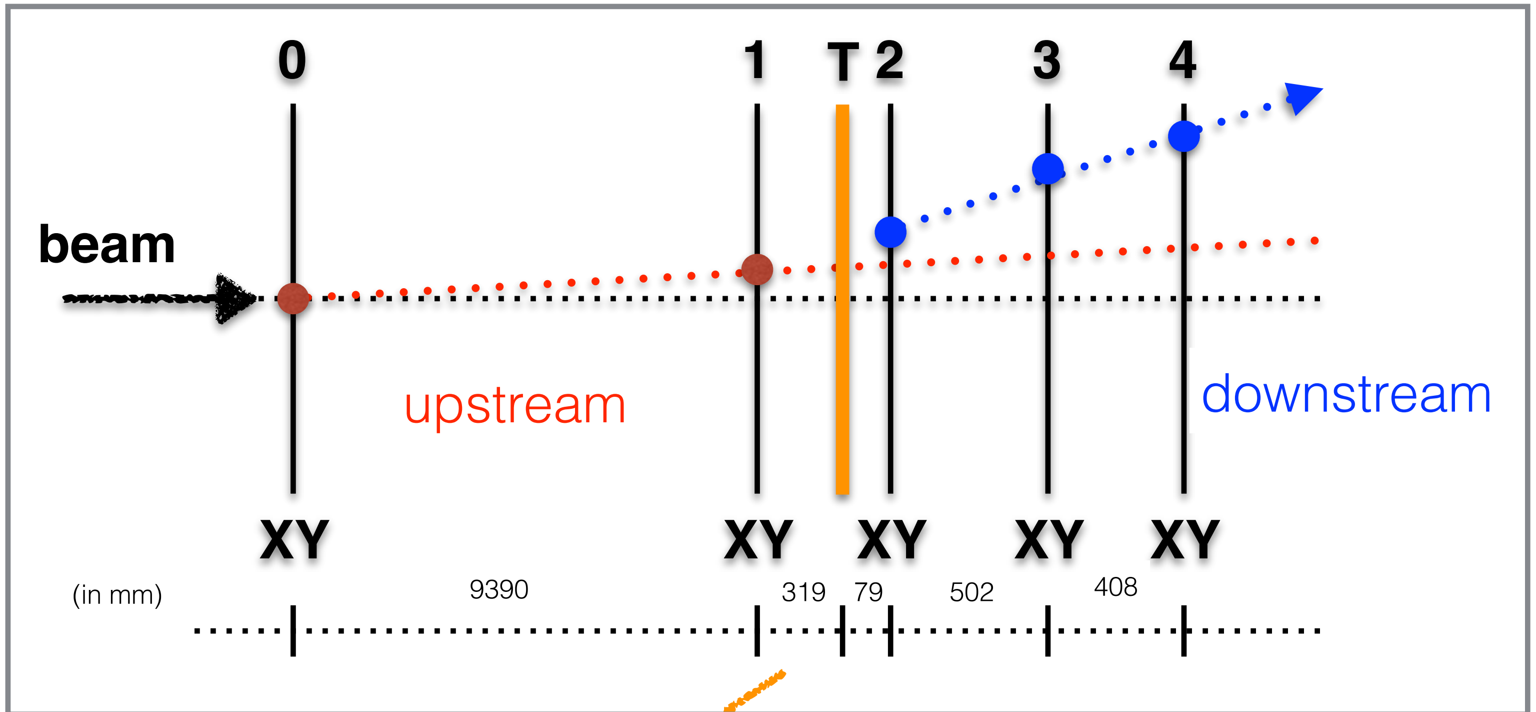
Test Beam analysis and preliminary comparison data / Geant4

