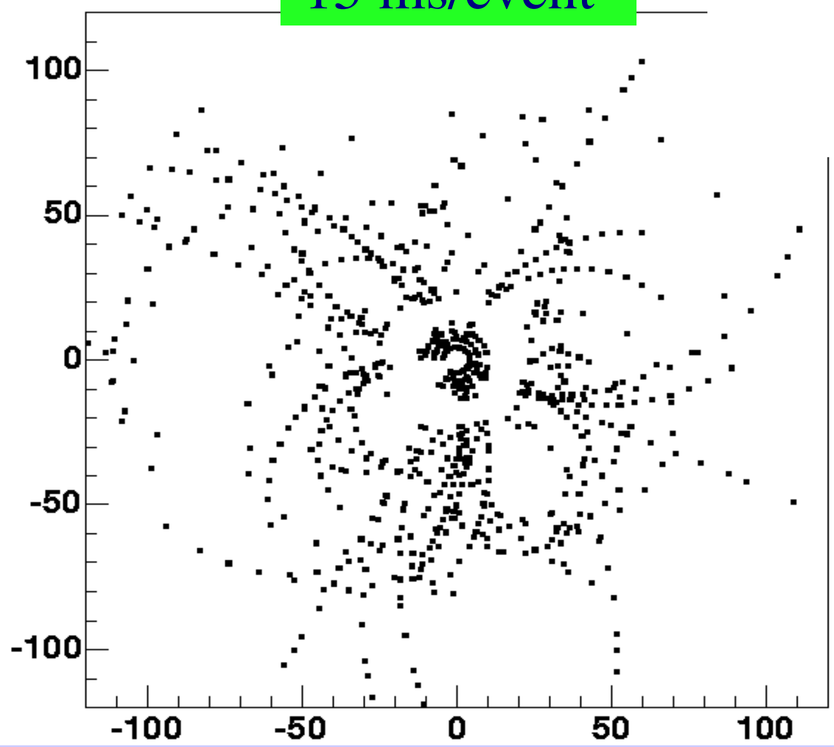
- The FSimEvent contains the history of the material effects in the tracker

- The correlation with the tracker simulation is being implemented for electrons

$H \rightarrow Z Z \rightarrow e^+e^-e^+e^-$
$m_H = 280$ GeV/c^2

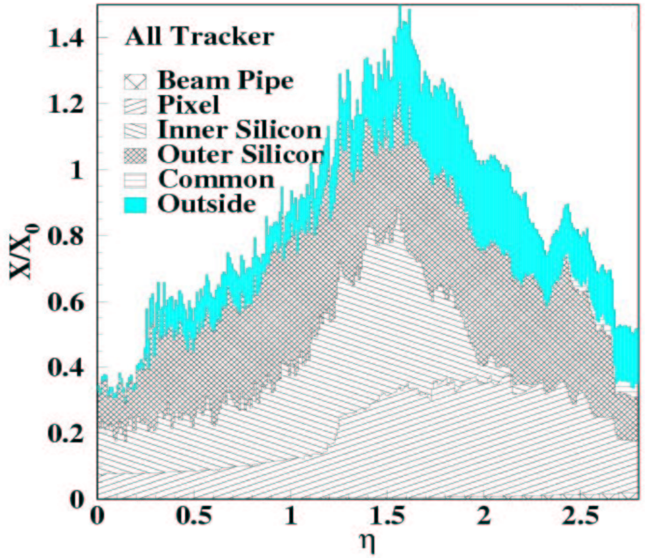
Transverse View

15 ms/event



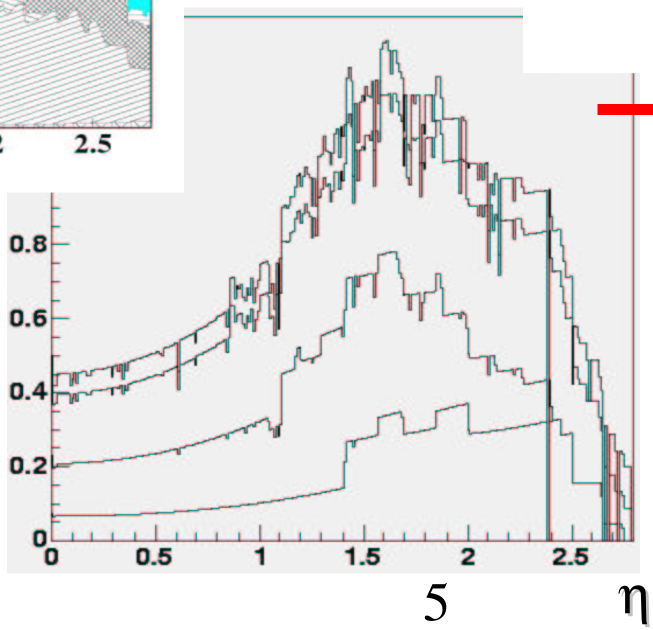
Material effect simulation

Radiation lengths seen by a photon

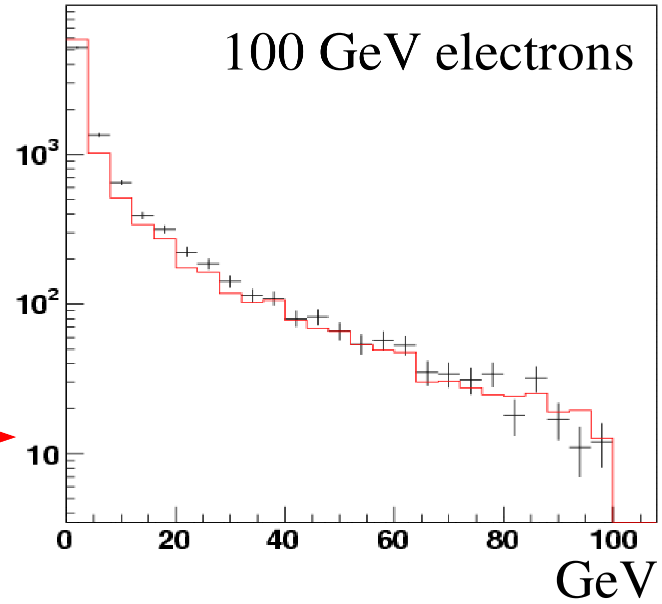


detailed simulation

FAMOS



Brem photon energy spectrum



Good agreement
(no tuning)

