Discussion of the

MPD beam-test program

D.Peresunko

RRC “Kurchatov institute”

Parameters to be checked

- ECAL parameters:
  - Energy
    - Resolution
    - Non-linearity
  - Position
    - Resolution
    - Shower depth correction/Non-perpendicular incidence correction
  - Shower shape
    - Input for MC modeling
    - Possibility of photon/hadron separation
  - Time measurement
    - Resolution, corrections
    - Possibility of photon/hadron separation

Goal of beam-test program:

- Validation of the expected parameters
- Input for the MC modeling

Summary of beam-test proposals

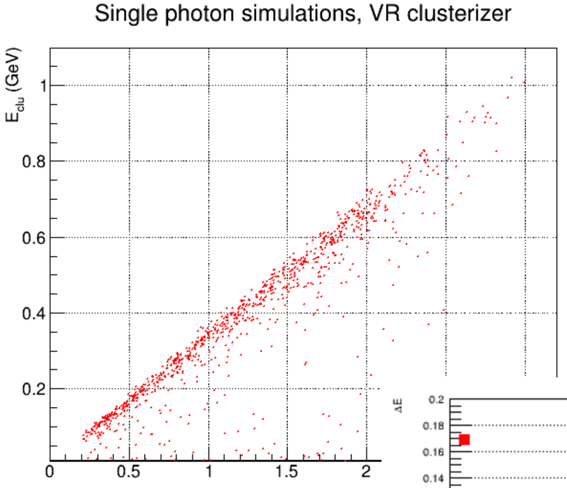
Beam setup	Measure
Electron beam, Several energies (0.4-2 GeV) Good dp/p <~10^{-3} resolution Wide beam ~width of the cell Small material budget in front of prototype	Energy resolution Non-linearity
Electron beam Several energies (0.4-2 GeV) Wide beam >~width of the cell Position detector in front of prototype Possibility of non-perpendicular incidence 5-10°	Position resolution Depth of the shower (with non-perpendicular beam) EM shower shape
Electron beam, Several energies (0.4-2 GeV) Start detector (scintillator?) in front of prototype	Time resolution vs E
Hadron beam: pions/protons Several energies (0.4-2 GeV)	Hadron shower shape

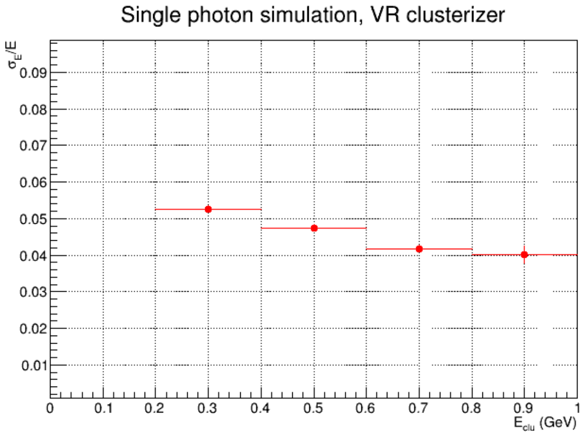
Realistic prototype: 8*8, final electronics, thermostabilization etc.

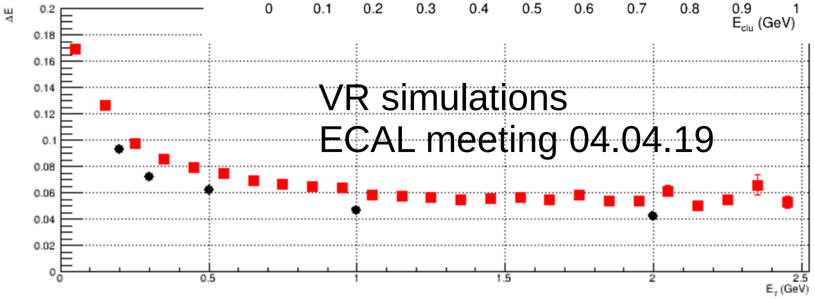
Energy resolution

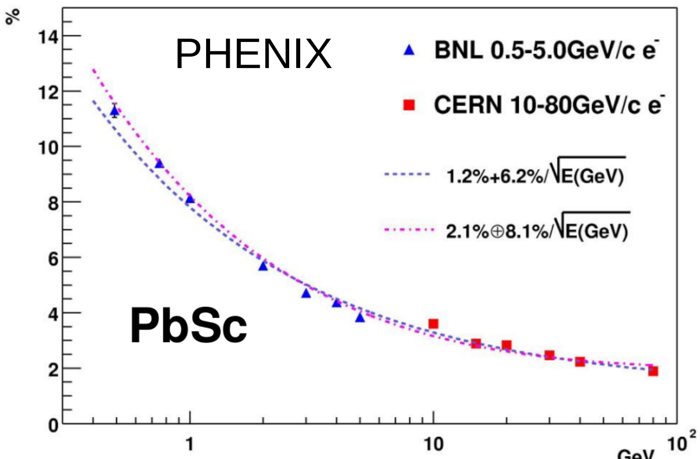
- Crucial input for MC simulation
- Resolution contains contributions with different dependence on E
  - Light production/collection
  - Electronic noise
  - De-calibration
  - => need wide E region to properly parameterize each contribution
- Comparison of MC simulations and beam-test?