A. Principe

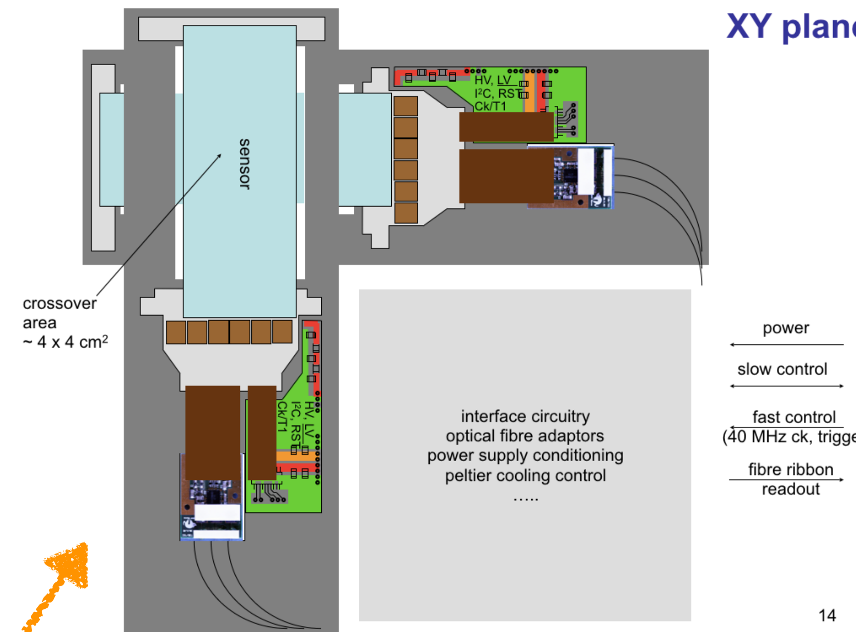
Summary

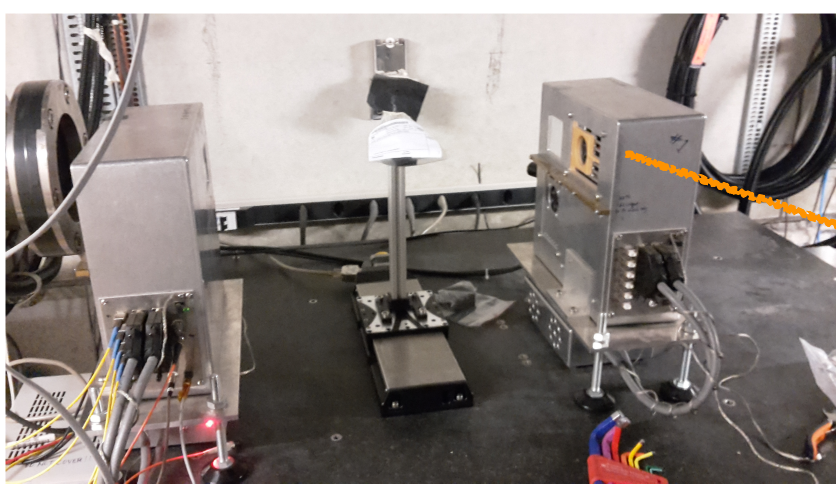
- One of the main systematics of our experiment proposal is Multiple Coulomb Scattering (MSC): its control is required at percent level at least, mainly on angle distribution cores.
- ***μ on e*** scattering takes place through matter, so MSC simulation are central aims of our feasibility studies.
- To achieve this precise control and so to evaluate the possibility of our measure, we've done a Test Beam in Sept-Oct 2017 at Cern: data analysis is still ongoing.
- Also, we're starting to compare data runs with MonteCarlo simulation of our apparatus, using Geant4.

Test beam apparatus

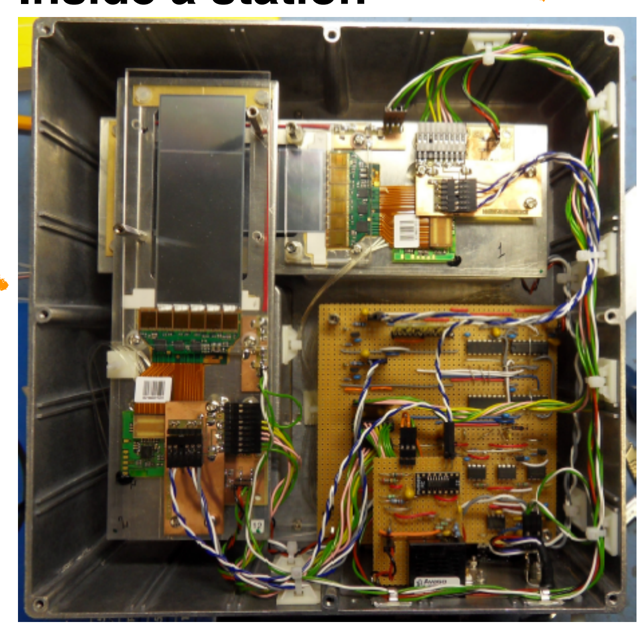


Silicon strips scheme X/Y





Inside a station



Silicon strips sensors:

- thickness: 320 μm single-sided;
- pitch: 60 μm pitch;
- point resolution: ~6.9 μm.

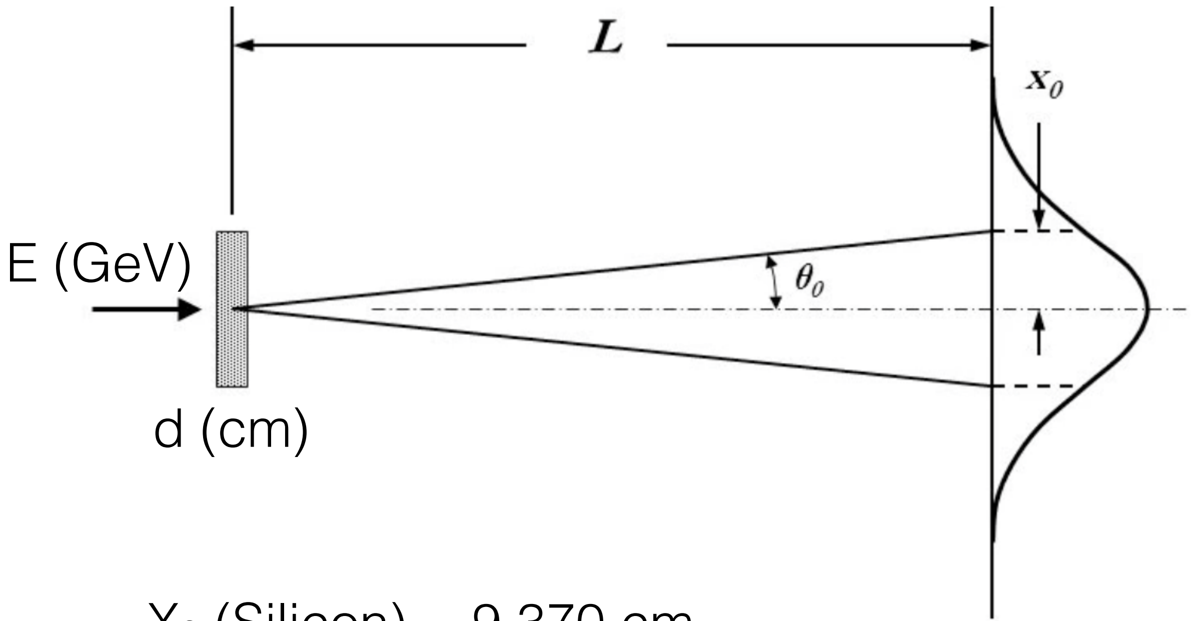
Beam energy:

- 12, 20 GeV.

Targets:

- Graphite (ρ=1.83 g/cm3)
- thickness: 2, 4, 8, 20 mm.

