Heidelberg Activities

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INSTITUTE
FOR PHYSICS

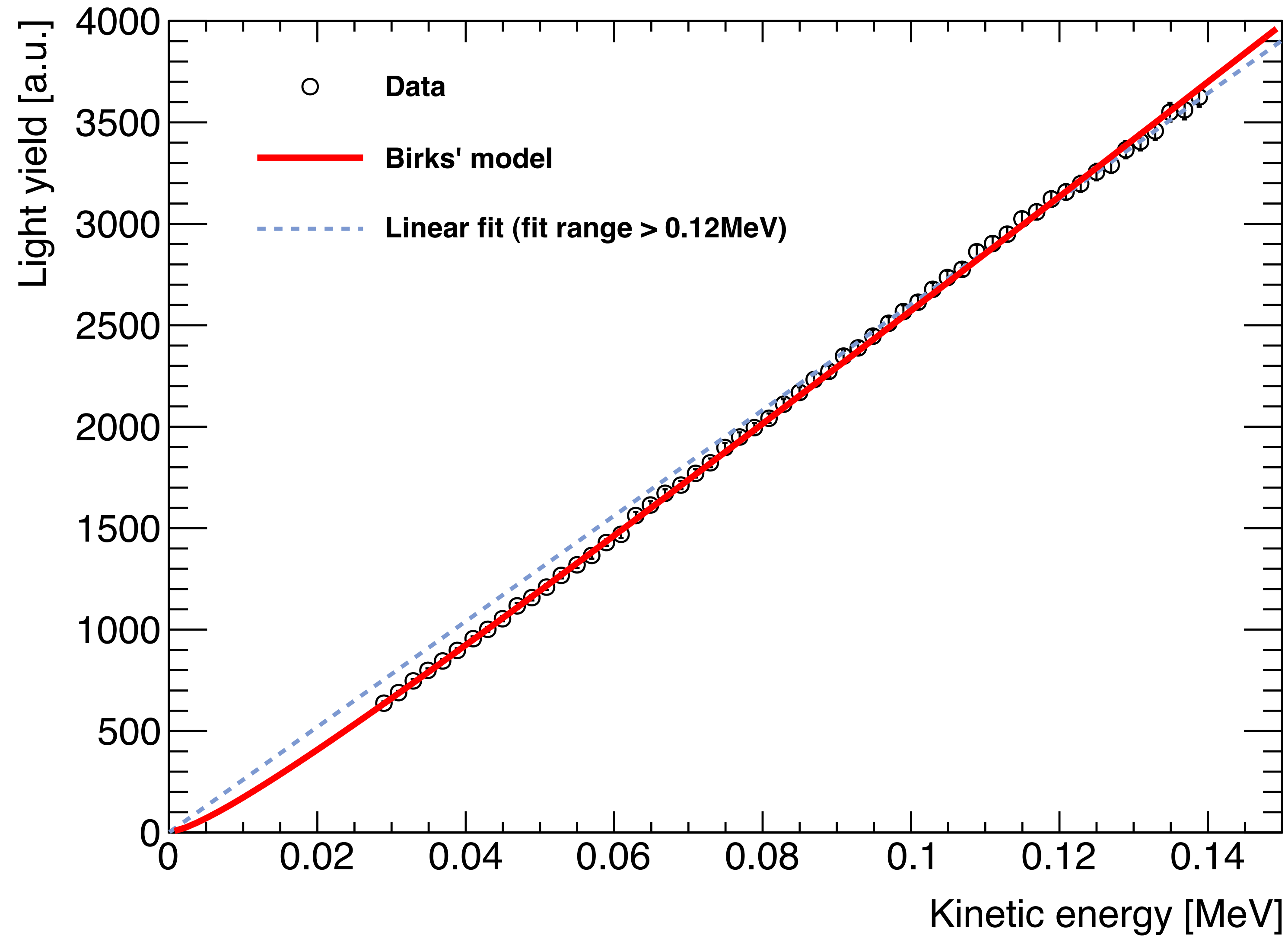
Outline

1. Status of Birks' law
   Implementation in Geant4
   First simulation results

2. Development of a tile/SiPM quality assurance system
   (Patrick Eckert)

Reminder: kB Measurement

- Light-yield of HCAL scintillator was measured as function of electron energy (MPIK Heidelberg)
- **Fit with Birks' model**
  ➜ Fit parameter **kB**



Fit function:

$$LY(E_0) = S \int_0^{E_0} \frac{1}{1 + kB\frac{dE}{dx}}\, dE$$

S: Scintillator efficiency

Fit result:
kB=0.0151 cm/MeV

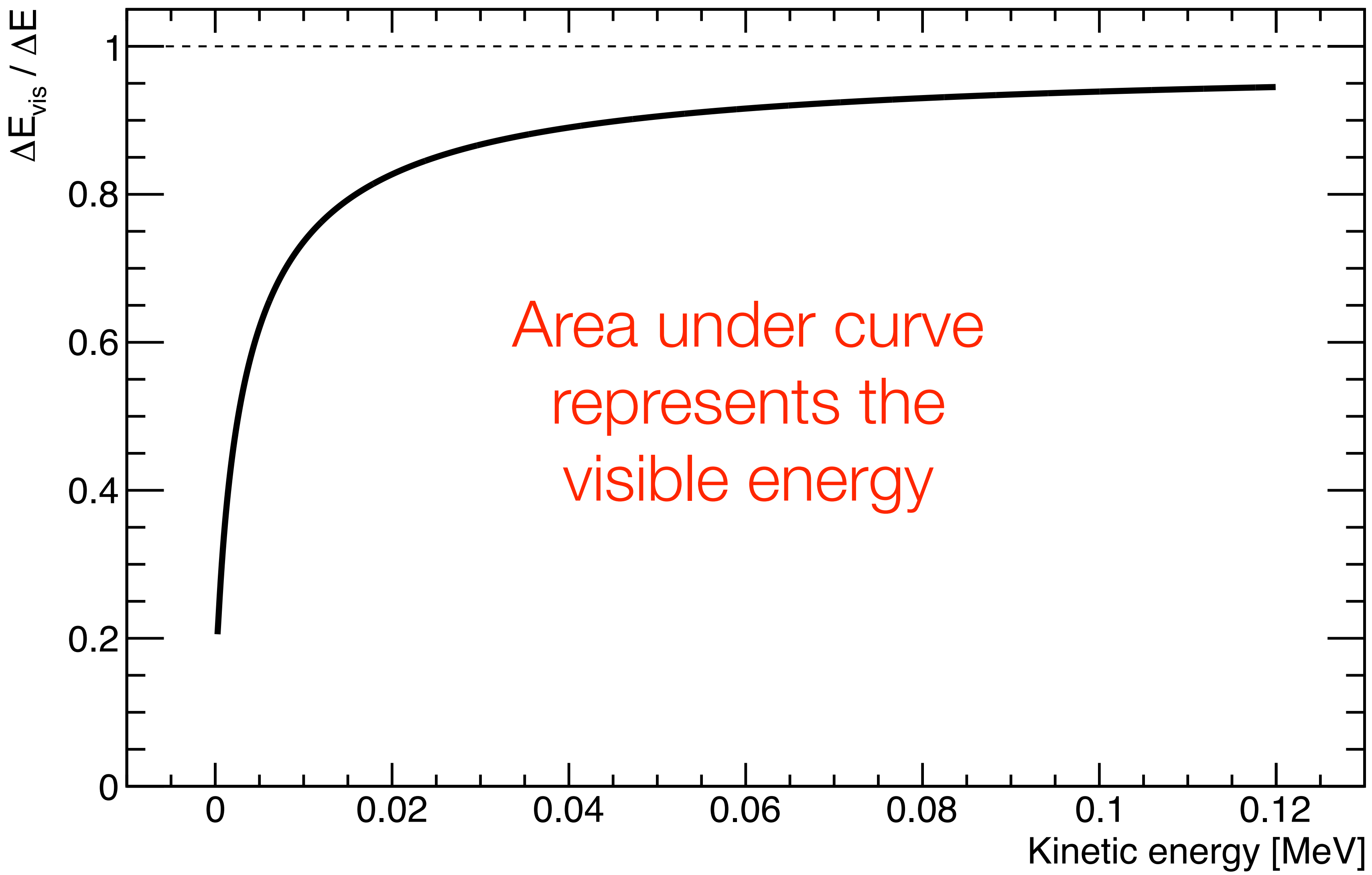
Currently used Mokka:
kB = 0.007943 cm/MeV