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ECAL simulation : strategy

<u>How to simulate the hits in the ECAL ?</u>

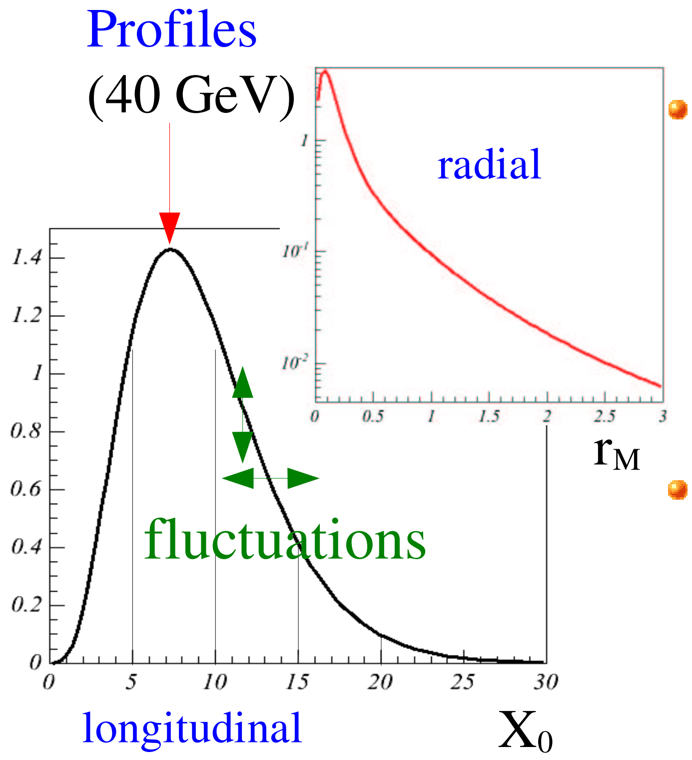
- Proceed in two steps :
  - generate the shower in a homogeneous medium
  - translate the simulated shower into the detector

<u>Shower simulation :</u>

- Electromagnetic showers are well understood
  - universal parametrization exists
  - the latest Grindhammer electron shower parametrization is used (à la GFlash)
  - OSCAR is needed only for the tuning

Shower simulation

- Each shower consists in thousands of energy spots
  - ~ linear with energy



- The energy in each longitudinal slice is determined
  - shower-to-shower
  - photostatistics
  - longitudinal non-uniformity

  } fluctuations are included

- In each slice, the spots are distributed along the radial profile (uniformly in φ)
  - correlations between longitudinal and radial fluctuations are included