Multiple Scattering



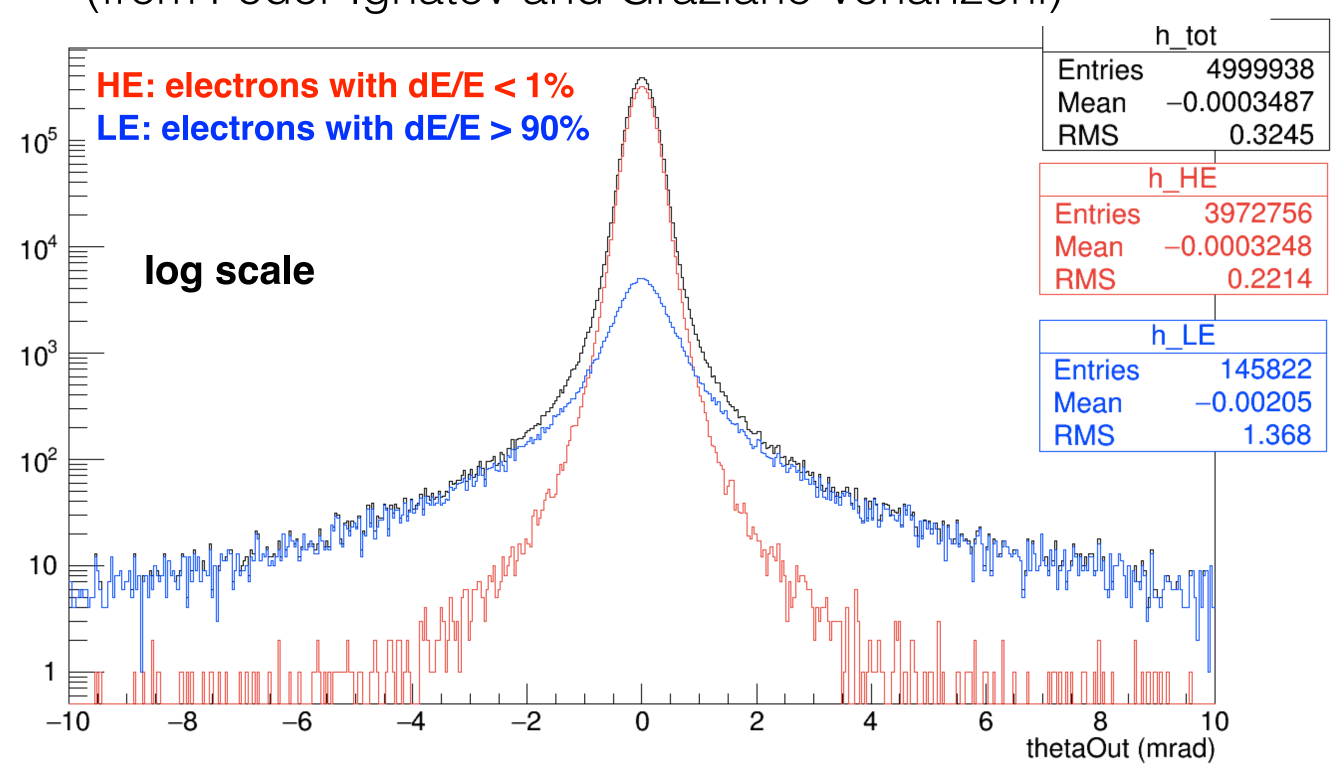
- Charged particles are deflected by many small angle scatters, mostly due to Coulomb scattering from nuclei.
- Via the central limit theorem, the net displacement distribution are Gaussian (Highland-Moliere formula):

$$\theta_0 = \frac{13.6}{E}\sqrt{\frac{d}{X_0}}\left(1 + 0.038\log\left(\frac{d}{X_0}\right)\right)$$

- Less frequent, “hard” scatters produce non-Gaussian tails.

X_0 (Silicon) = 9.370 cm
X_0 (graphite) = 23.33 cm
X_0 (air) = 305.5 m

Geant4 simulation of 12 GeV electrons on 8 mm graphite: exit projected angle distribution
(from Fedor Ignatov and Graziano Venanzoni)