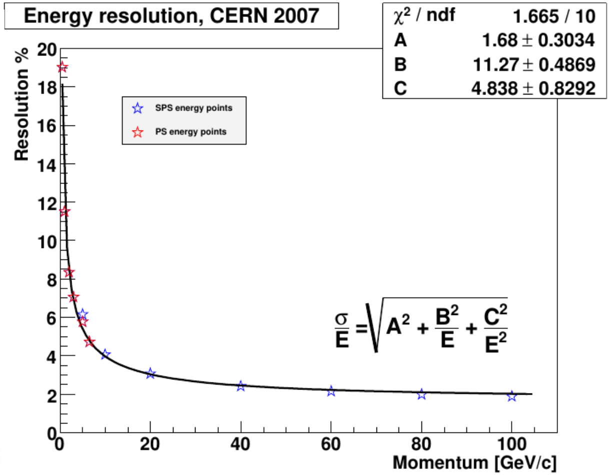
Reconstructed energy ~1/3 of photon energy???
Energy resolution ~2 times better (?) than in similar calorimeters ALICE/EMCAL, PHENIX/PbSc?











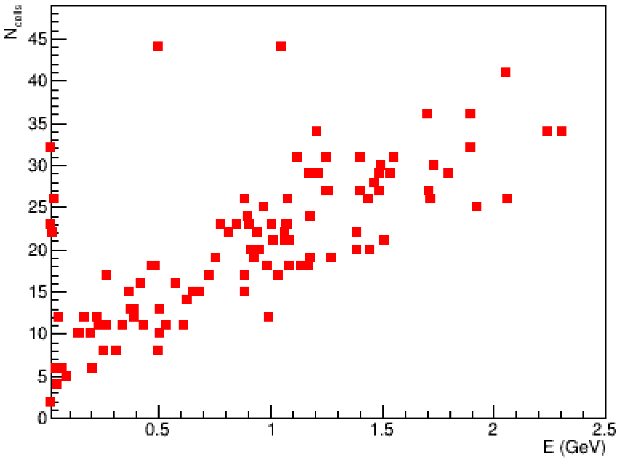
Non-linearity correction

- Can be extracted from (realistic) beam tests
  - Need full cluster reconstruction in beam test
    - => at least 4*8 or better 8*8 assembly
- Extracted *in-situ* using m(p_T) dependence
  - Works at mid-p_T, but hard at high-p_T

Expected non-linearity ~3%

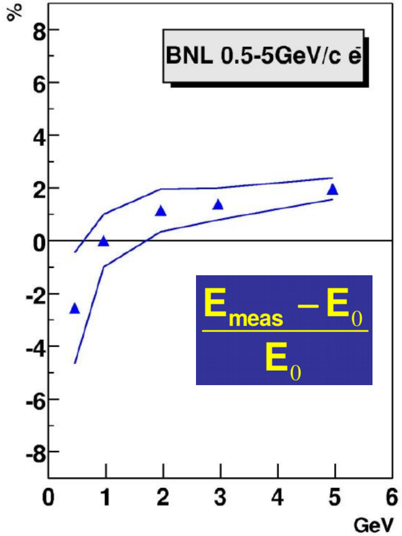
VR clusterizer,

Single photon simulation

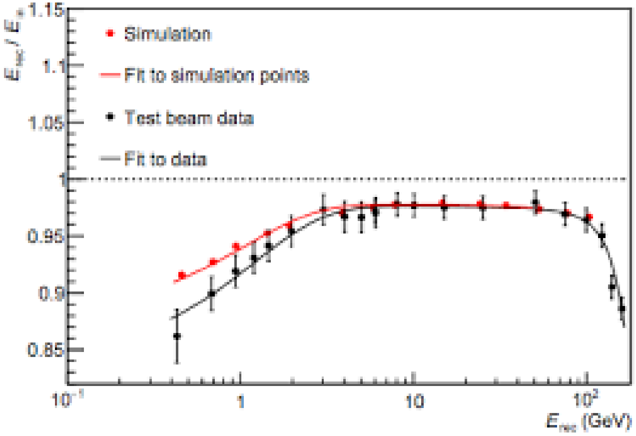


Cluster size logariphmically grows with energy
At E~2 GeV cluster size ~6*6 cells