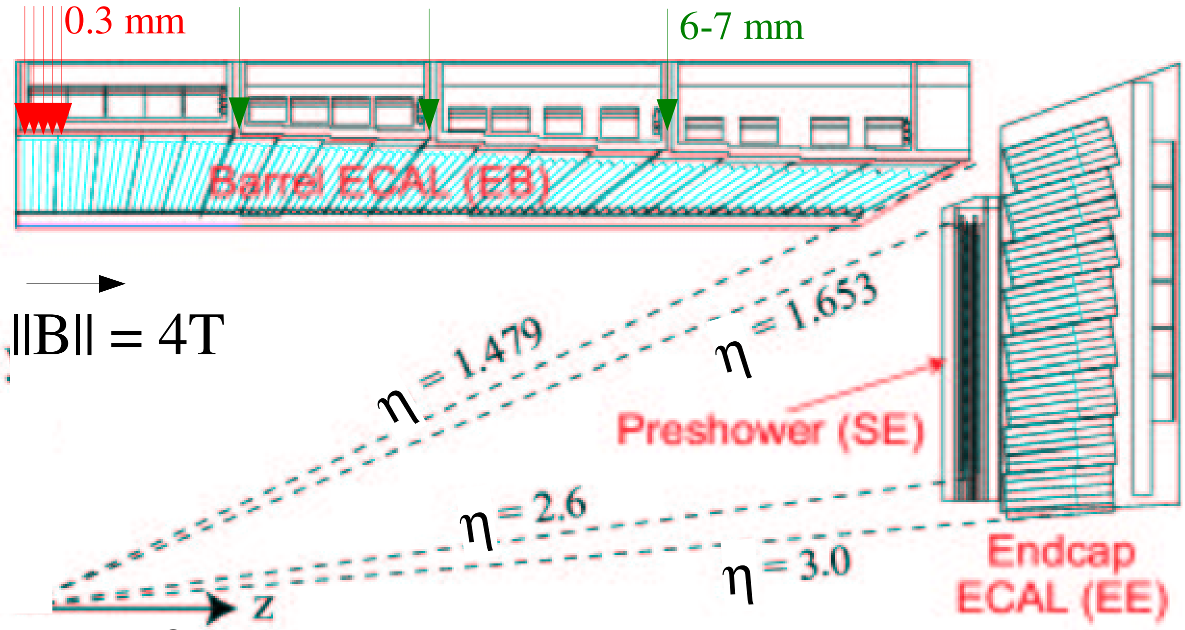
CPU ~ 12 ms for a 40 GeV shower

Detector simulation

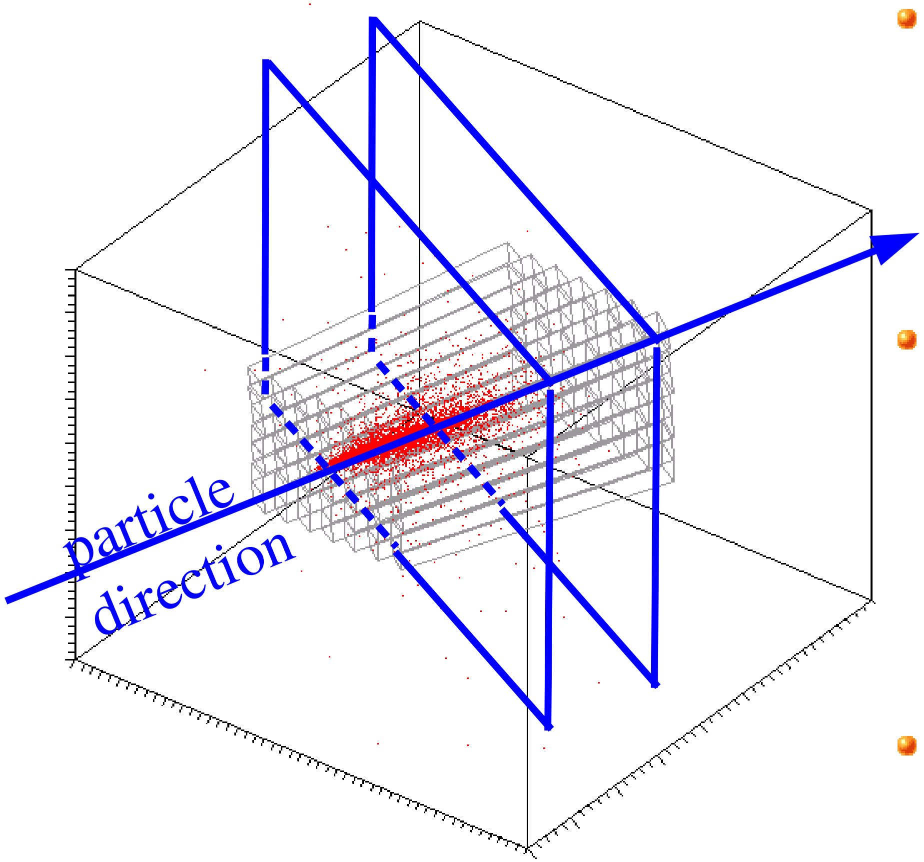
The generated energy spots should be affected to the crystals taking into account the essential following effects :

- different types of gaps (between crystals / modules)
- front and rear shower leakage
- magnetic field (which enlarges the shower)
- electronic noise

The challenge is to do it in a very short time



2D treatment



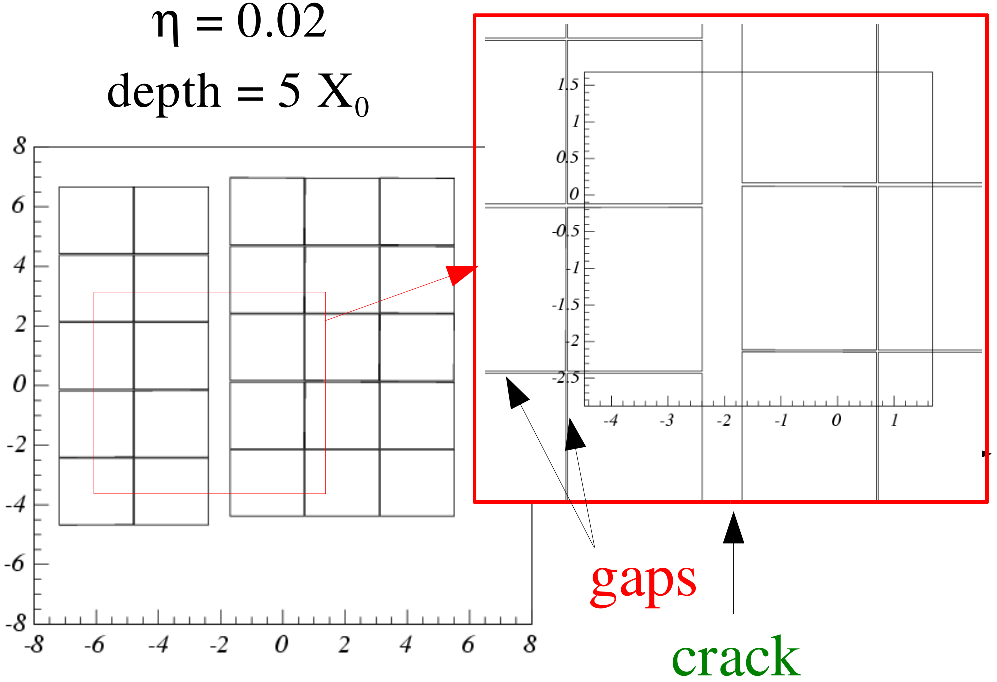
a 40 GeV electron shower
in a 7x7 crystal window

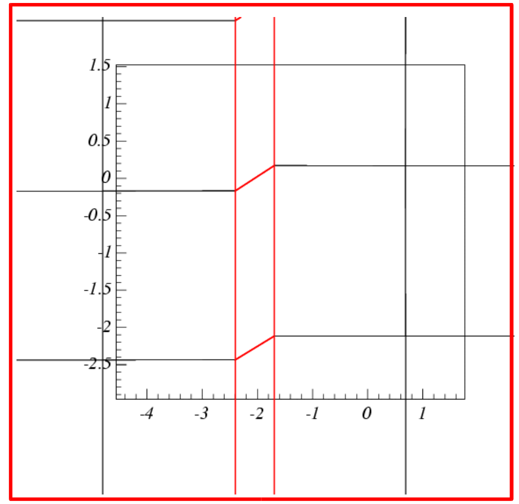
- Since the detailed geometry has to be used a 3D treatment can be very time consuming:
  - > 700 ms / particle with the standard tools
- The longitudinal segmentation of the algorithm fortunately makes the 2D approach natural
  - less calculations → fast
- Moreover a limited area of the calorimeter is used : a 7x7 crystal window around the crystal hit by the track

Grid construction

$\eta = 0.02$

depth = 5 X_0





The pads are then reorganized taking into account:

- gaps/cracks
- magnetic field
- front/rear leakage

At a given depth, the intersections between the crystals and the plane ⊥ particle direction are determined

ORCA interface

- For each longitudinal slice of the shower , the grid is calculated
  - the spots are distributed in 2D chessboard
  - each pad corresponds to a crystal
- The total amount of energy in each crystal of the grid is determined
- The electronic noise is added