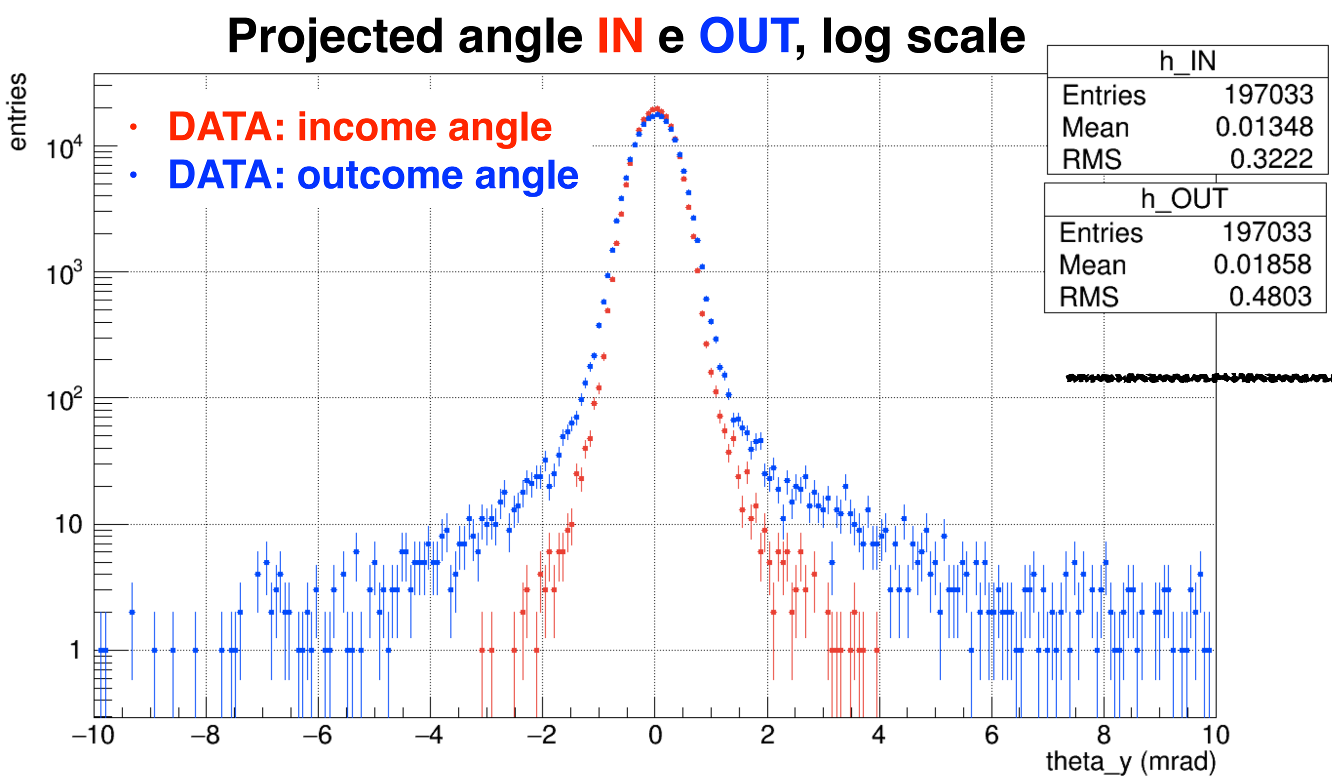


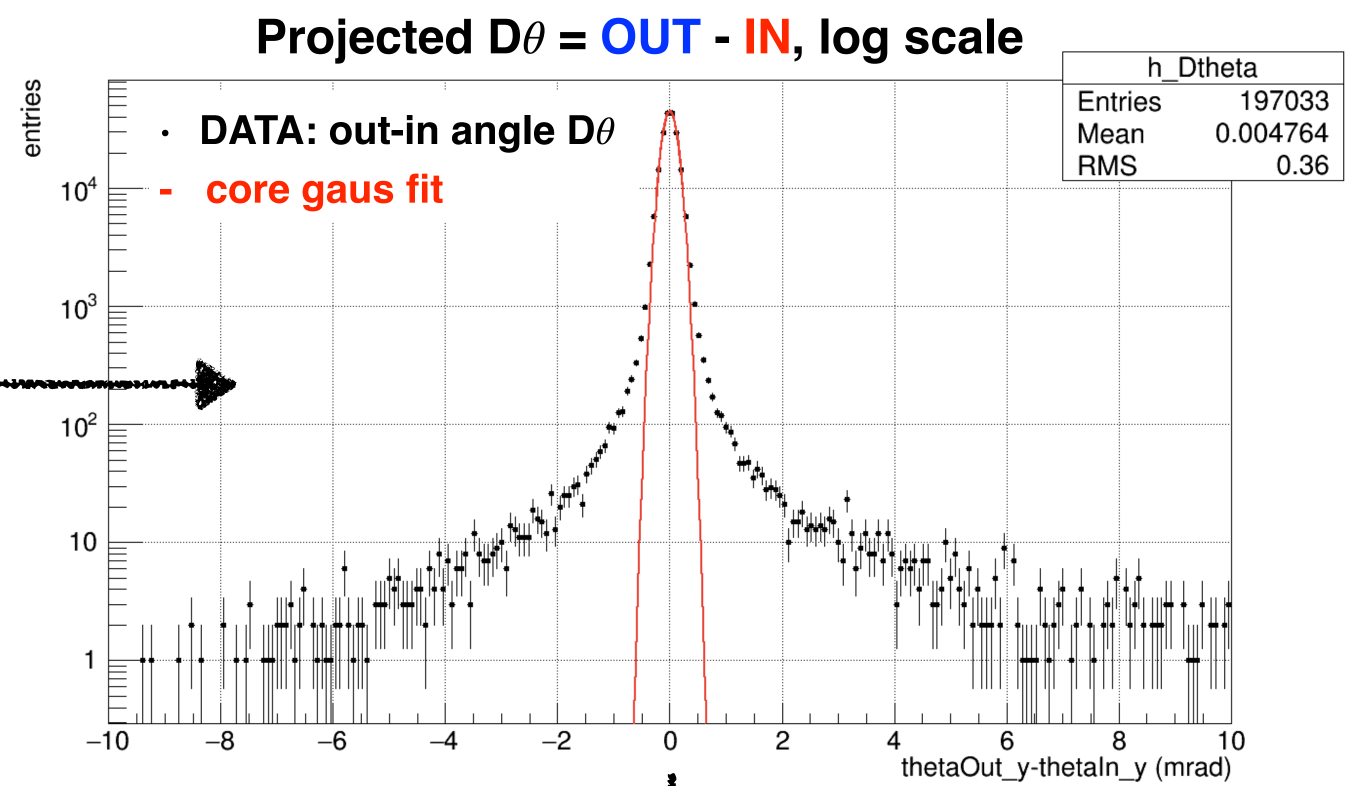
- Into gaussian cores (**red curve**), there are particles which have lost just a little amount of their energy;
- into tails (**blue curve**), at large angle, we find particles which have lost most of their energy (radiative process).