PHENIX/PbSc



ALICE/EMCAL

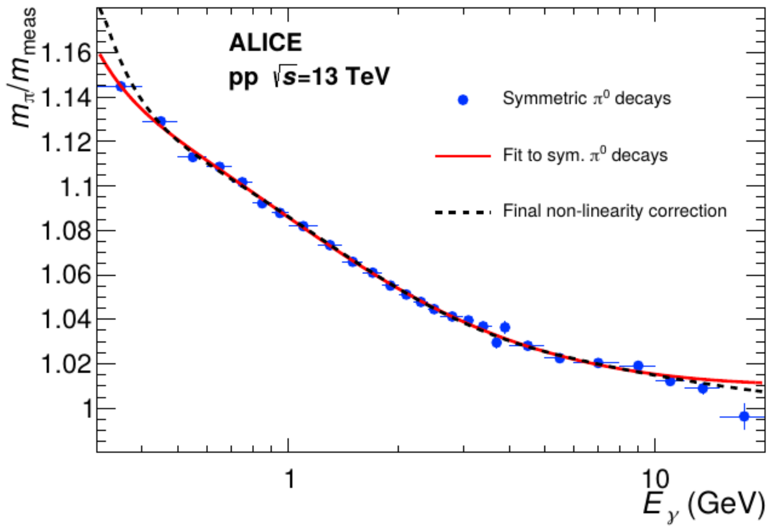


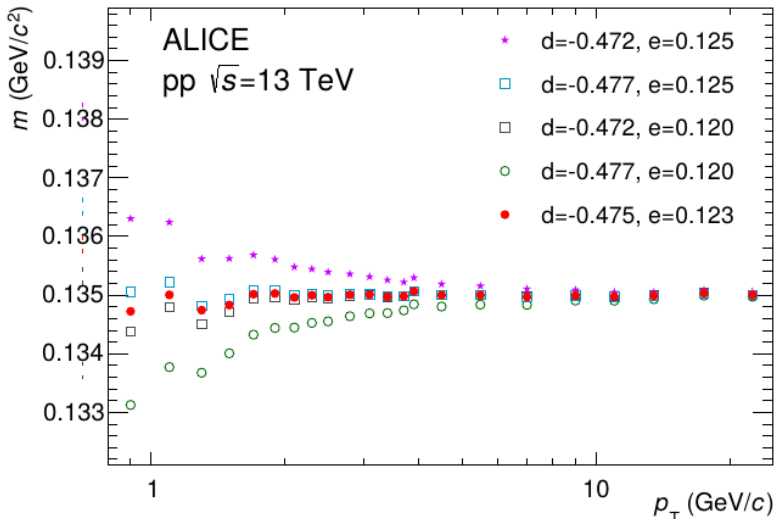
Non-linearity: pion mass position

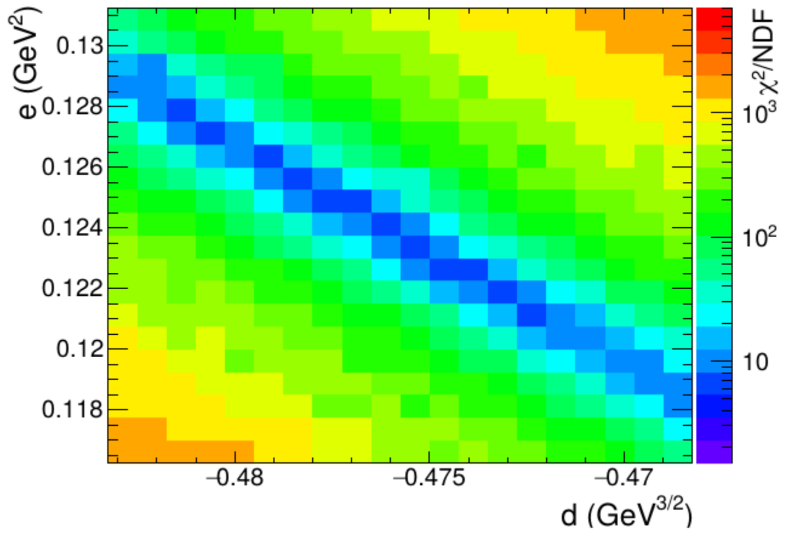
Example from ALICE/PHOS:
JINST 14 (2019) no.05, P05025

- Symmetric decays
  - Hard at low p_T (acceptance) and high p_T (statistics, cluster merging)
- All decays (extremely time-consuming procedure)

$$E_{\rm corr} = \begin{cases} aE + b\sqrt{E} + c + d/\sqrt{E} + e/E, & E \le E_0 \\ \alpha E + \beta\sqrt{E}, & E > E_0 \end{cases}$$