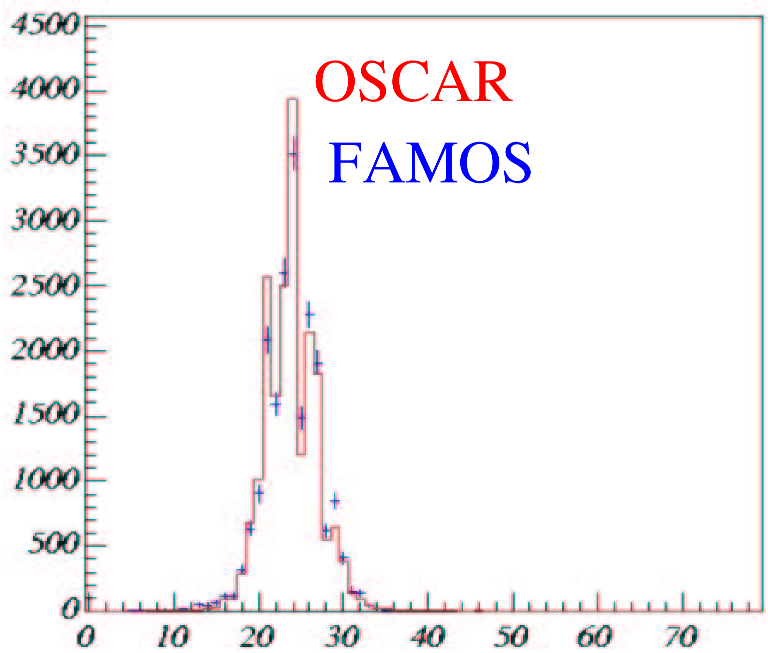
- The result is turned into standard CaloRecHits and ECALPlusHcalTowers (together with the HCAL simulation)

- The standard ORCA algorithms are then applied to reconstruct the clusters and the superclusters (SC)
  - accessible with the same syntax as in ORCA

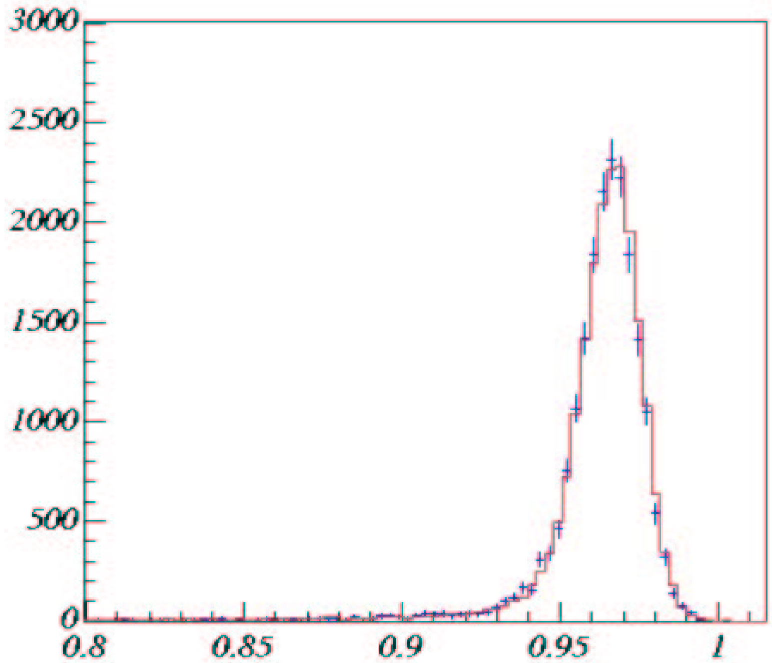
First results

Unconverted photons (E_T=35 GeV) in the barrel

Number of crystals in a SC



Total energy

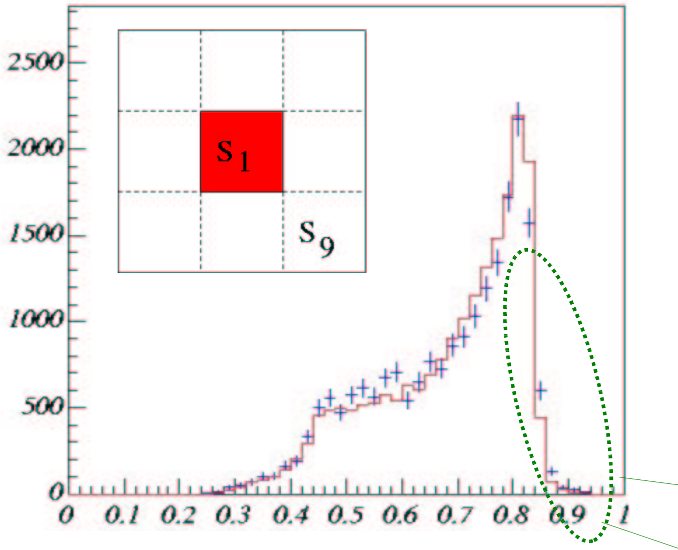


E_{SC}/E_{true}

Distributions obtained with essentially no tuning

Transverse shape

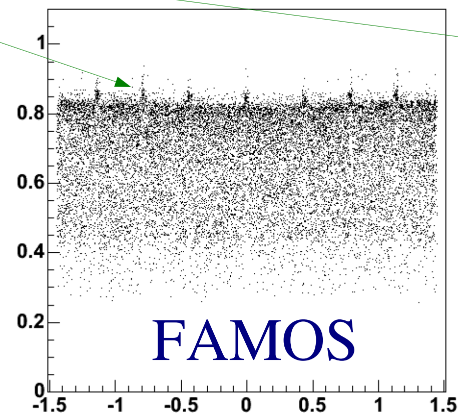
FAMOS
OSCAR

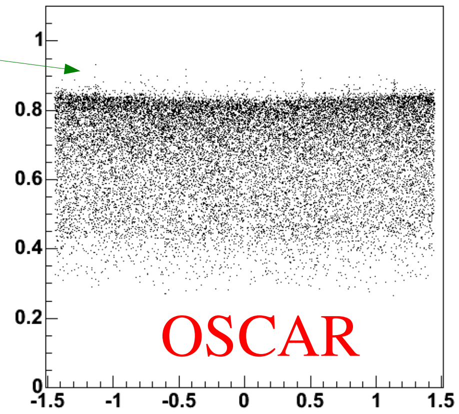


S_1/S_9

- Ratio of the energy contained in the most energetic crystals over the 9 most energetic crystals : S_1/S_9
  - sensitive to the transverse profile