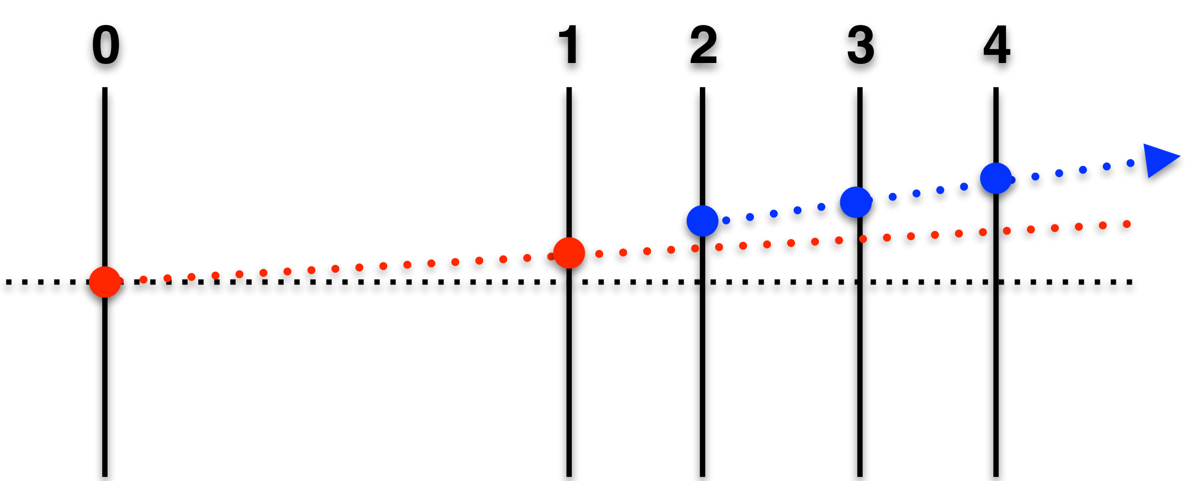
Data analysis

(run 12 GeV electrons, without and with 20 mm graphite)