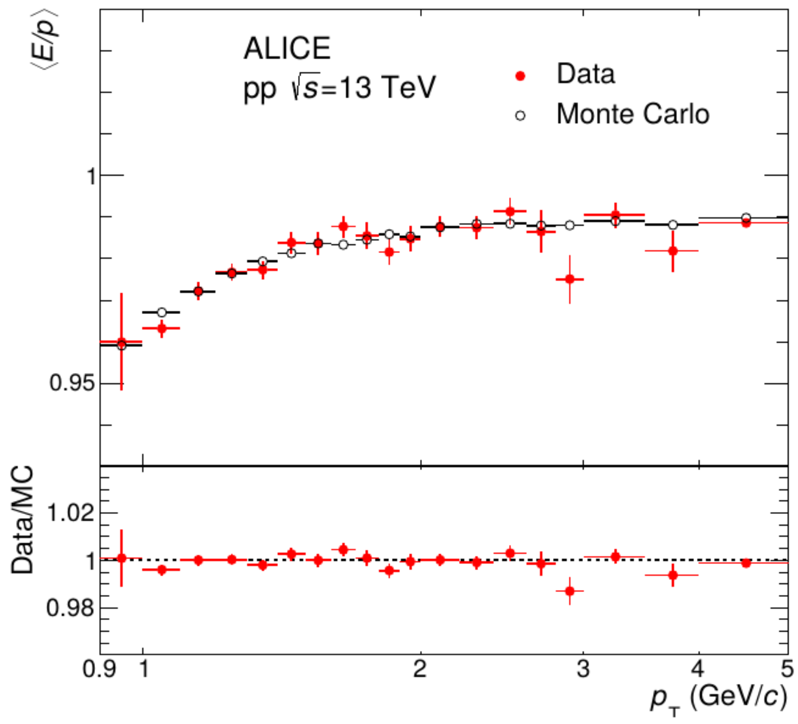




Example from ALICE/PHOS:
JINST 14 (2019) no.05, P05025

Non-linearity: electron E/p

- Extracted in citu from electron E/p peak position
  - Non-linearly depends on material budget
    - => precise description of material in MC
- Hard at high p_T (statistics) and at low-p_T (precise description of detector material)



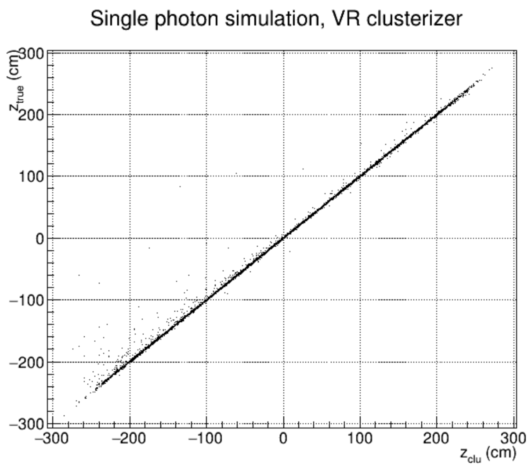
Though in-situ methods of non-linearity exist, they all provide relatively poor accuracy.
Precise non-linearity parametrization from beam-test data is necessary
- electron beam-test with large prototype (8*8), final electronics, thermostabilization etc.
- wide (to probe all incident points in cell) monochromatic ($dp/p<10^{-3}$) electron beam

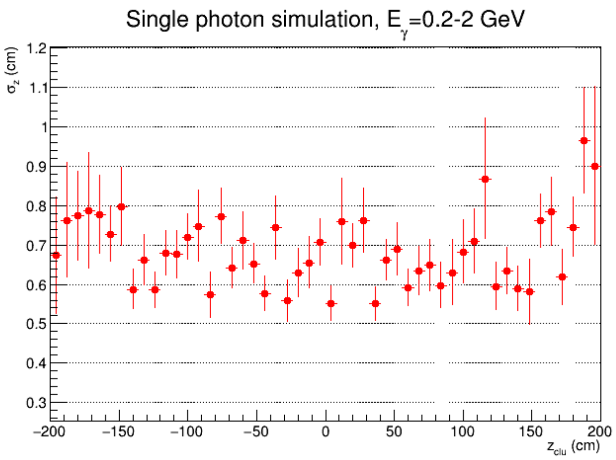
Position resolution

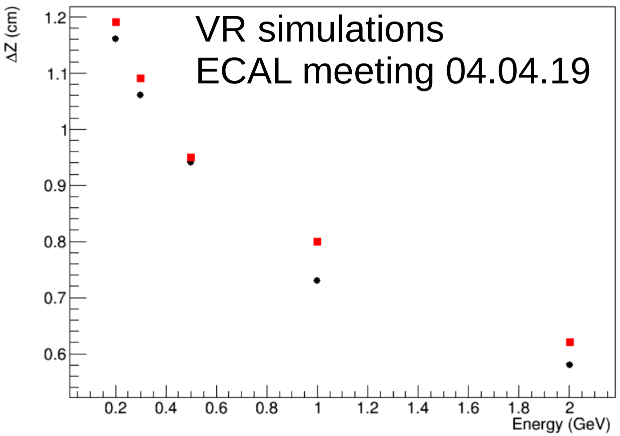
- Crucial input for MC simulation
- Is comparison of MC simulations and beam-test available?