M. Hirschberg et. al.,
IEEE Trans. Nucl. Sc., Vol. 39, No. 4, 1992

Birks' coefficient in Geant4

$$\frac{dL/S}{dE} = \frac{dE_{vis}}{dE} = \frac{1}{1 + kB\frac{dE}{dx}}$$

Curve shows 120keV e^- with kB=0.0151cm/MeV



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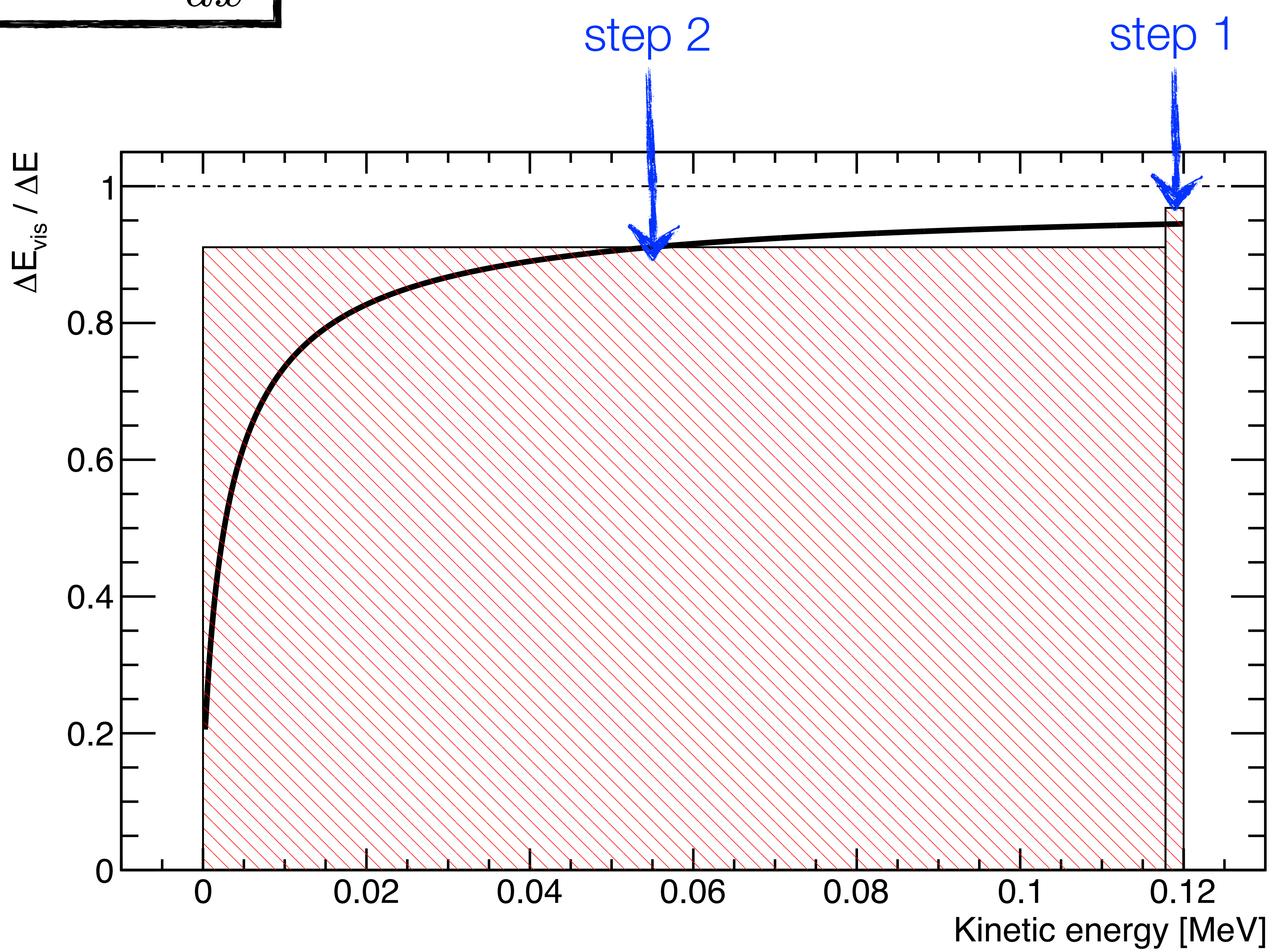
Geant4 with default settings and kB=0.0151cm/MeV

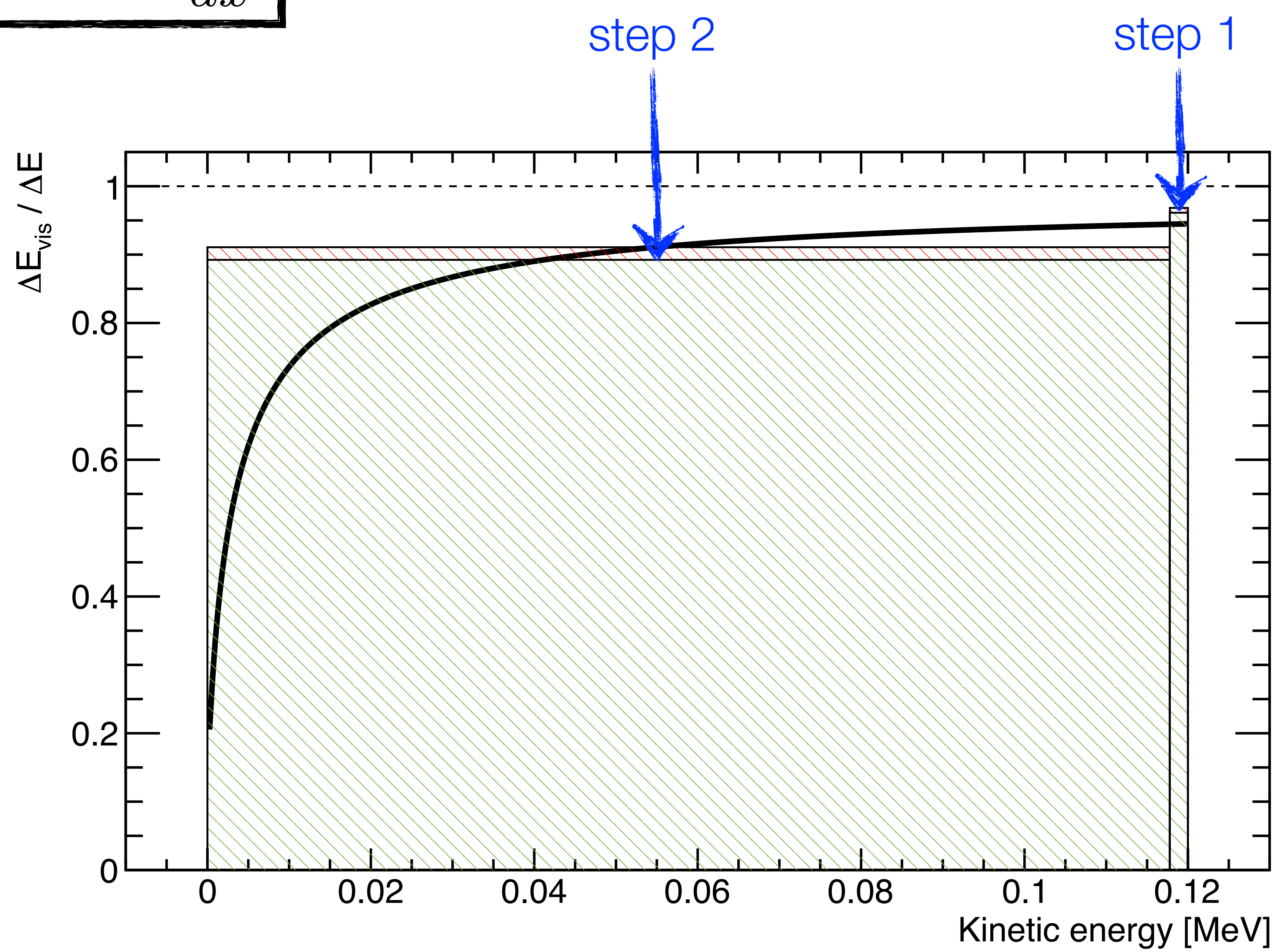
Visible energy is overestimated!