Angle distributions: 12 GeV electrons without target



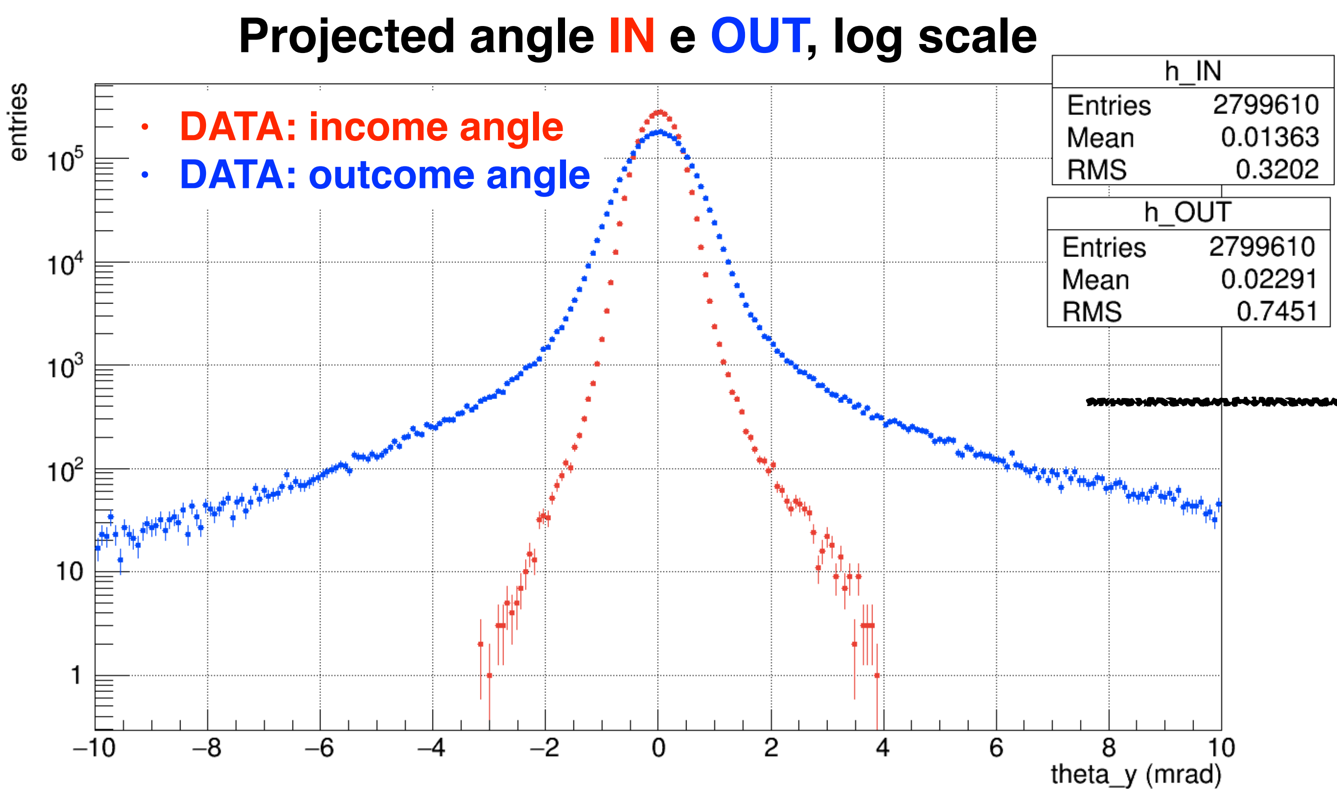


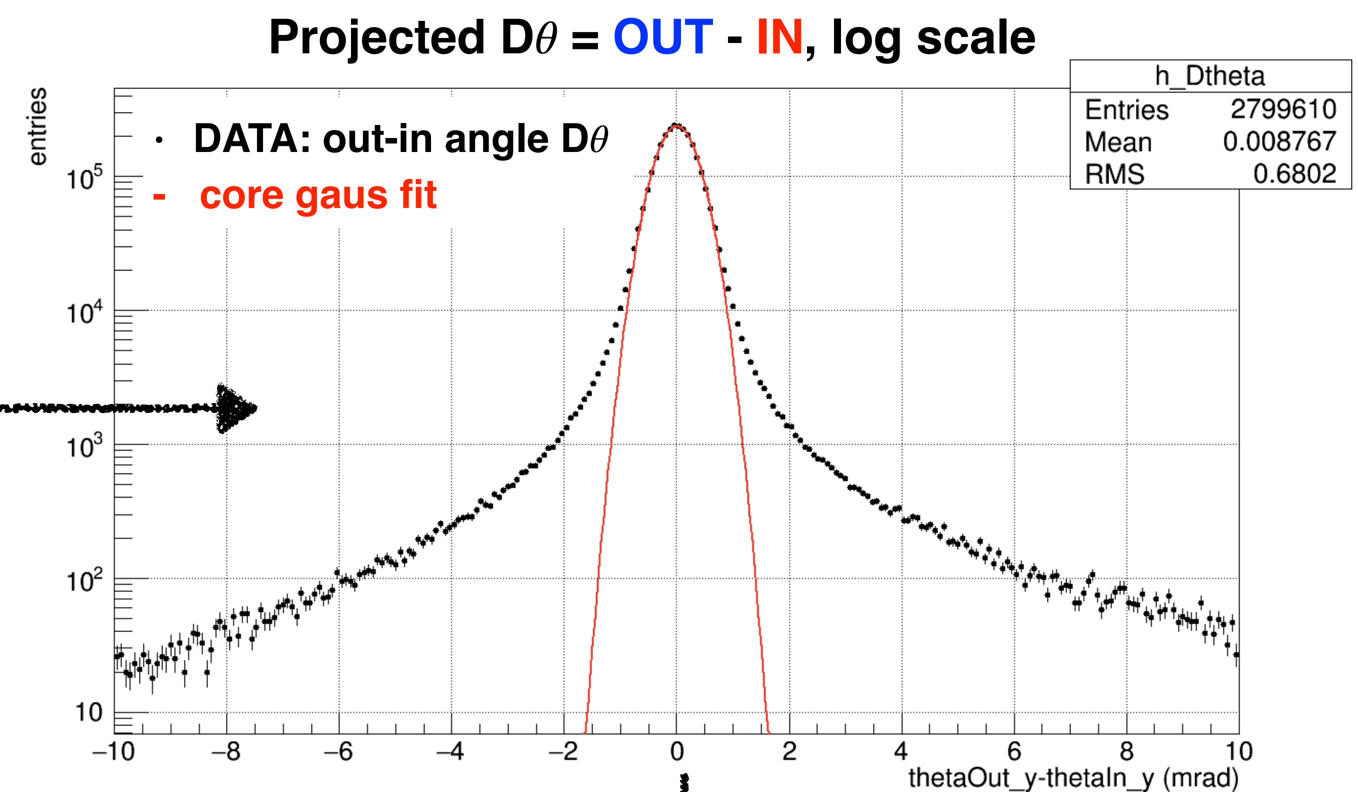


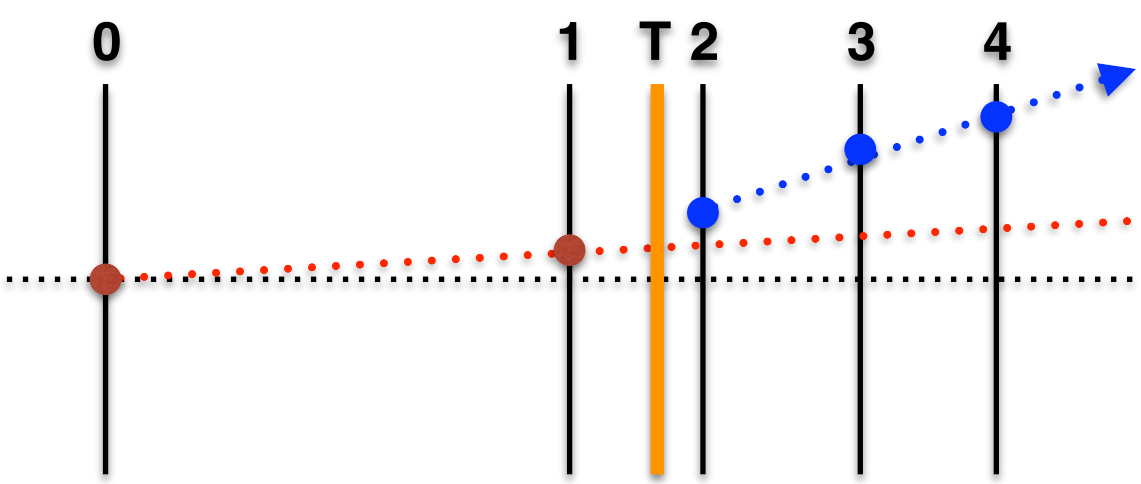
- Gaussian core contains ~ 90% of single events.
- Fit results of the core [-0.25, 0.25] mrad:
  mean = (0.06 ± 0.38) · 10^{-3} mrad
  sigma = (0.1320 ± 0.0004) mrad

- We aligned data hits thanks to the contribution of Giovanni Abbiendi, Clara Matteuzzi and Umberto Marconi.
- These angle distributions are essentially due to silicon MSC and to a (little) energy loss in each tracker station.
- Distribution of difference (run without target) represents our method resolution on **Dθ.**

Angle distributions: 12 GeV electrons on 20 mm graphite







- Core contains ~ 90% of single events.
- Fit results of the core [-0.70, 0.70] mrad:
  mean = (0.9 ± 0.4) · 10^{-3} mrad
  sigma = (0.3551± 0.0002) mrad