Present MC simulation predicts ~2 times better resolution than one in existing calorimeters

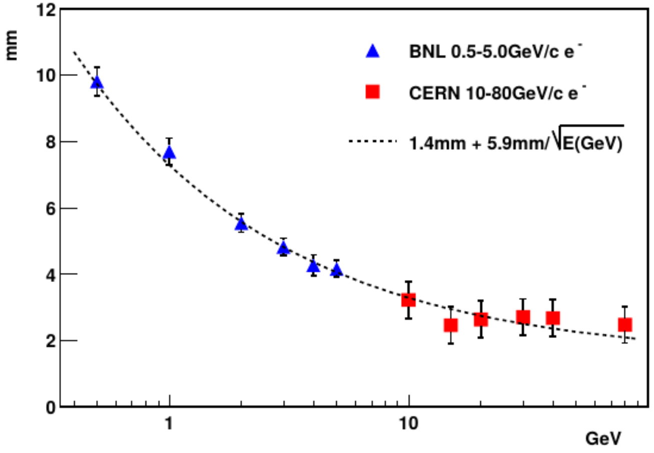
Need beam test with electron beam and position detector in front of prototype with position resolution ~0.5-1 mm



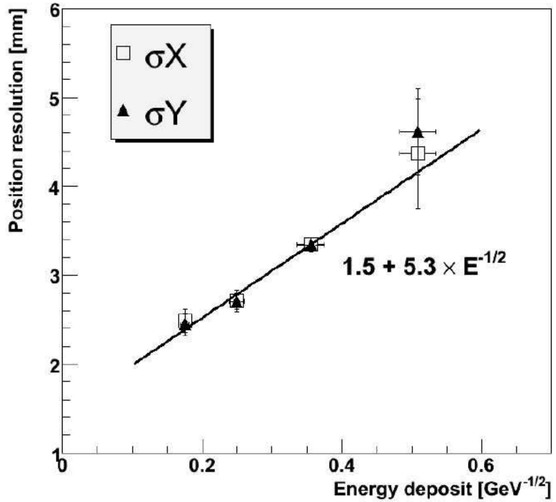




PHENIX/PbSc,
nucl-ex/0202009.pdf

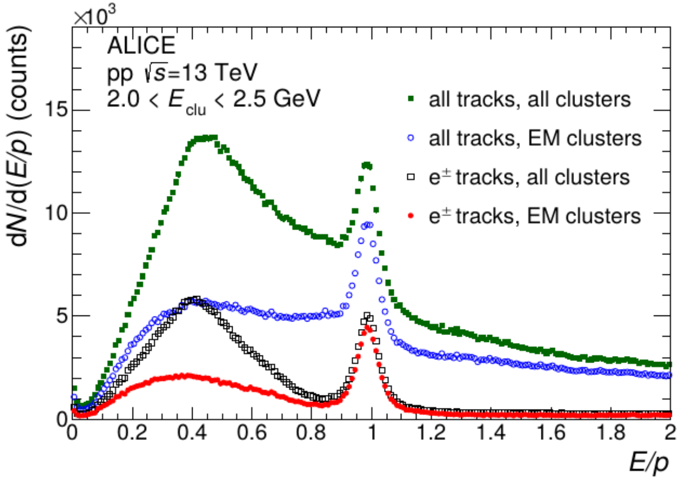


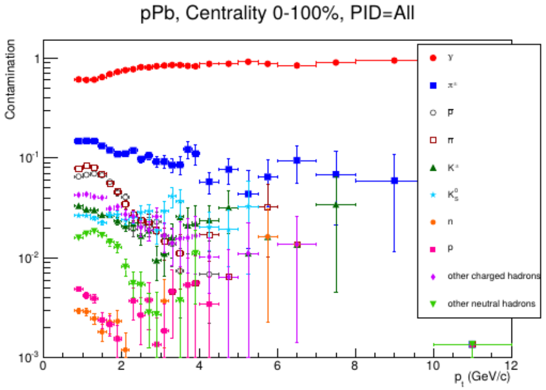
ALICE/EMCAL TDR:
CERN-LHCC-2008-014

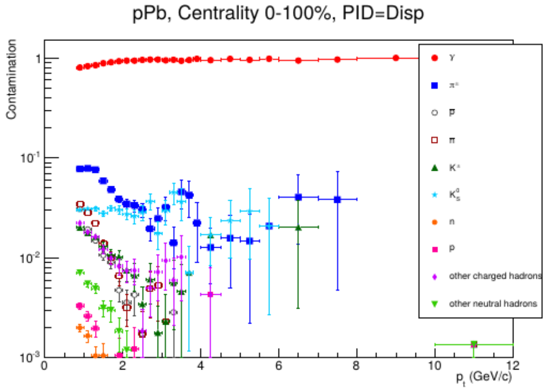


Photon/electron identification

- Photon and electron clusters can be identified by shower shape (narrower than hadron one)