Birks' coefficient in Geant4

$$\frac{dL/S}{dE} = \frac{dE_{vis}}{dE} = \frac{1}{1 + kB\,\frac{dE}{dx}}$$

Curve shows 120keV e⁻ with kB=0.0151cm/MeV



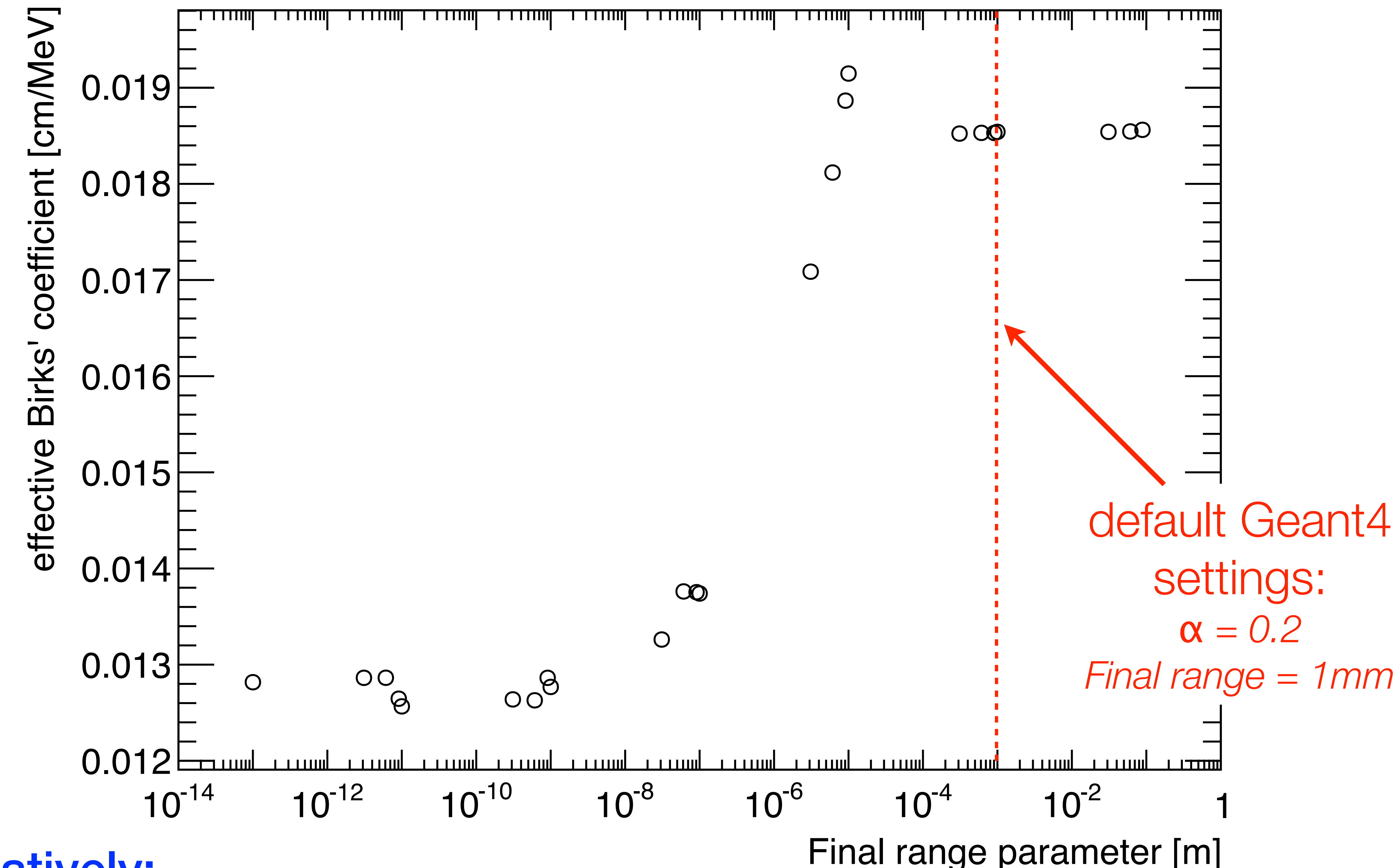
Geant4 with default settings and kB=0.0151cm/MeV

Visible energy is overestimated!

Possible solution:

Use "effective" Birks' coefficient to get the correct result kB=0.0186cm/MeV

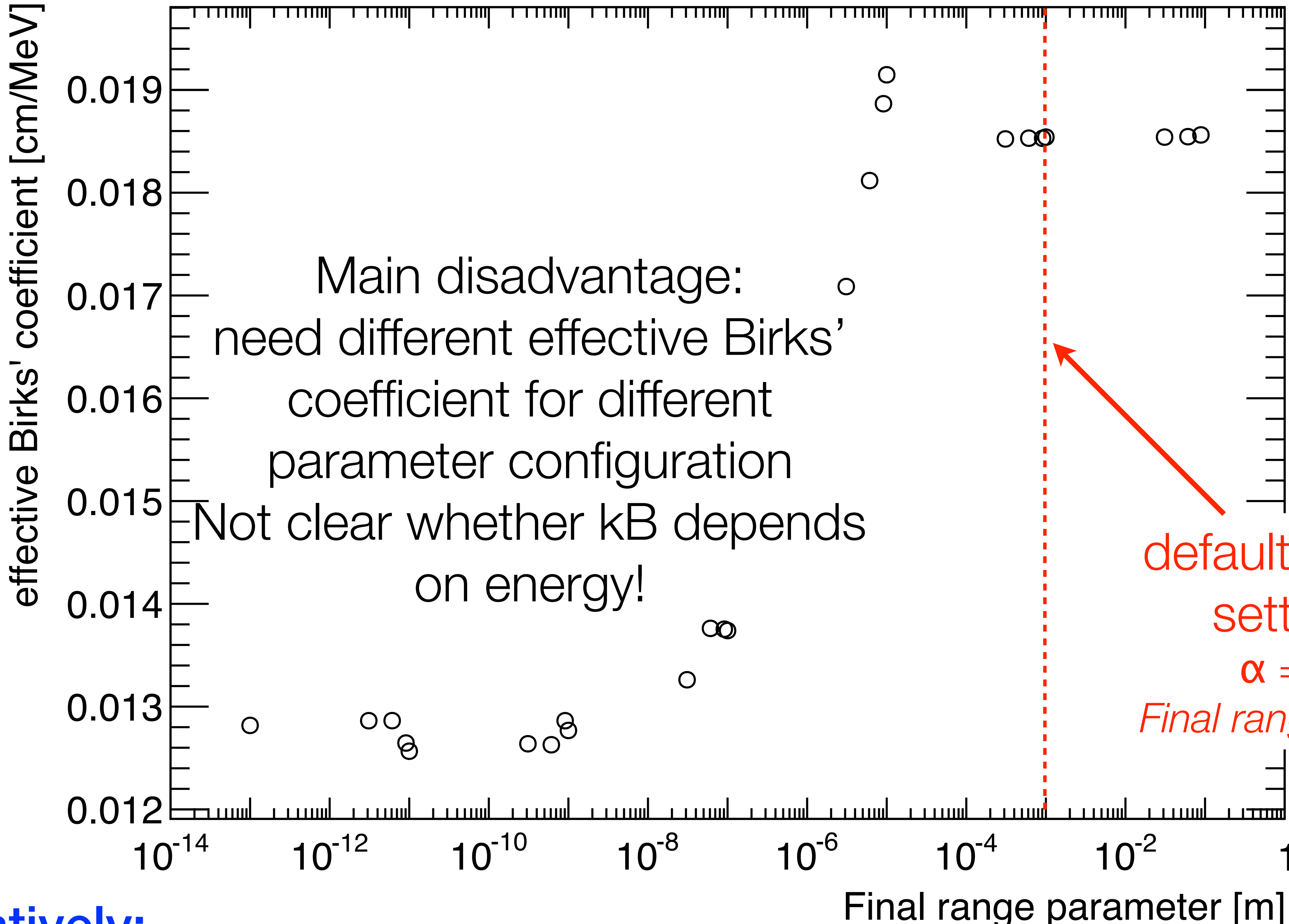
Birks' coefficient in Geant4



qualitatively:

smaller steps ⟷ larger steps

Birks' coefficient in Geant4



Main disadvantage:
need different effective Birks' coefficient for different parameter configuration
Not clear whether kB depends on energy!