- Some tuning necessary in the cracks (between modules)
  - energy lost in the cracks overestimated leads to a smaller S_9



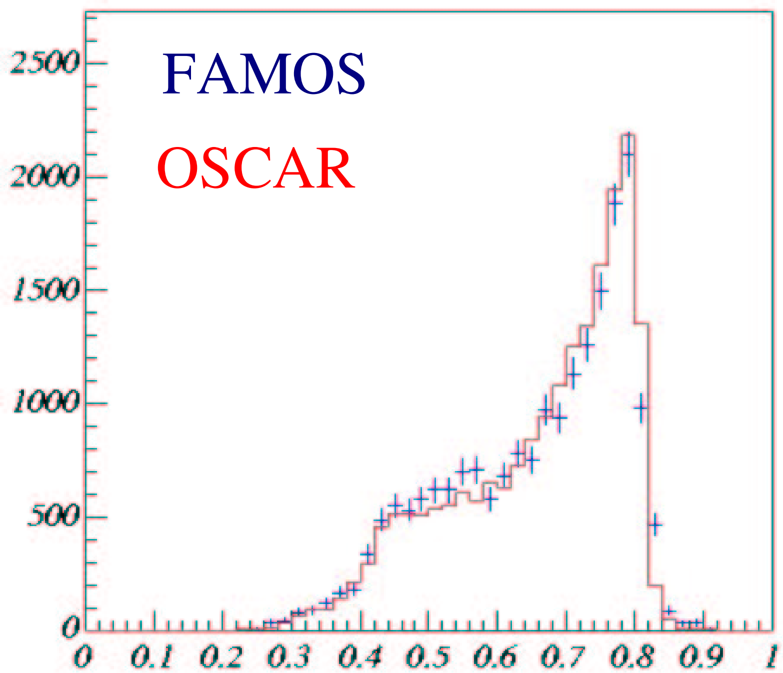


η η

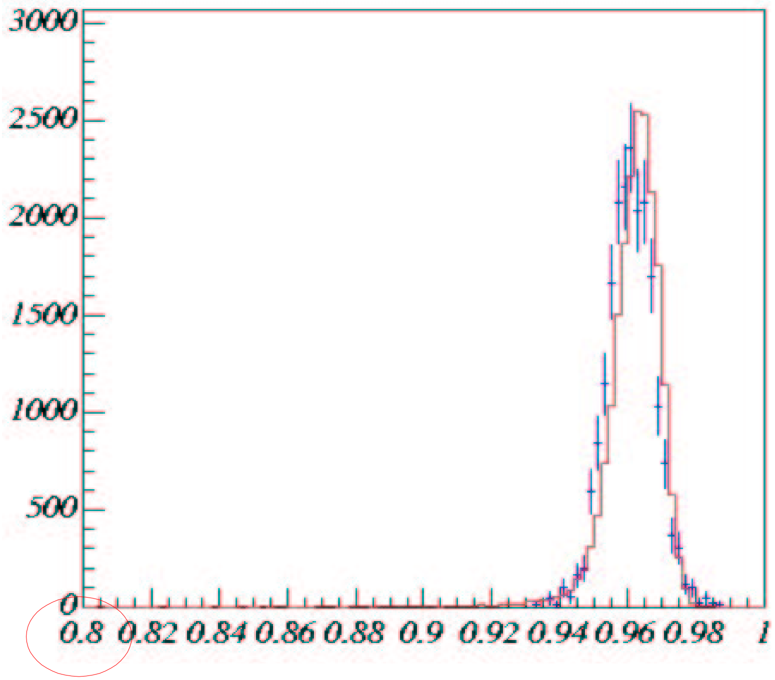
Good agreement with essentially no tuning