  - Increase of putrity of photon sample
  - Increase of purity of electron sample
  - Increase of S/Bg in two-photon invariant mass spectrum







Variables to describe shower shape

ALICE/PHOS example (R_M=2.2 cm)

- Dispersion

$$D^2 = \frac{\sum\left((x_i-\bar{x})^2+(y_i-\bar{y})^2\right)w_i}{\sum w_i}$$

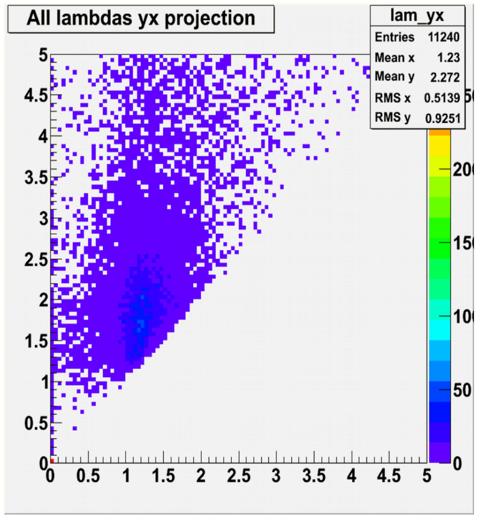
- Eigenvalues of second momenta tensor

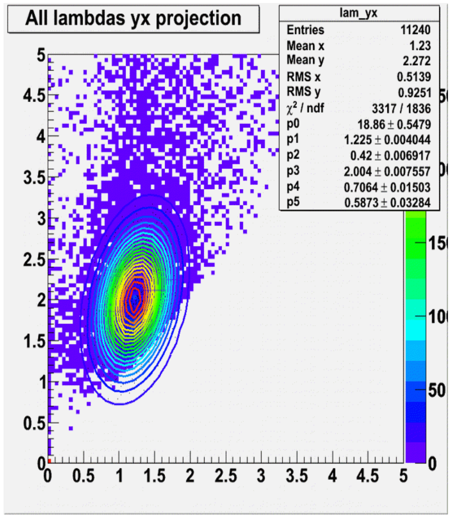
$$D^{ij} = \frac{\sum_k w_k (x_k^i - \bar{x^i})(x_k^j - \bar{x^j})}{\sum_k w_k}$$

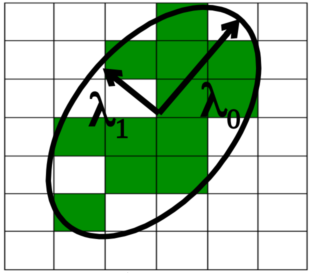
$$\lambda_{1,2} = \frac{1}{2}(D_{xx}+D_{zz}) \pm \sqrt{(D_{xx}-D_{zz})^2/4+D_{xz}^2}$$