default Geant4 settings:
α = *0.2*
Final range = 1mm

qualitatively:
smaller steps ⟷ larger steps

Method Improvement

Default Geant4

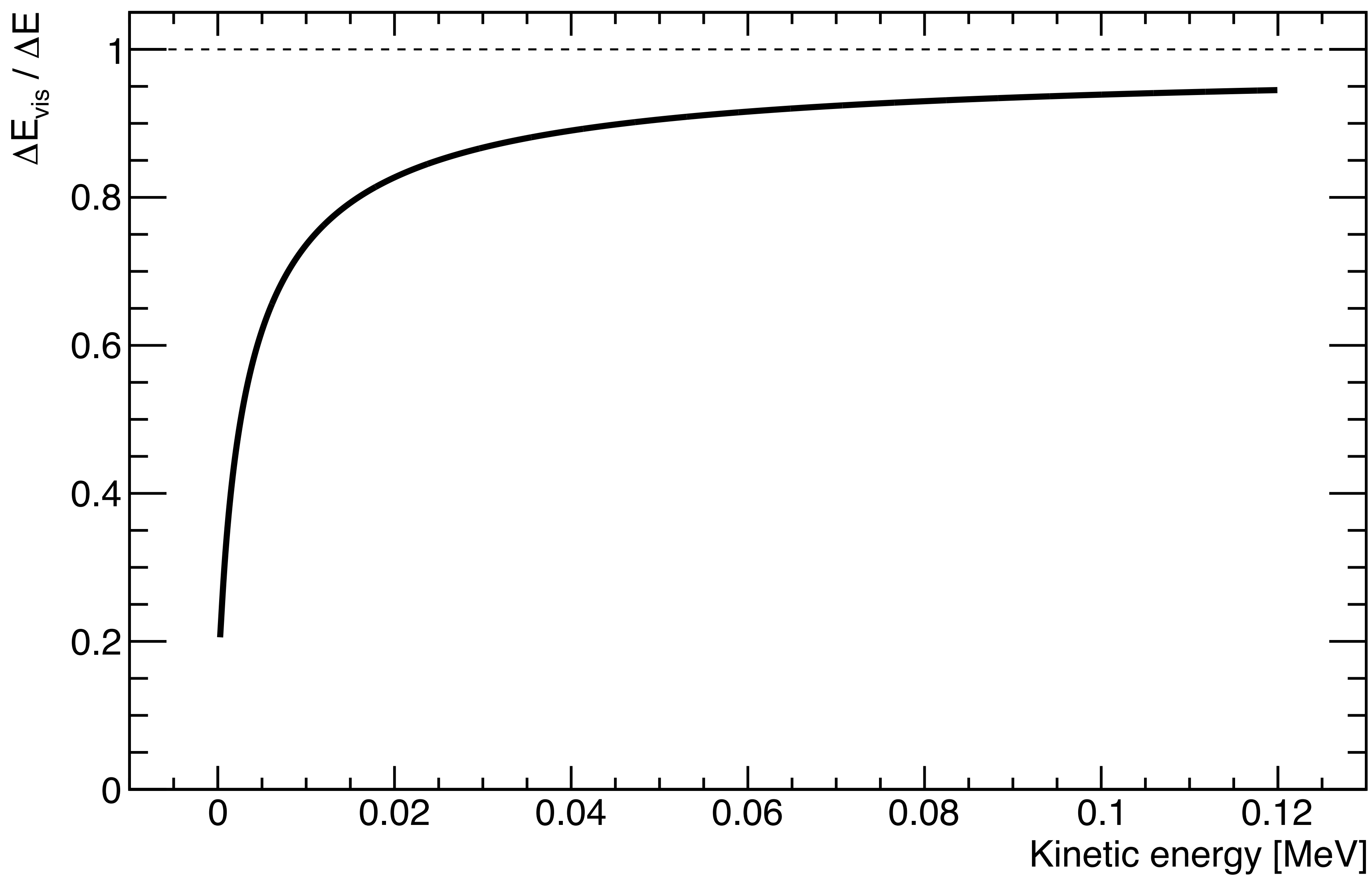
$$LY = S \sum_{i=1}^{n_{step}} \frac{\Delta E_i}{1 + kB \frac{\Delta E_i}{dx_i}}$$

→

Improved Geant4

$$LY = S \sum_{i=1}^{n} \int_{E_i}^{E_{i-1}} \frac{1}{1 + kB \frac{dE}{dx}} dE$$

- Simulation process untouched!
- Only calculation of visible energy changed
- Use method of Monte Carlo integration to sample the integral
- Correct calculation of visible energy



Method Improvement

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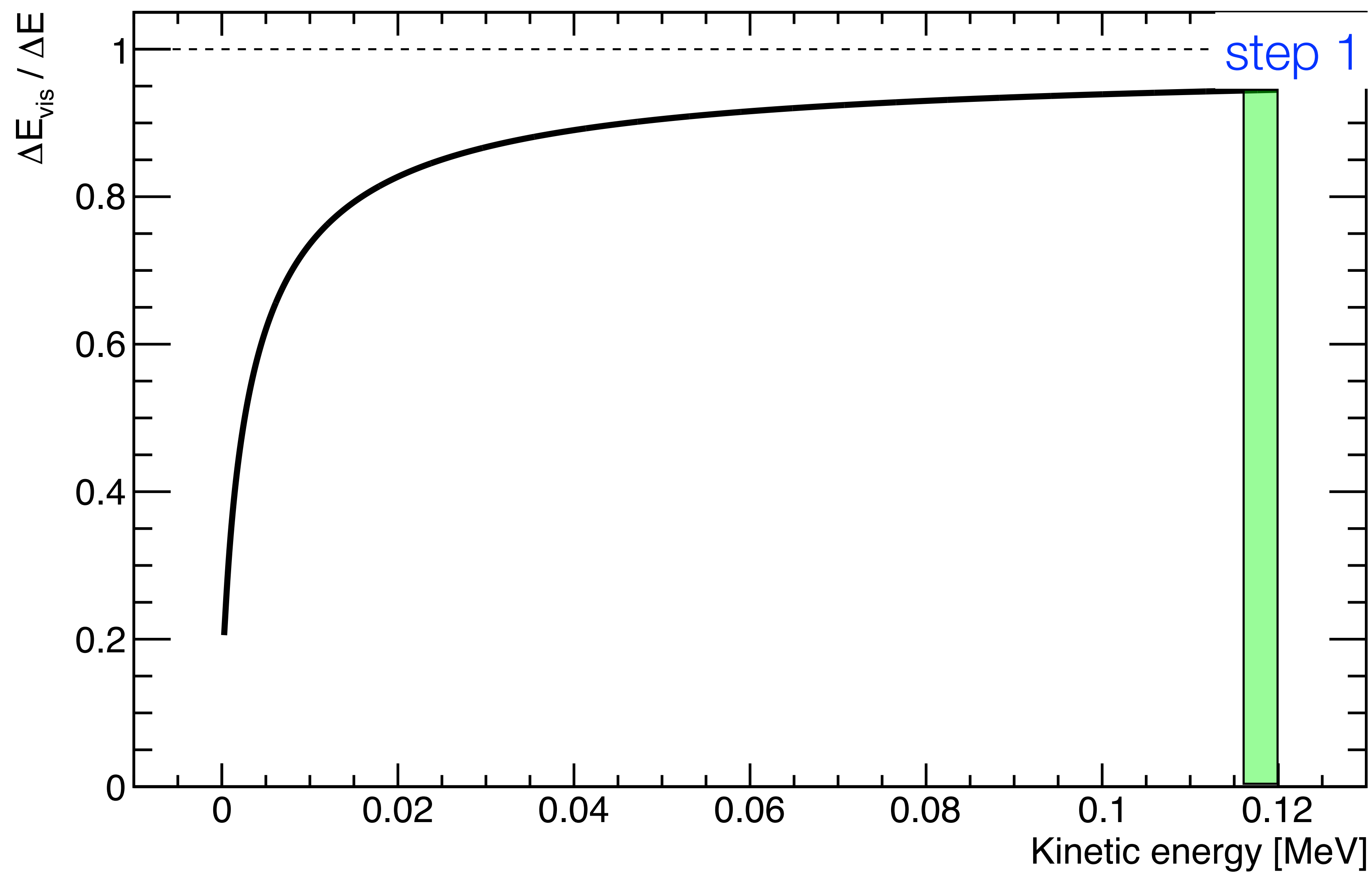

Method Improvement

Default Geant4

$$LY = S \sum_{i=1}^{n_{step}} \frac{\Delta E_i}{1 + kB \frac{\Delta E_i}{dx_i}}$$