Transverse shape

S_1/S_{25}



S_9/S_{25}

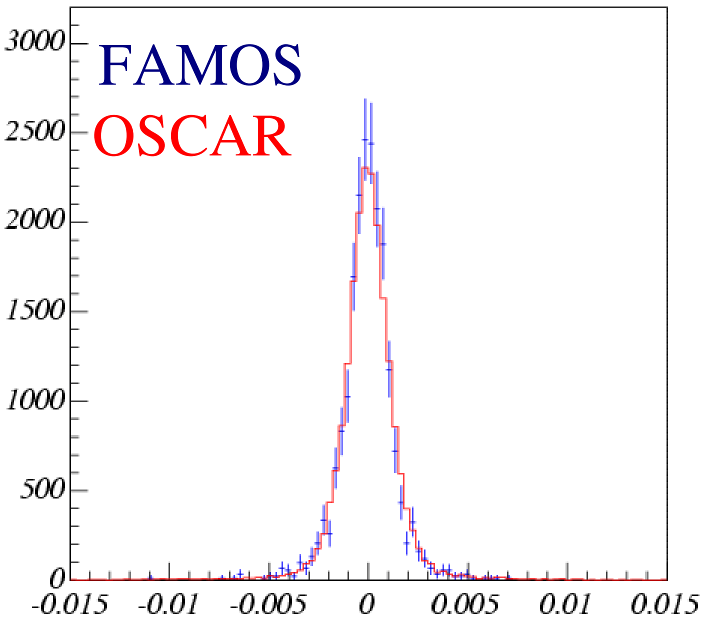


Nice agreement but the showers are slightly too large in FAMOS

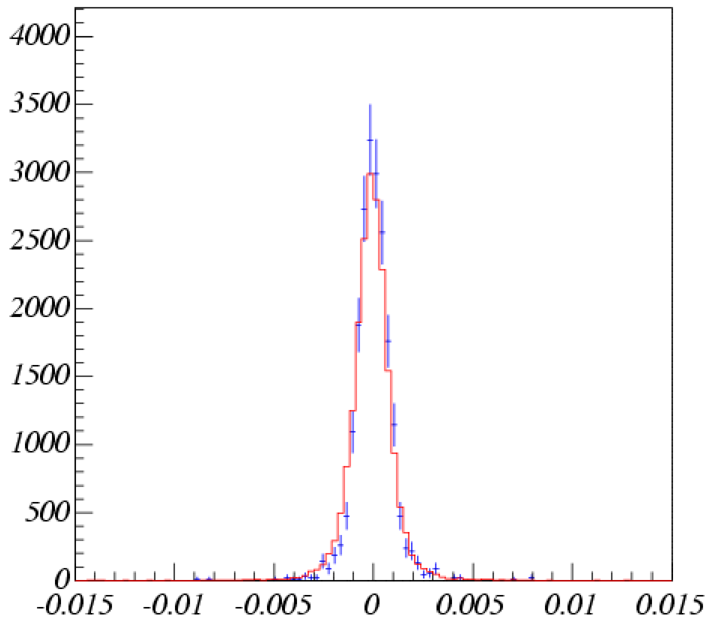
- tuning

Position resolution

$\eta_{measured}-\eta_{generated}$



$\varphi_{measured}-\varphi_{generated}$

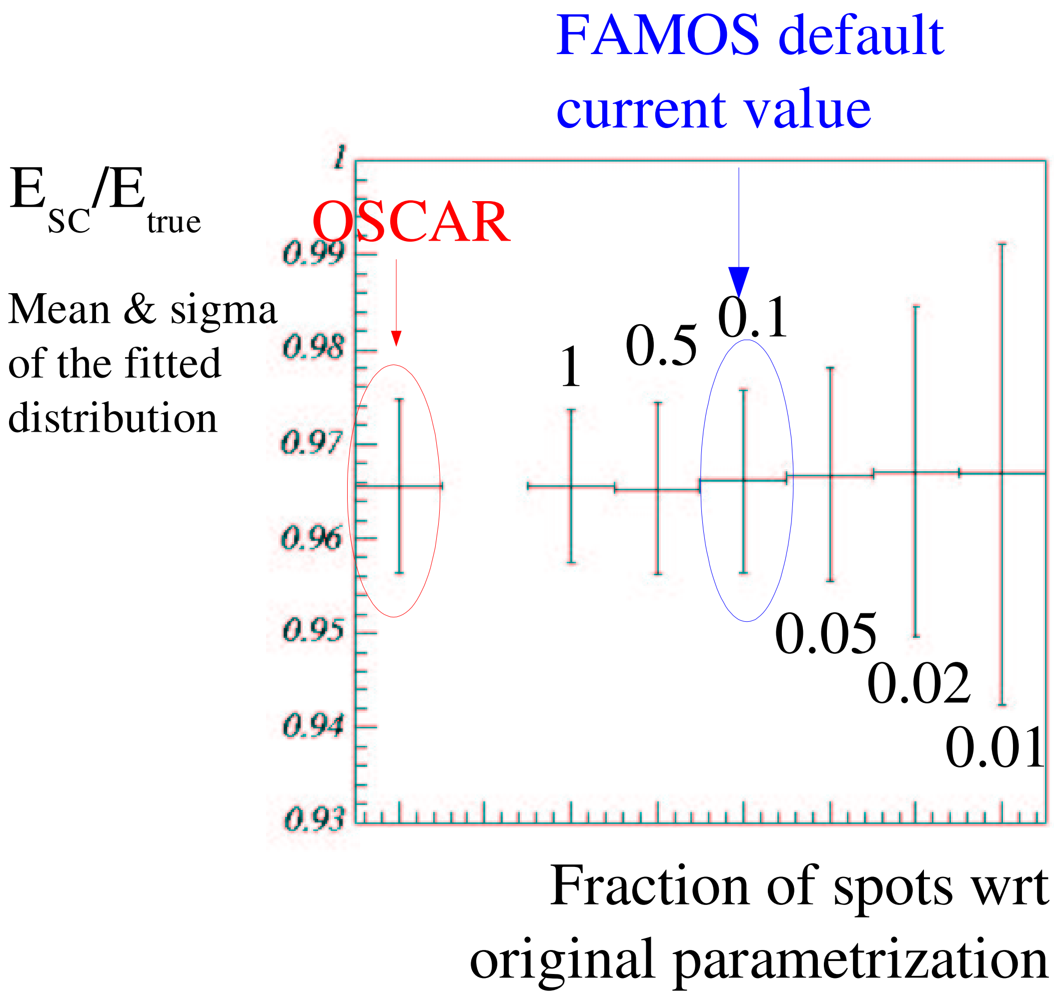


The position resolutions are very well reproduced

➡ Good results, with a reasonable timing : 44ms / photon (E_T=35 GeV)

($2X_0$ segmentation)

Timing vs Tuning



- The number of spots per shower has a major impact on the timing
  - the resolution is spoilt if the number of spots is too small
- The impact of the longitudinal segmentation has also been studied
  - no visible impact with $5X_0$ steps

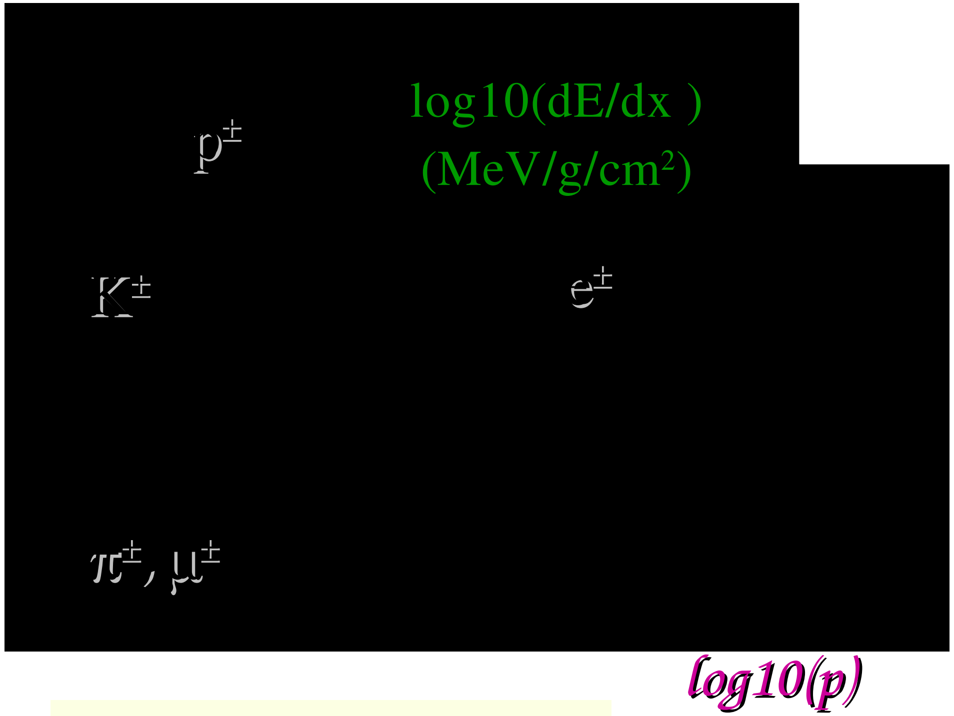
Timing :12 ms / photon
(with no visible difference
on the previous distributions)
600ms / $Z \rightarrow e^+e^-$ event