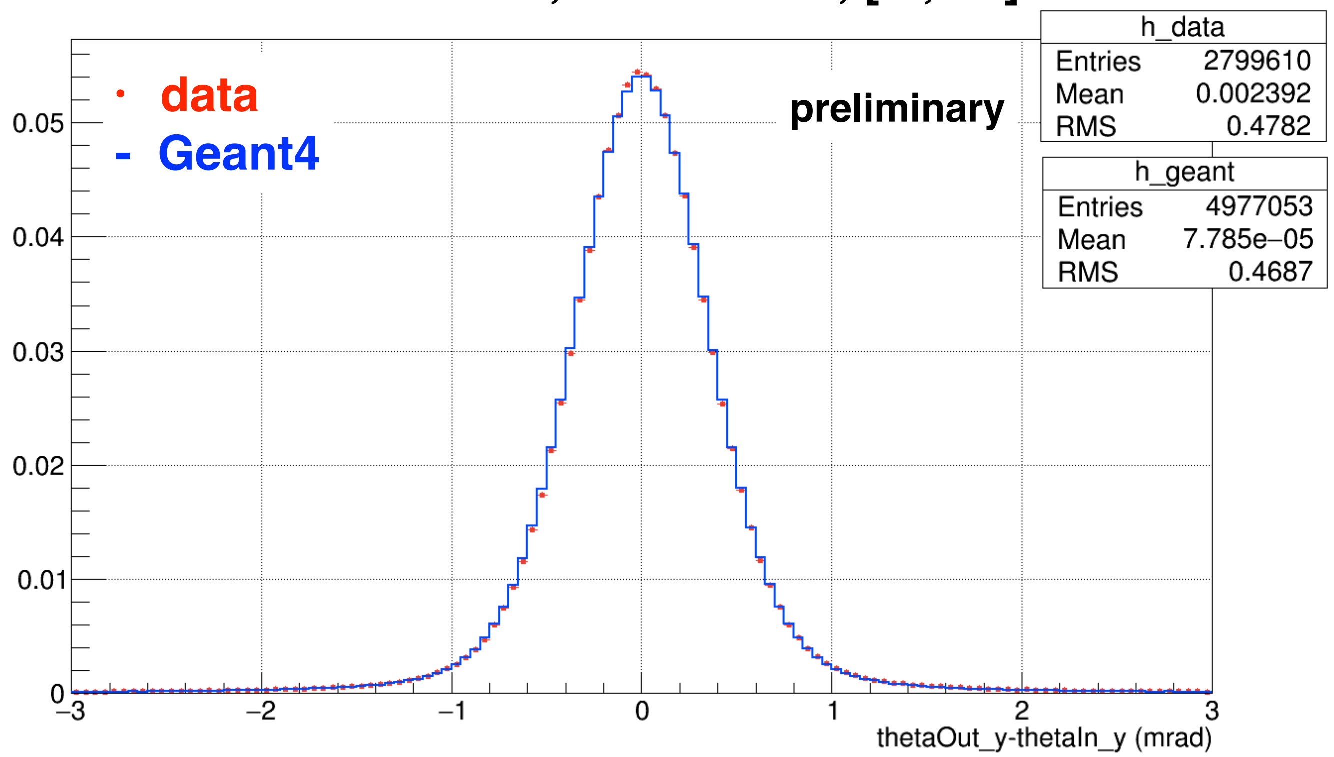
- Outcome distribution is wider than previous one: target MSC and energy loss are causes of higher smearing.
- Angle distribution shape of income and outcome particles depends on beam profile.

Preliminary comparison data / MC

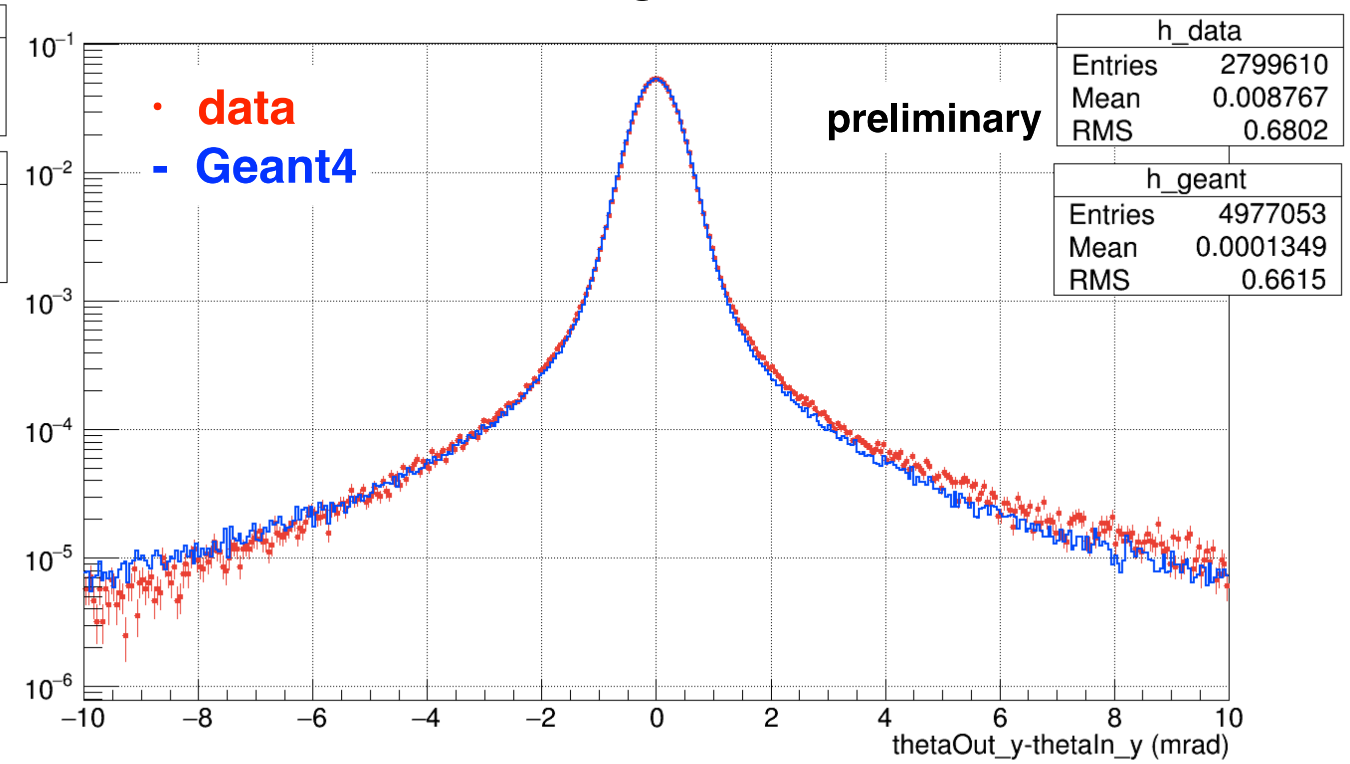
(Geant4 complete apparatus)