$\longrightarrow$

Improved Geant4

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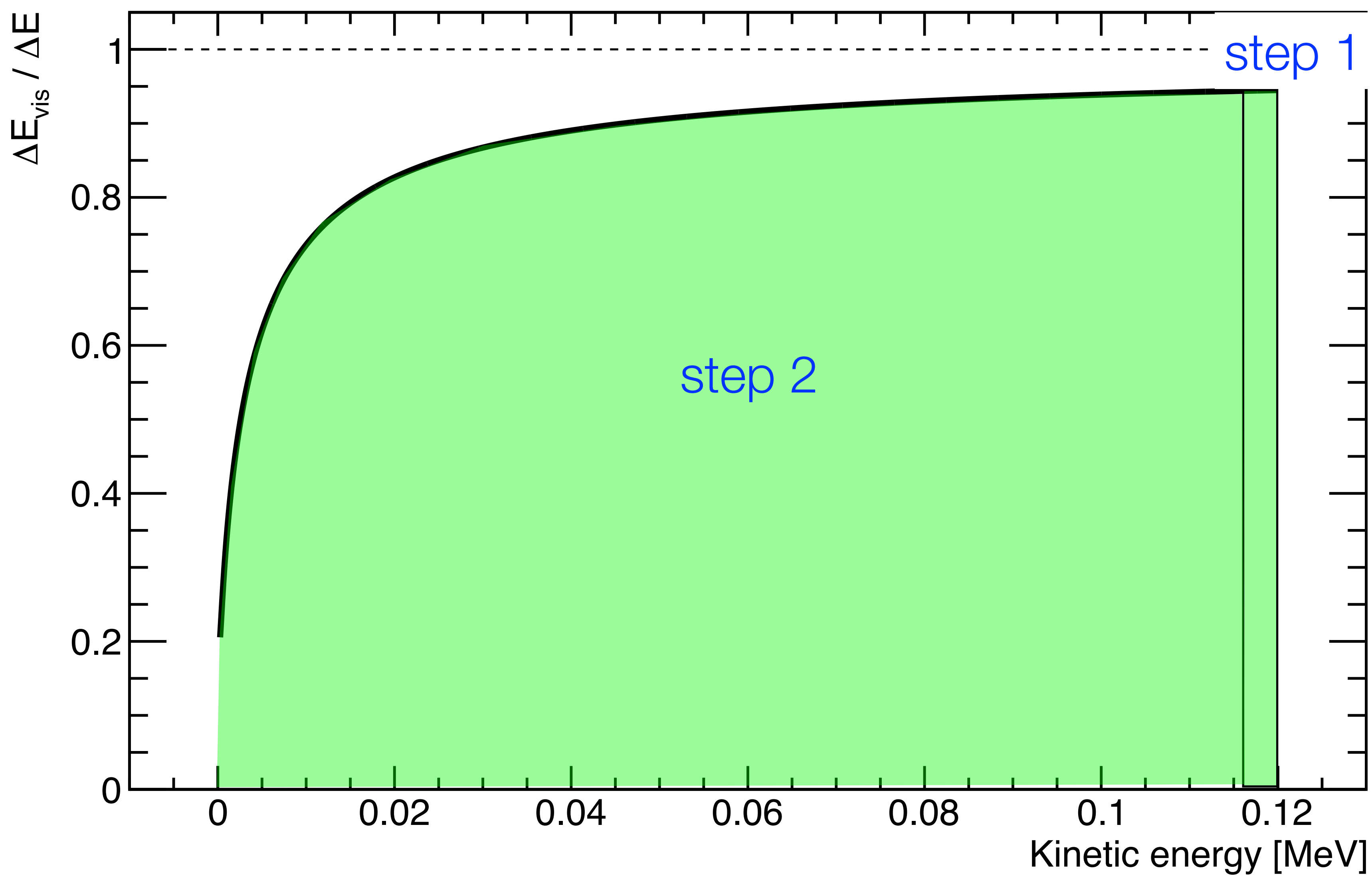
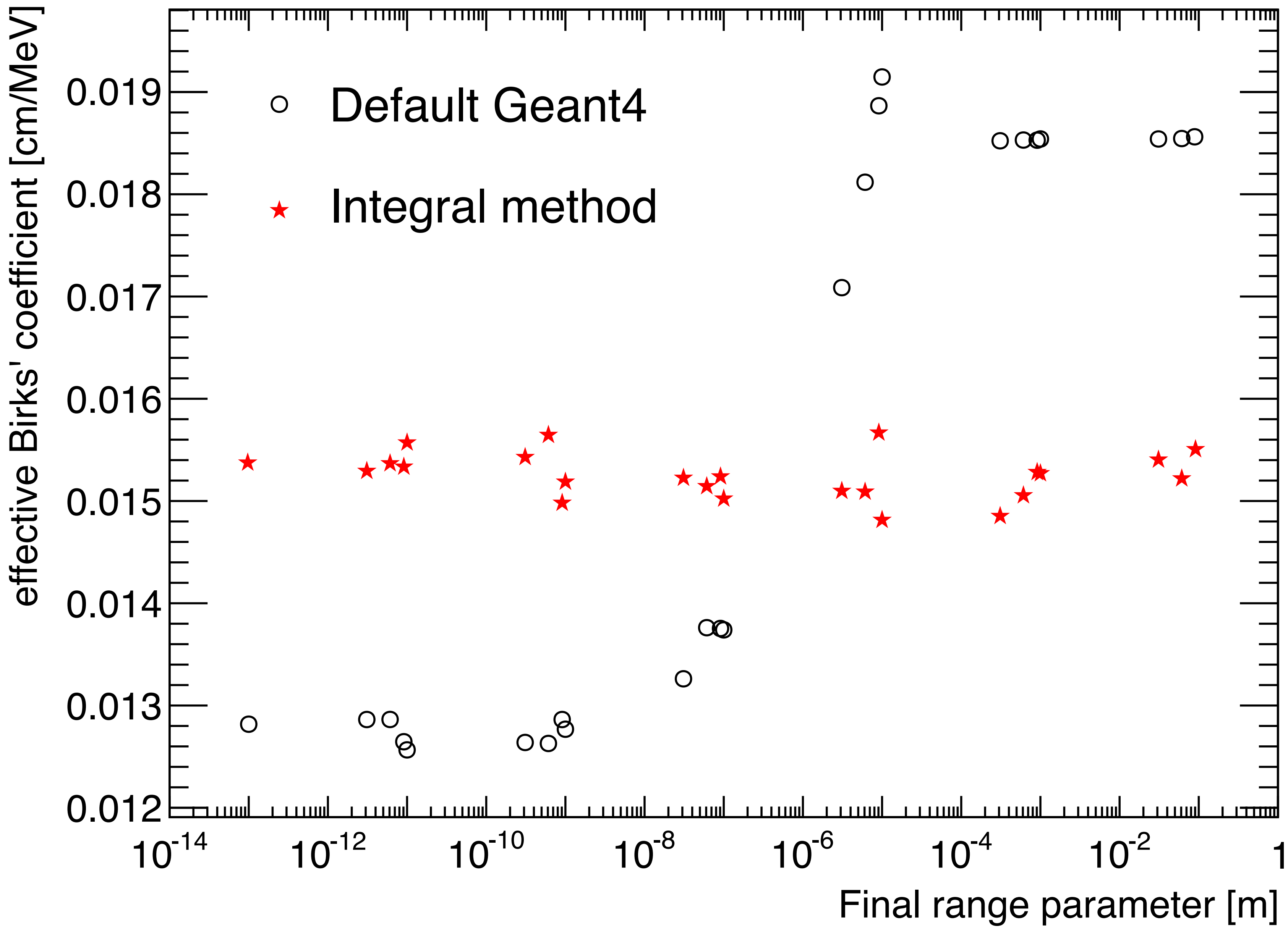


Method Comparison

- Birks' coefficient independent of final range parameter (step-size)
- Residual fluctuation from fit instabilities (production of delta-electrons)



qualitatively: smaller steps ⟷ larger steps

First look on EM showers

- Simulation:
  Mokka 7-02 / geant4-9.3
  - Modified Birks' saturation class (interface remains identical)
  - Birks' parameter can be specified
- Digitization:
  calice software version 04-01
- 5 different combinations simulated:

1. **kB = 0.007943cm/MeV (default)**
2. **kB = 0.0151cm/MeV (integral)**
3. kB = 0.007943cm/MeV (integral)
4. kB = 0.0151cm/MeV (default)
5. kB = 0 (Birks' law switched off)

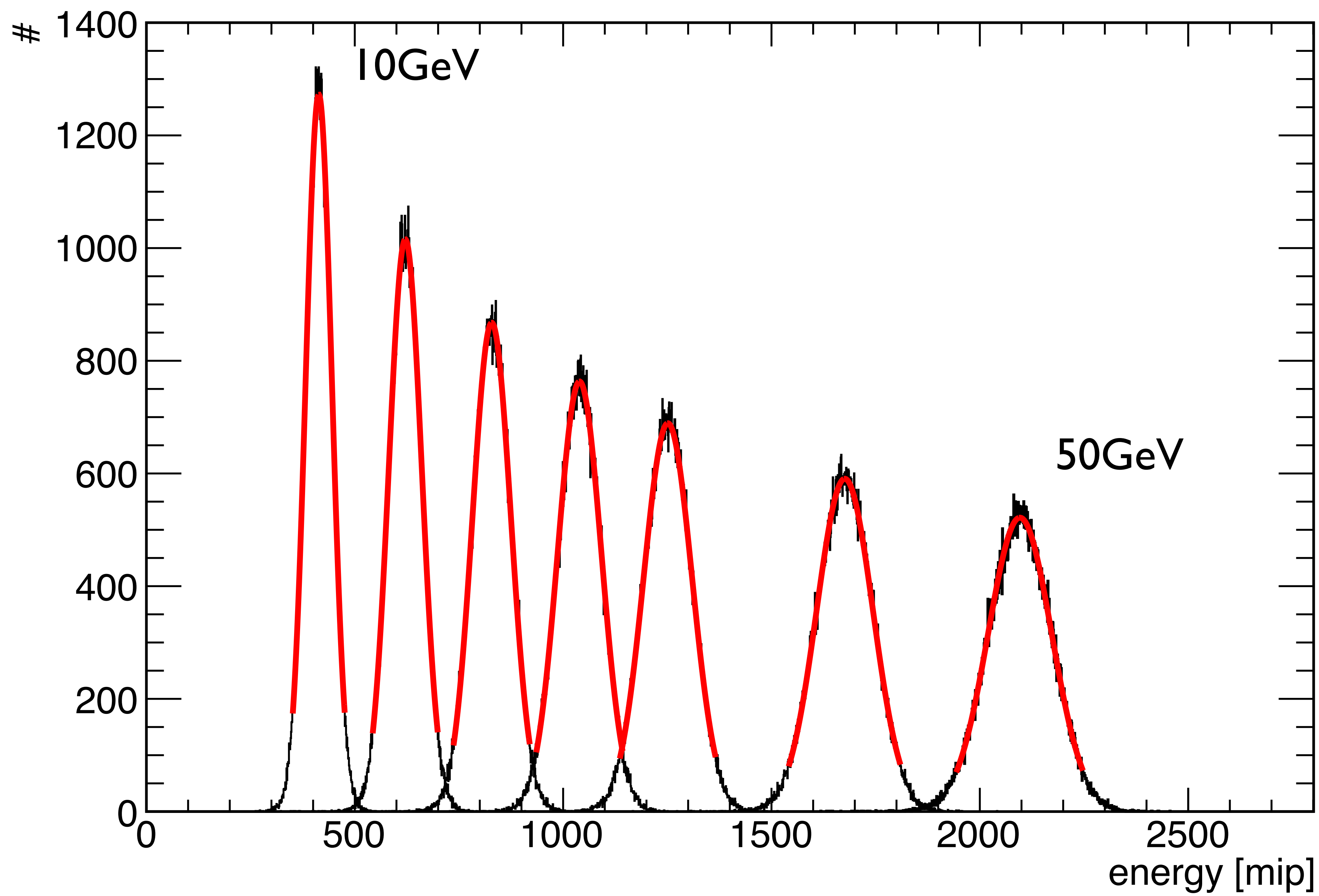
(3.–5.: Only for reference)