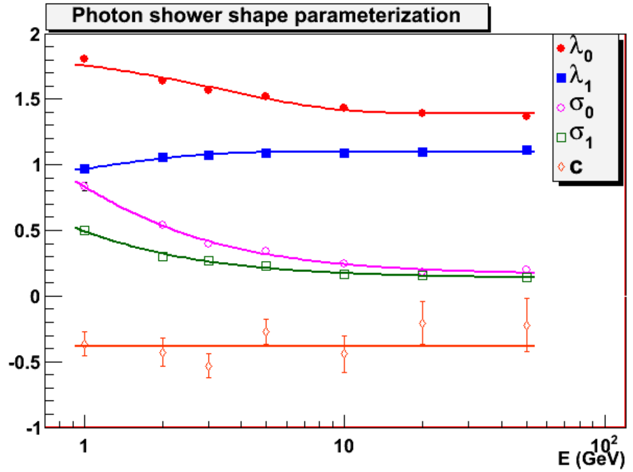
- Fit to reference EM shape

χ^2



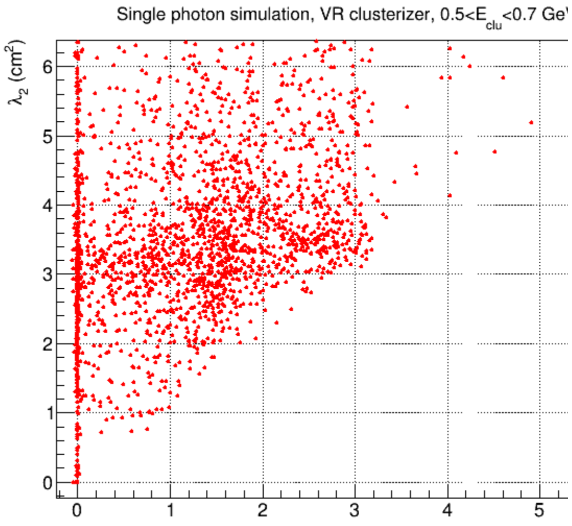


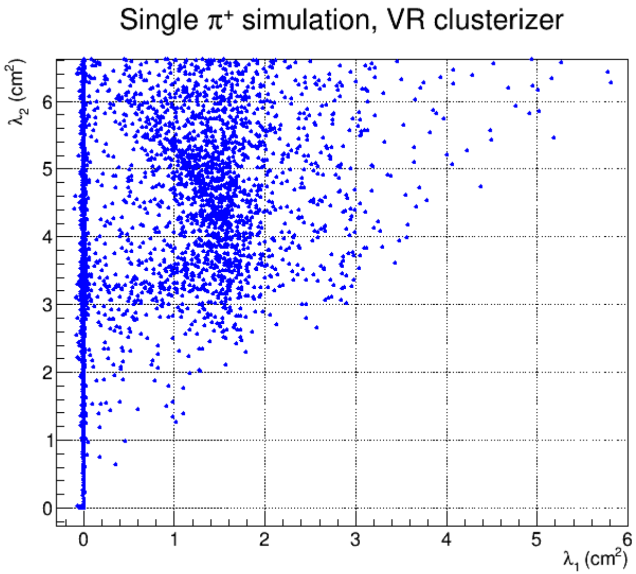


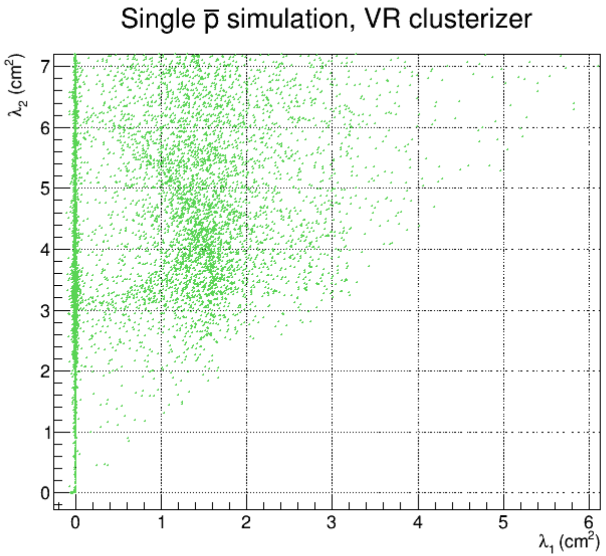


Dispersion in ECAL

- For the test purposes λ_{12} calculation was implemented to the cluster calculation in VR clusterizer
- Distributions for single photon and for charged pion/pbar looks different
  - Define cut, estimate purity/efficiency
  - Difference remains in high-multiplicity environment?