Conclusion

- The CMS fast simulation, FAMOS, has been presented
- The first results of the ECAL simulation are promising:
  - it is fast : 400 times faster than the detailed simulation, and there is plenty of room for improvement: a factor of 1000 can be achieved
  - it is accurate even with a preliminary tuning
  - The HCAL simulation is being improved following a similar approach
- FAMOS is a flexible and user-friendly tool
  - will soon be a good way for the new user to get started with ORCA
- The first version of FAMOS aimed at physics is scheduled on December 04

Backup

Material effects : dE/dx



Landau Fluctuations:

$$\Omega\left(\lambda=\frac{dE/dx-dE/dx_{p.p}}{\xi}\right)=\frac{1}{\sqrt{2\pi}}\exp(-0.5(\lambda+e^{-\lambda}))$$

dE/dx treatment (pure Si):

$$\frac{dE}{dx}_{p.p}=\xi\{\log\frac{2m_e\beta^2\gamma^2\xi}{I^2}-\beta^2+1-\gamma_E$$

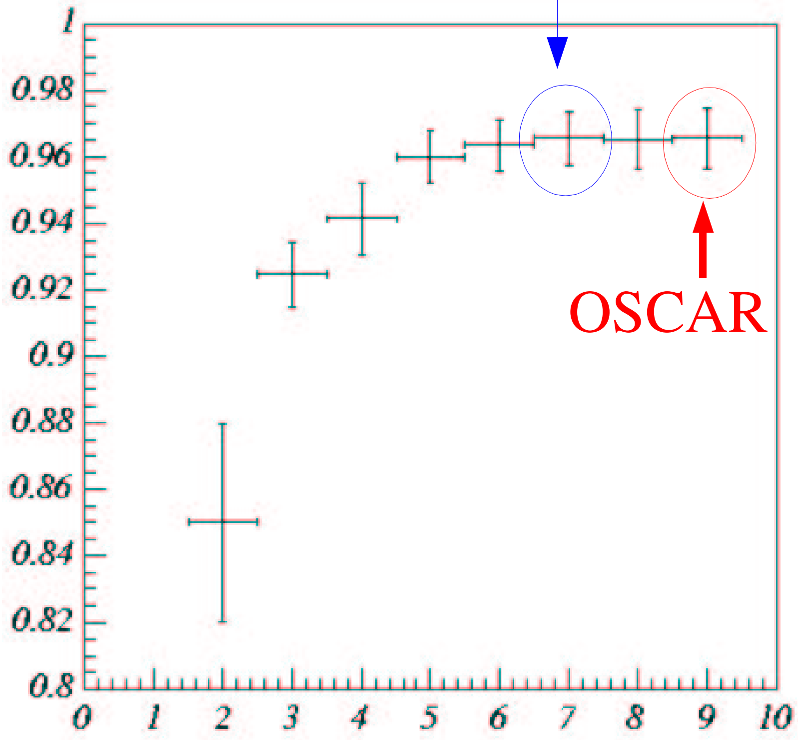
avec $\xi=\frac{0.1536}{\beta^2}\frac{Z}{A}x[\text{ MeV}]$