Simulated runs:

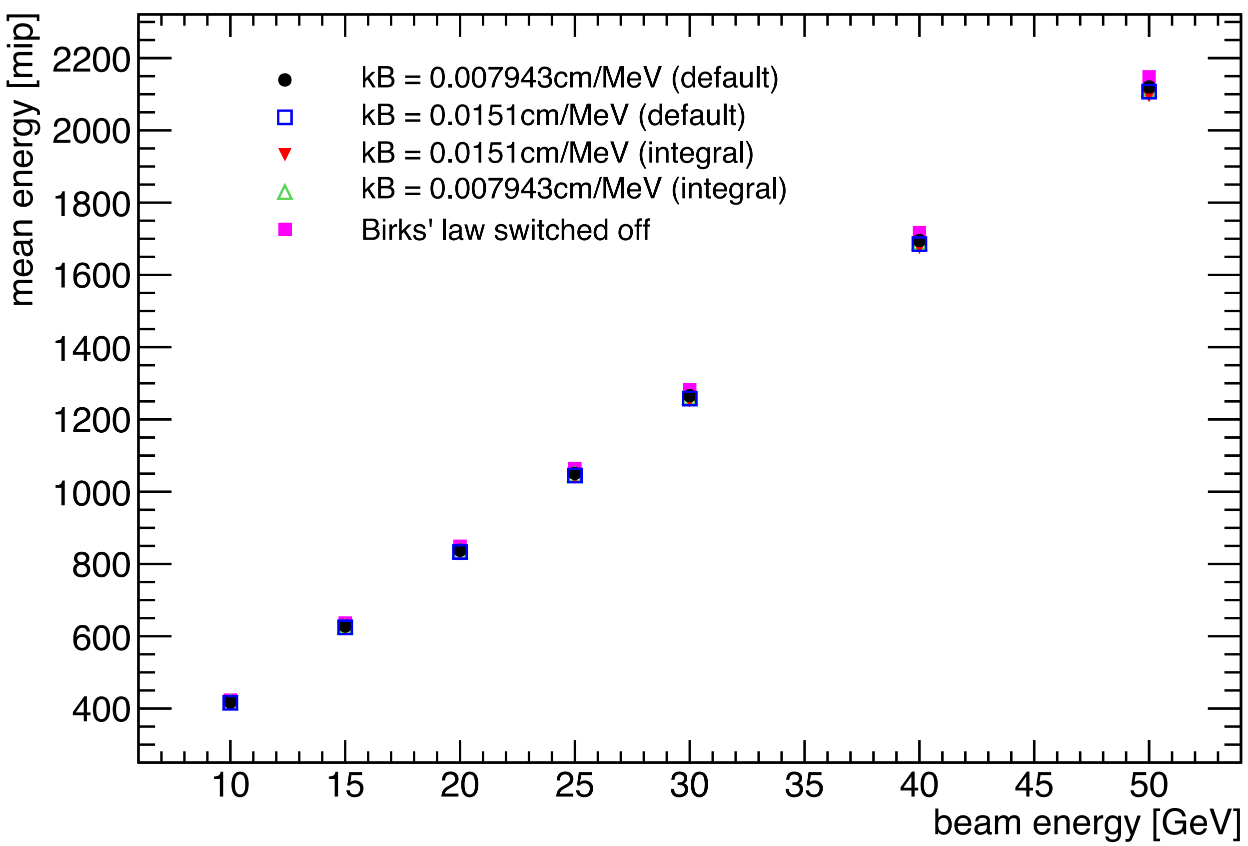
run id	beam energy [GeV]	particle
350118	10	e+
350117	15	e+
350114	20	e+
350113	25	e+
350111	30	e+
350110	40	e+
350128	50	e+

Run Analysis

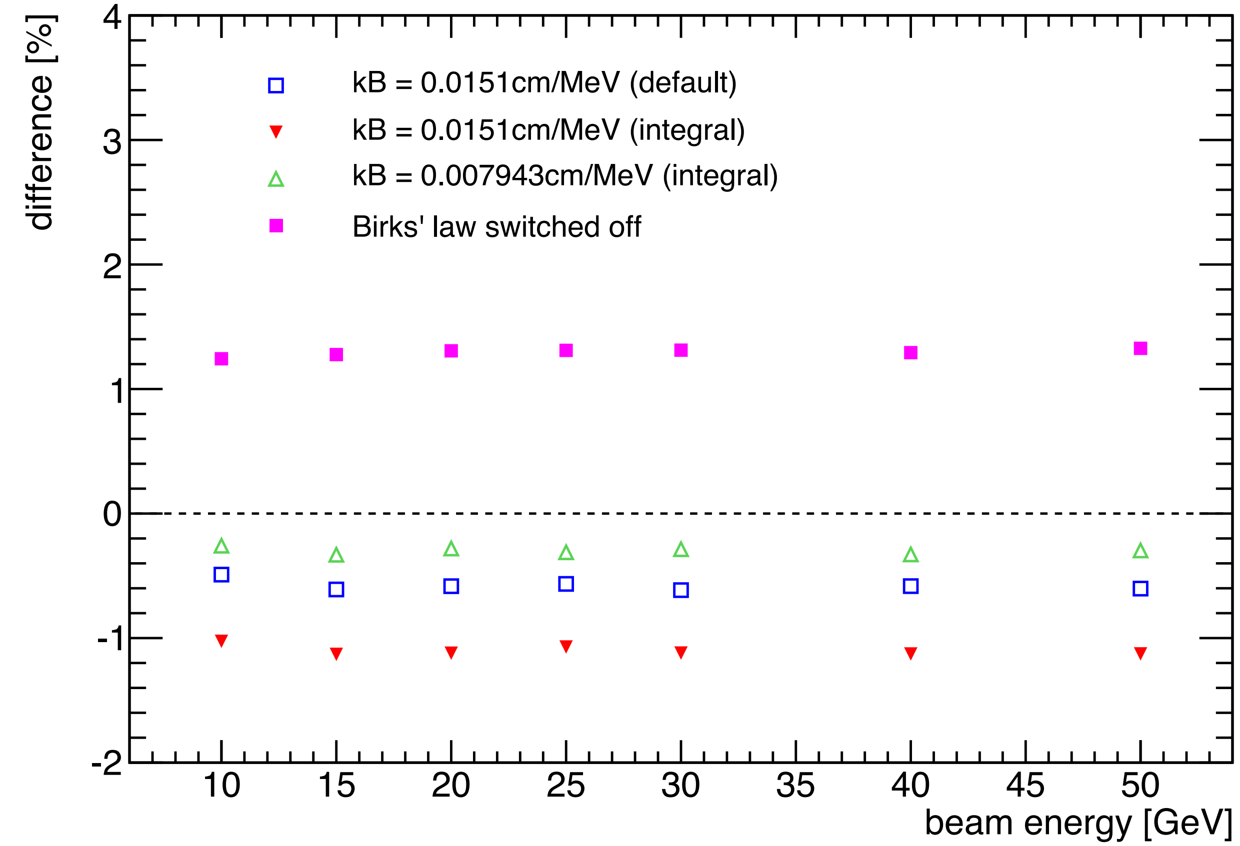
- Constrains:
- Number of hits > 65
- Shower center of gravity in first half of calorimeter
- Gauss fit in 2 sigma range