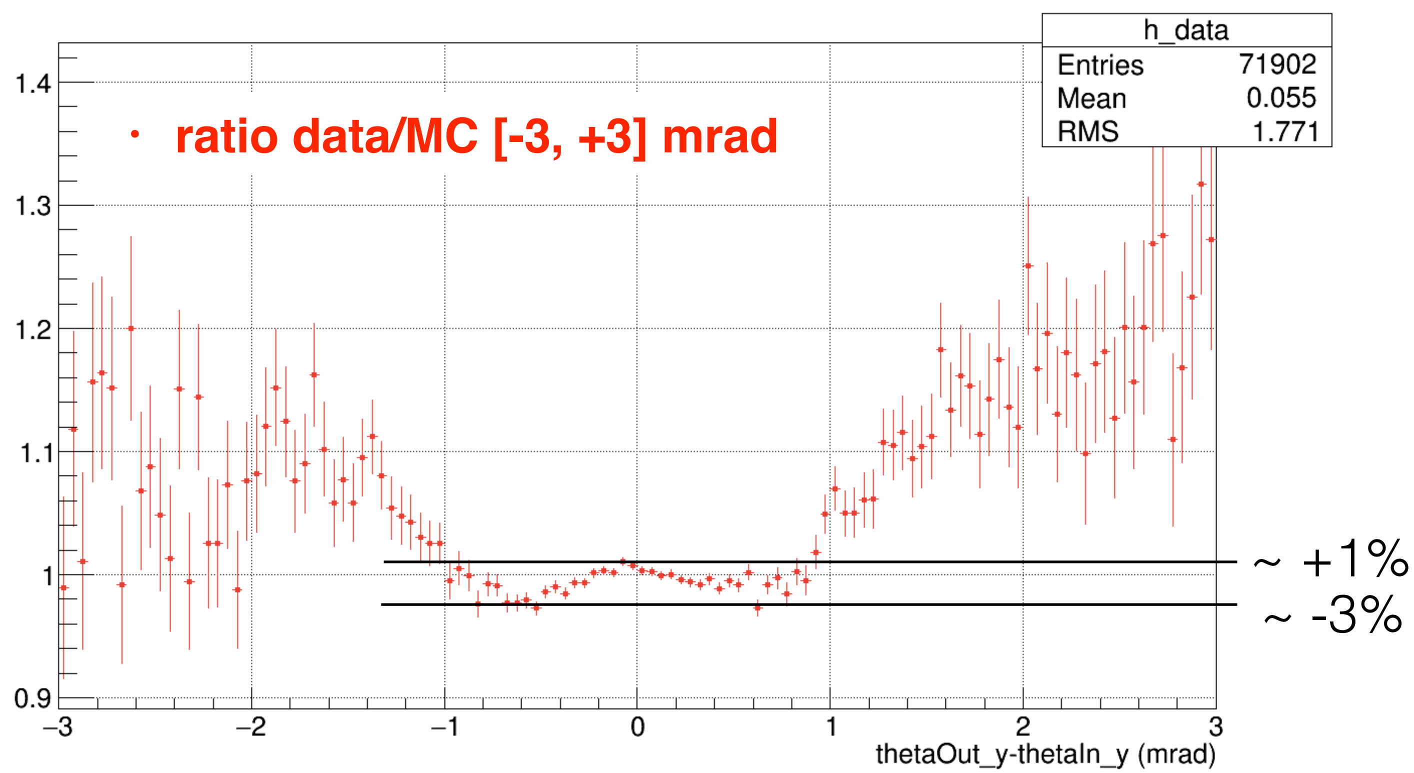
Data / MC: 12 GeV electrons on 20 mm graphite

Dθ distribution, linear scale, [-3, +3] mrad



Dθ distribution, log scale, [-10, +10] mrad





- Gaus fit results of the **core**, [-0.7, +0.7] mrad (mean X/Y view):
  DATA Dθ sigma = (0.3538 ± 0.0002) mrad
  MC Dθ sigma = (0.3564 ± 0.0001) mrad

- MC core is +0.73% from data one;
- bin per bin ratio: ~1-3% core, >10% tails.
- This agreement is a good starting point.

Remarks

- We've completed hits alignment and tracking reconstruction.
- Now, we're starting comparison data / MC, using Geant4 and exploring possibility of parameters fine tuning: multiple scattering and energy loss are complex effects to study and simulate.
- In any case, our first comparisons about runs with target are promising: preliminary agreement on cores is at level of a few percent.
- Test Beam data are also important to figure out detector optimisation: how do we need to know precisely MSC effect on core and on tails?

- These analysis are due to the fundamental contributions of **Giovanni Abbiendi, Fedor Ignatov, Clara Matteuzzi, Umberto Marconi and Graziano Venanzoni**.

Backup slides

Analysis and comparisons are ongoing…

$D\theta$ = core sigma distribution Out-In, runs with target.

σ_0 = apparatus resolution **on** $D\theta$ (from core sigma Out-In, runs without target).

$$\theta_{MS} = \sqrt{D\theta^2 - \sigma_0^2}$$

	DATA with target $D\theta$ (mrad)	method resolution from DATA σ_0 (mrad)	GEANT (graphite ρ=1.83 g/cm3) $D\theta$ (mrad)	method resolution from GEANT σ_0 (mrad)	DATA θ_{MS}	GEANT θ_{MS}
12 GeV 8 mm (e-)	0.23924	0.13139	0.24875 **(+3.8% from data)**	0.15424 **(+15% from data)**	0.19993	0.19516 (-2.4% from data)
20 GeV 8 mm (e-)	0.14405	0.08031	0.14854 **(+3.0% from data)**	0.09298 **(+14% from data)**	0.11959	0.11584 (-3.2% from data)
12 GeV 20 mm (e-)	0.35377	0.13139	0.35641 **(+0.74% from data)**	0.15424 **(+15% from data)**	0.32847	0.32131 (-2.2% from data)