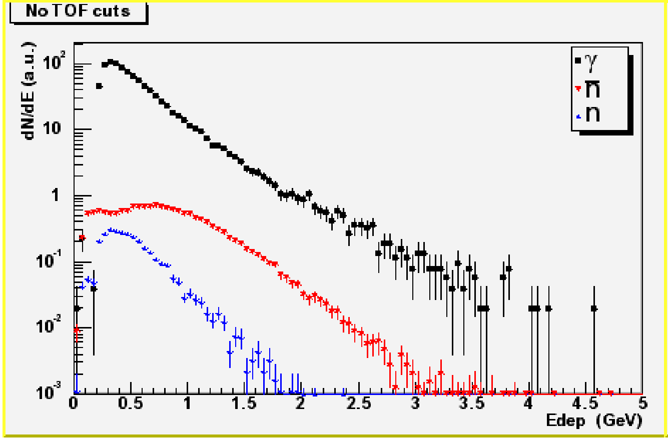


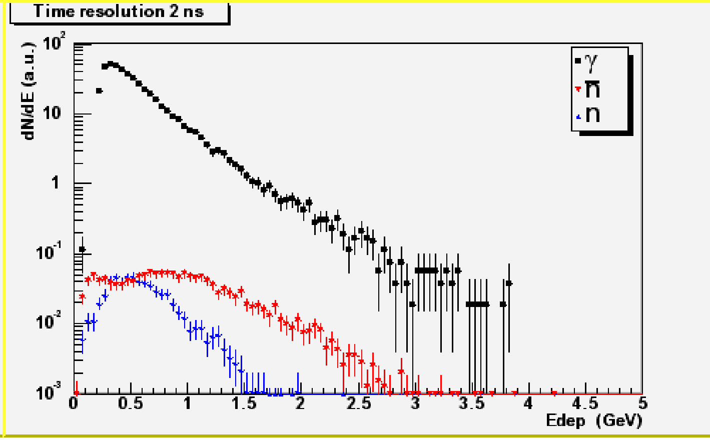


Geant3/Geant4 description of hadron interactions are relatively imprecise. Need real data to parameterize photon/electron and hadron shower shapes

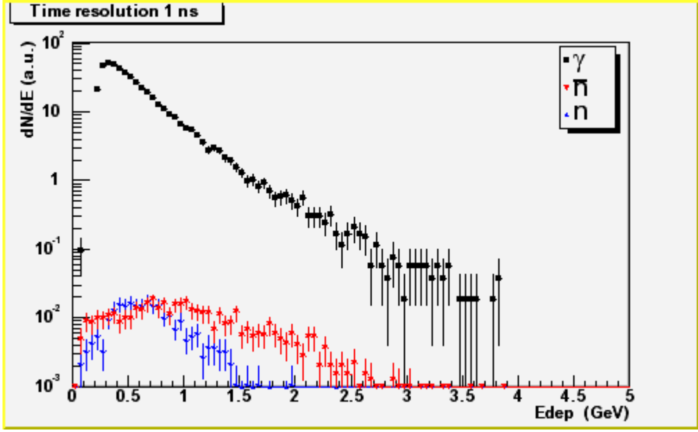
Time of flight cut

- TOF cut is the most efficient cut at low p_T
- To be efficient, time resolution ~1 ns is necessary.

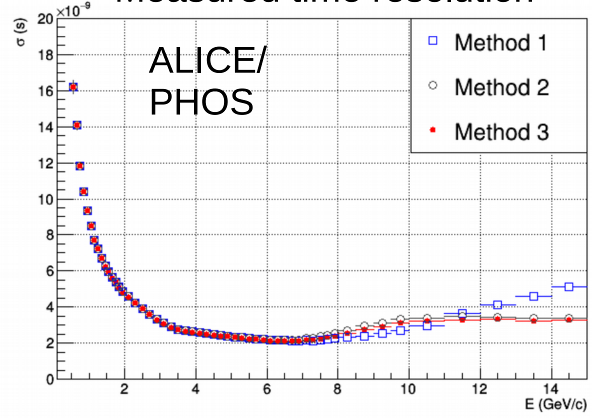




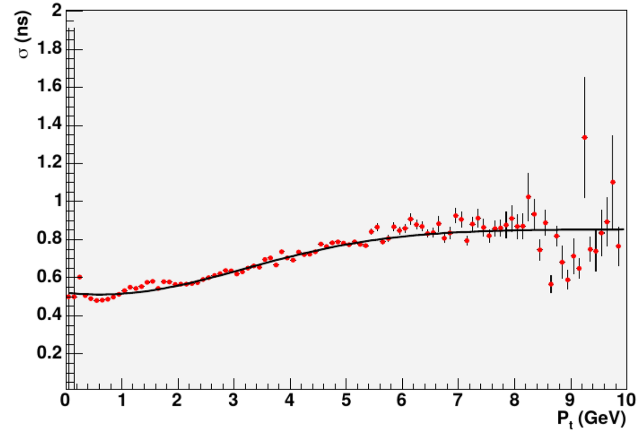
PHOS simulation
Distance to IP=460 cm



Measured time resolution



PHENIX/PbSc



Summary of beam-test proposals

Beam setup	Measure
Electron beam, Several energies (0.4-2 GeV) Good dp/p $<\sim 10^{-3}$ resolution Wide beam ~width of the cell Small material budget in front of prototype	Energy resolution Non-linearity
Electron beam Several energies (0.4-2 GeV) Wide beam $>\sim$width of the cell Position detector in front of prototype Possibility of non-perpendicular incidence 5-10°	Position resolution Depth of the shower (with non-perpendicular beam) EM shower shape
Electron beam, Several energies (0.4-2 GeV) Start detector (scintillator?) in front of prototype	Time resolution vs E
Hadron beam: pions/protons Several energies (0.4-2 GeV)	Hadron shower shape

Realistic prototype: 8*8, final electronics, thermostabilization etc.