Mean shower energy



Relative difference to **kB = 0.007943cm/MeV (integral)** simulation



- New (integral) method with new Birks' coefficient (0.0151cm/MeV) results in ~1% smaller signal
- Effect is approximately constant over the full energy range
- Small influence is expected as the dE/dx of electrons/positrons relatively small
-> Relative amount of energy lost due to quenching is small

Conclusion & Outlook

- Measured Birks' coefficient higher than currently used one
  Measured value: kB = 0.0151cm/MeV *("old": kB = 0.007943cm/MeV)*
- Default Geant4: Effective Birks' coefficient needed in order to describe visible energy correctly (kB is step-size dependent)
- Integral method allows to calculate precisely the visible energy deposition for each step (kB is step-size independent)
- To Do
  - Influence on hadronic showers (stronger influence expected)
  - Performance optimization (integral sampling)
- -> Tile quality assurance

Tile Quality Assurance

Patrick Eckert

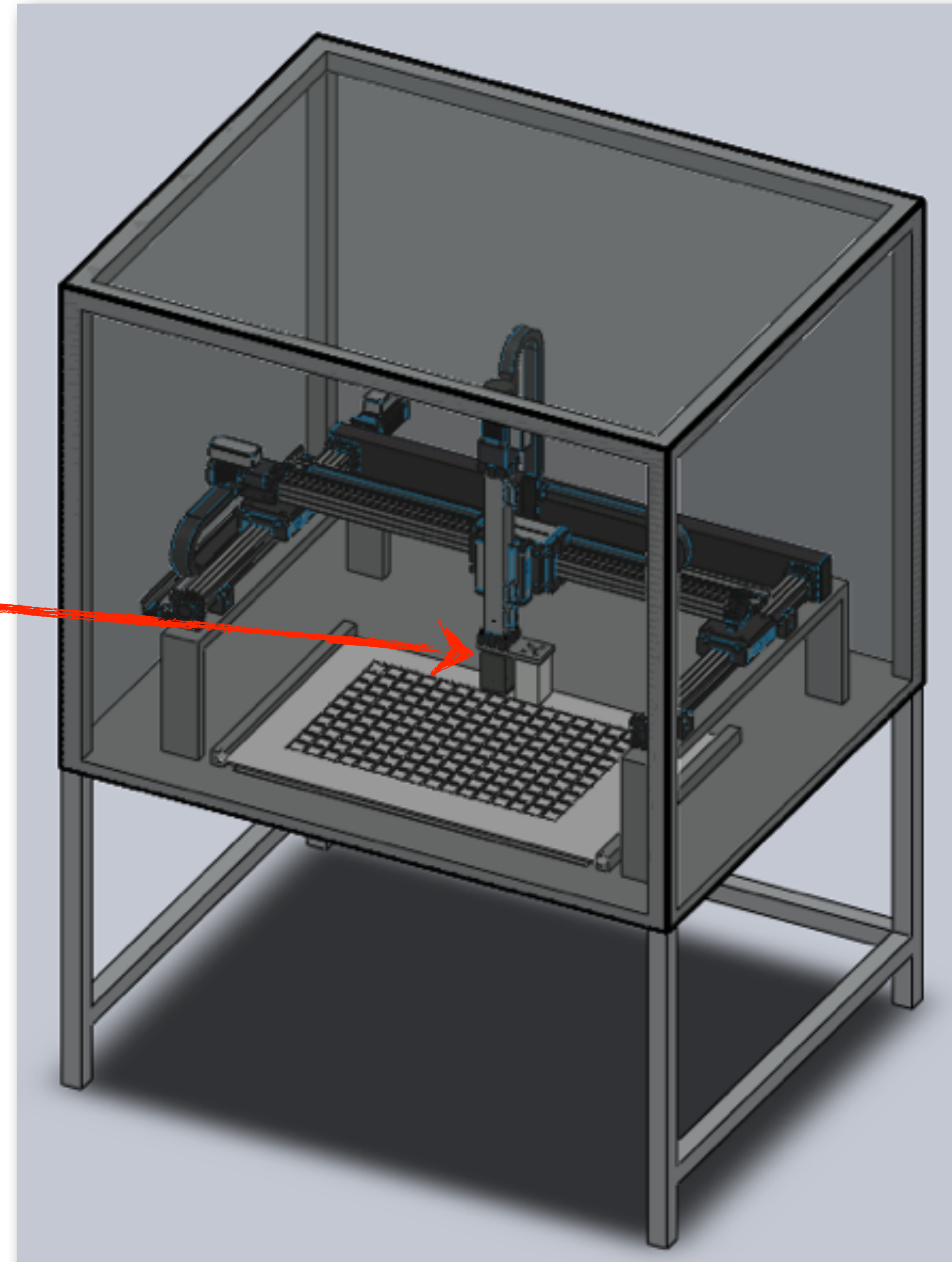
Tile Quality Assurance

Reminder:

- Development of a scalable measurement system which allows to test millions of tiles +SiPMs in reasonable time
- Complete characterization of one tile within a few seconds

Two sources for testing:

- UV-LED for SiPM properties (gain, saturation curve)
- Sr90 for for SiPM/Tile properties (MIP response)



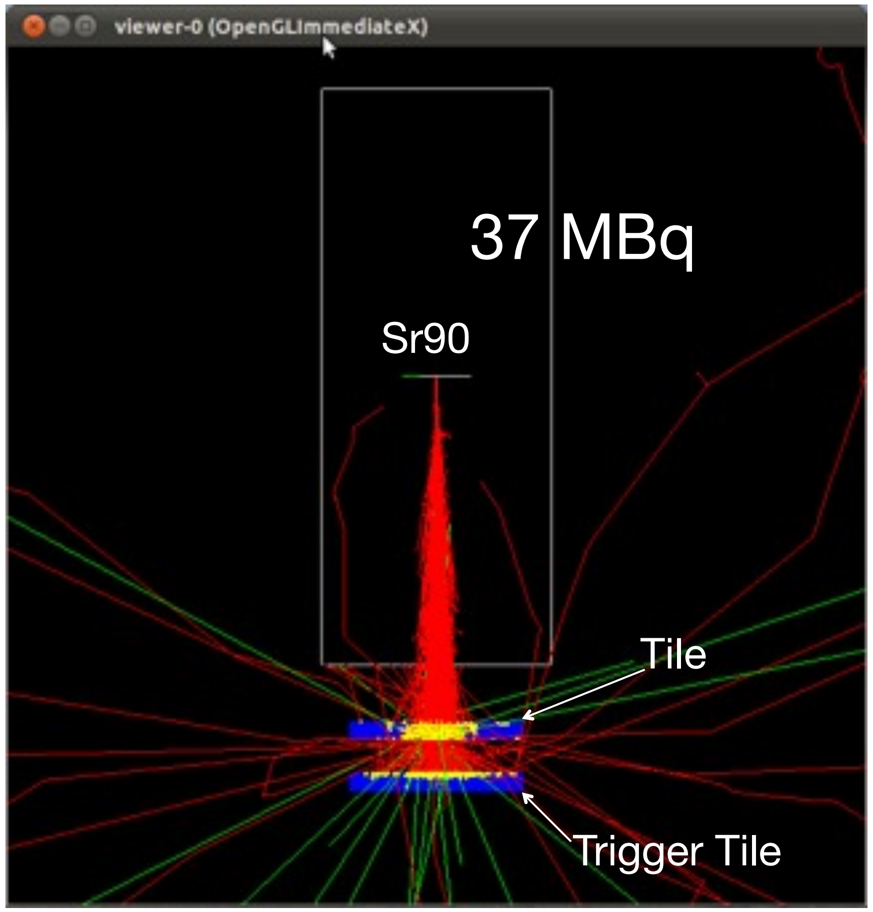
Tile Tester prototype design mostly completed – assembly in progress

Geant4 Design studies

Geant4 studies for design optimization
Goal: sufficient MIP spectrum quality at high rate

	High signal to noise (slow)	low signal to noise (fast)
Size of trigger tile	small	large
Collimator radius	small	large
Trigger threshold	high	low