Timing/Tuning

FAMOS default
current value

E_{SC}/E_{true}

Mean & sigma
of the fitted
distribution



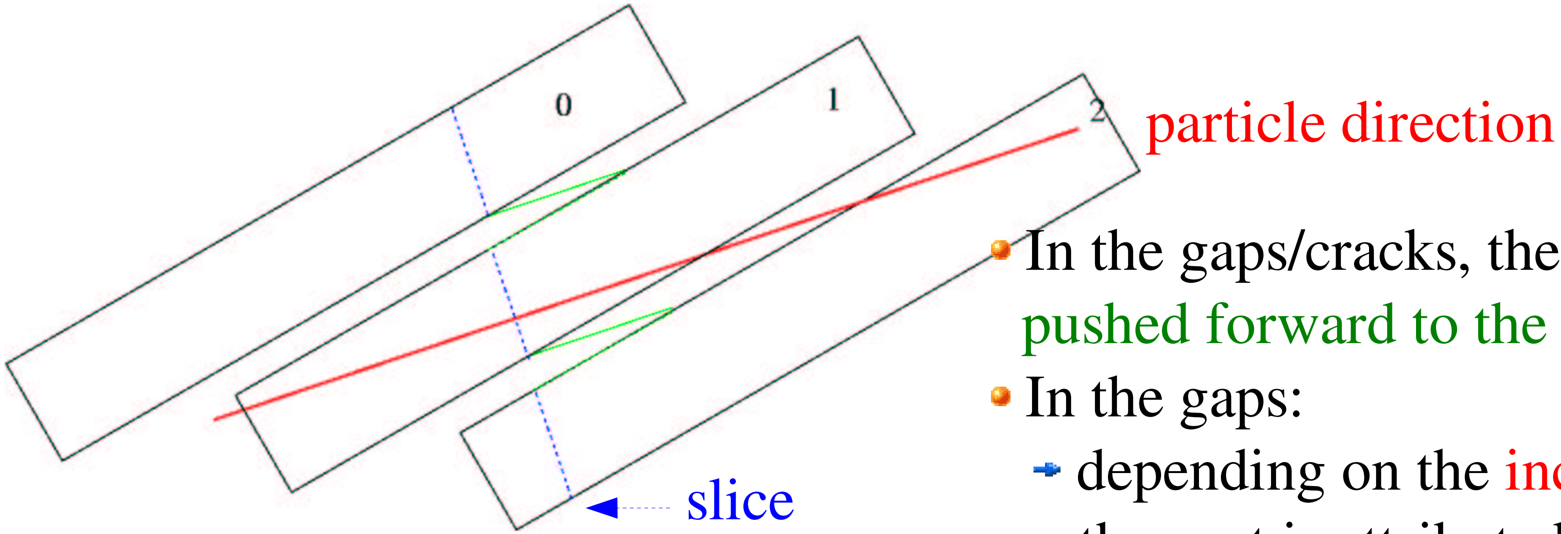
grid size

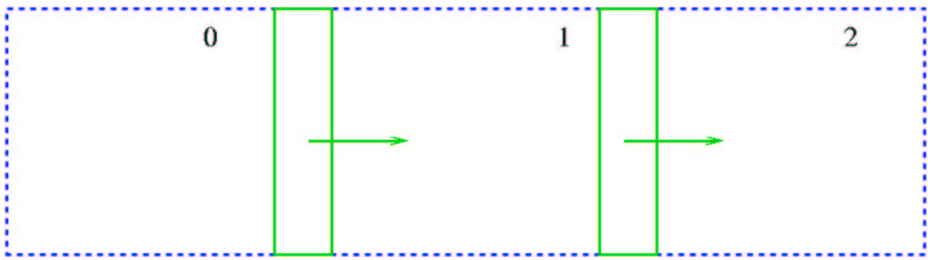
The size of the grid has
an impact of the timing

If the grid is too small, it does
not contain the full shower

- stay with a 7x7 grid

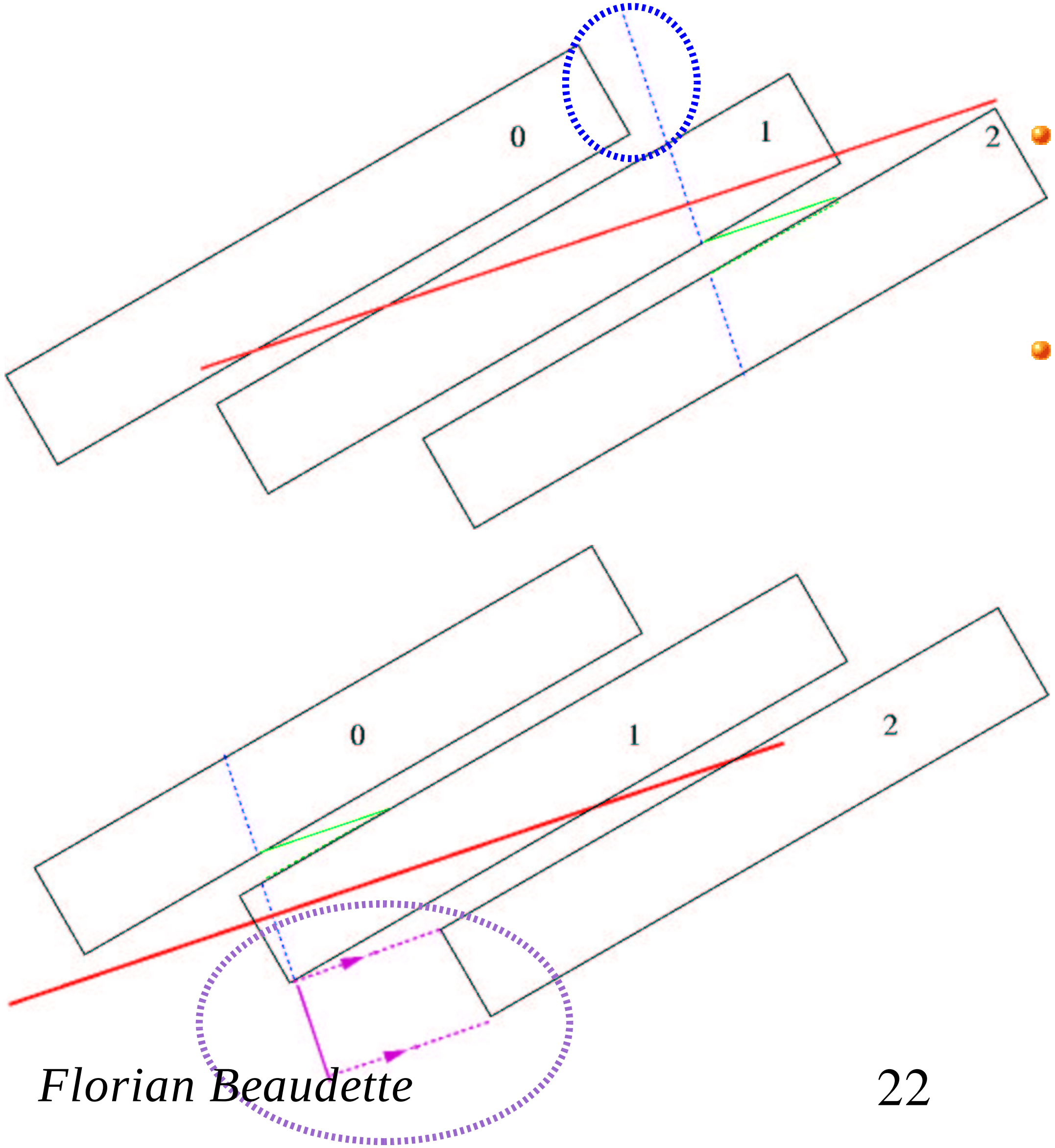
FamosGrid





- In the gaps/cracks, the shower is pushed forward to the next crystal
- In the gaps:
  - depending on the incident angle, the spot is attributed to the « left/right » crystal
  - no energy loss is currently included
- In the cracks:
  - a new pad is created attached to the relevant neighbour
  - a spot loss probability is given to the pad

Rear/Front leakage



- The rear leakage should be automatically reproduced
- Front leakage :
  - the spots in front of a crystal may reach it
  - a new pad is projected onto the front face of the crytal
  - a survival coefficient < 1 is attributed to this pad (tuning!)
  - a dependence of this coefficient on the distance to the crystal can be implemented if necessary