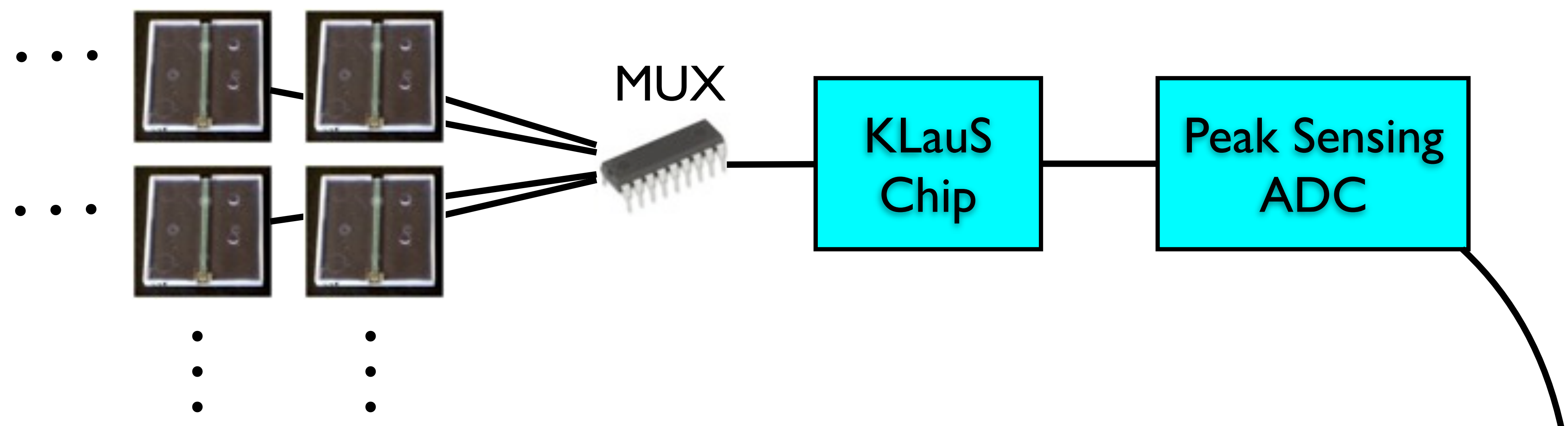
Side view of source and tile



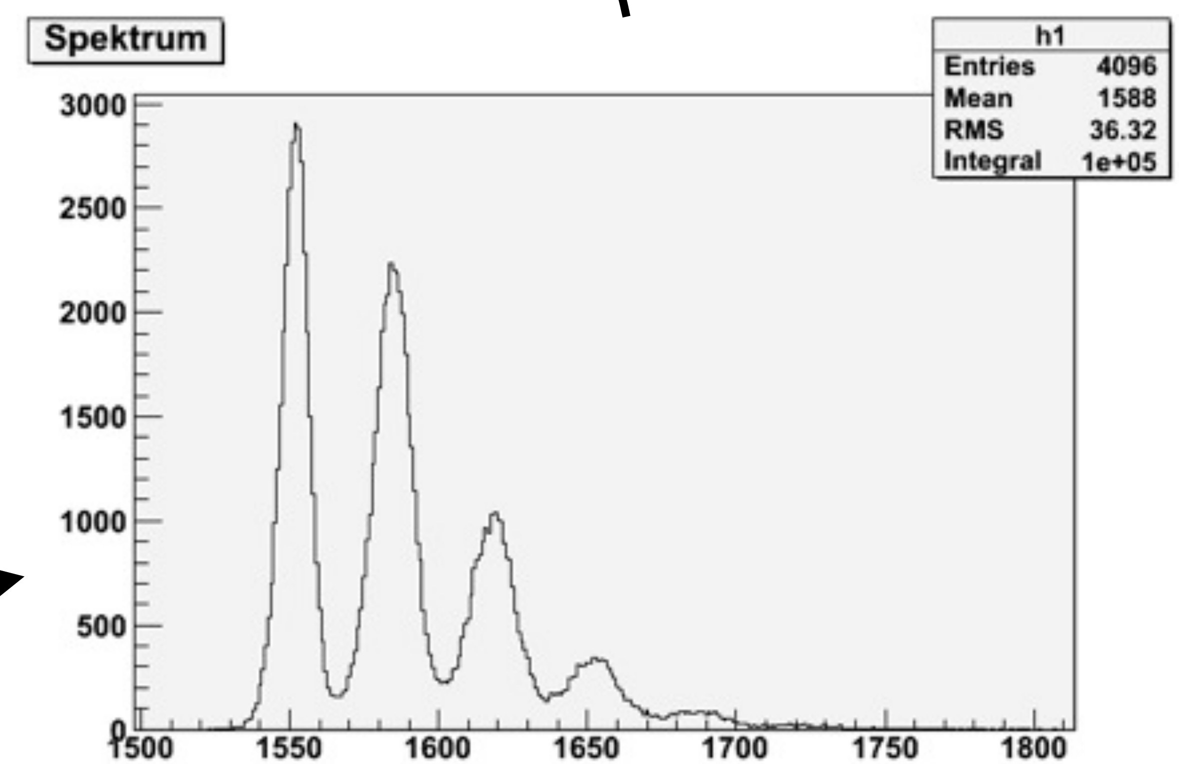
Accuracy vs. speed:
Trigger rate should be ≈10kHz
Optimize trigger tile size
Optimize collimation radius
Optimize trigger threshold

Sr90 different from real MIP:
How to derive MIP response from Sr90 signal

Readout Scheme



- Signal multiplexing: commercial IC controlled with FPGA
- SiPM readout with KLauS chip
- First single pixel spectra recorded
  Same quality as QDC measurement

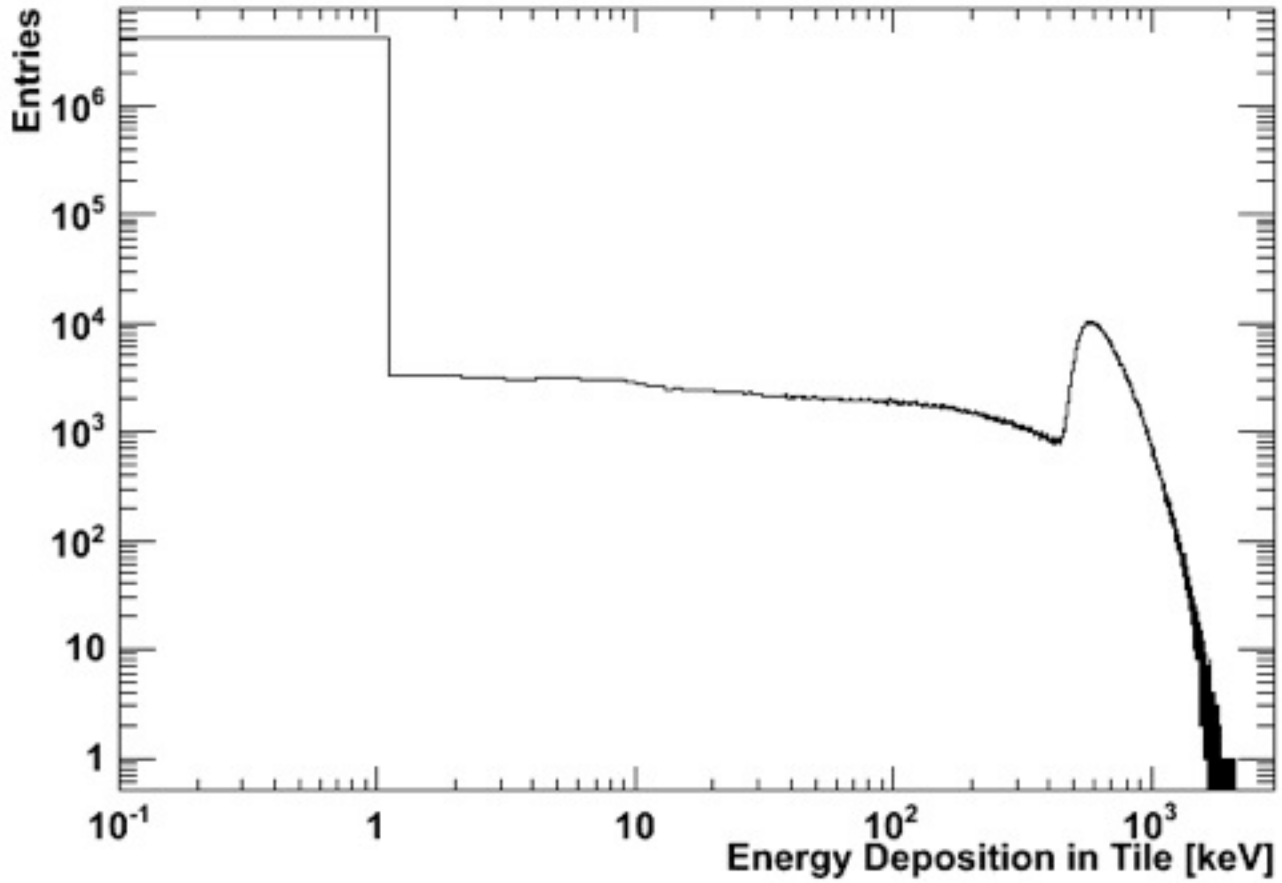


400 pixel MPPC G ~ 500.000

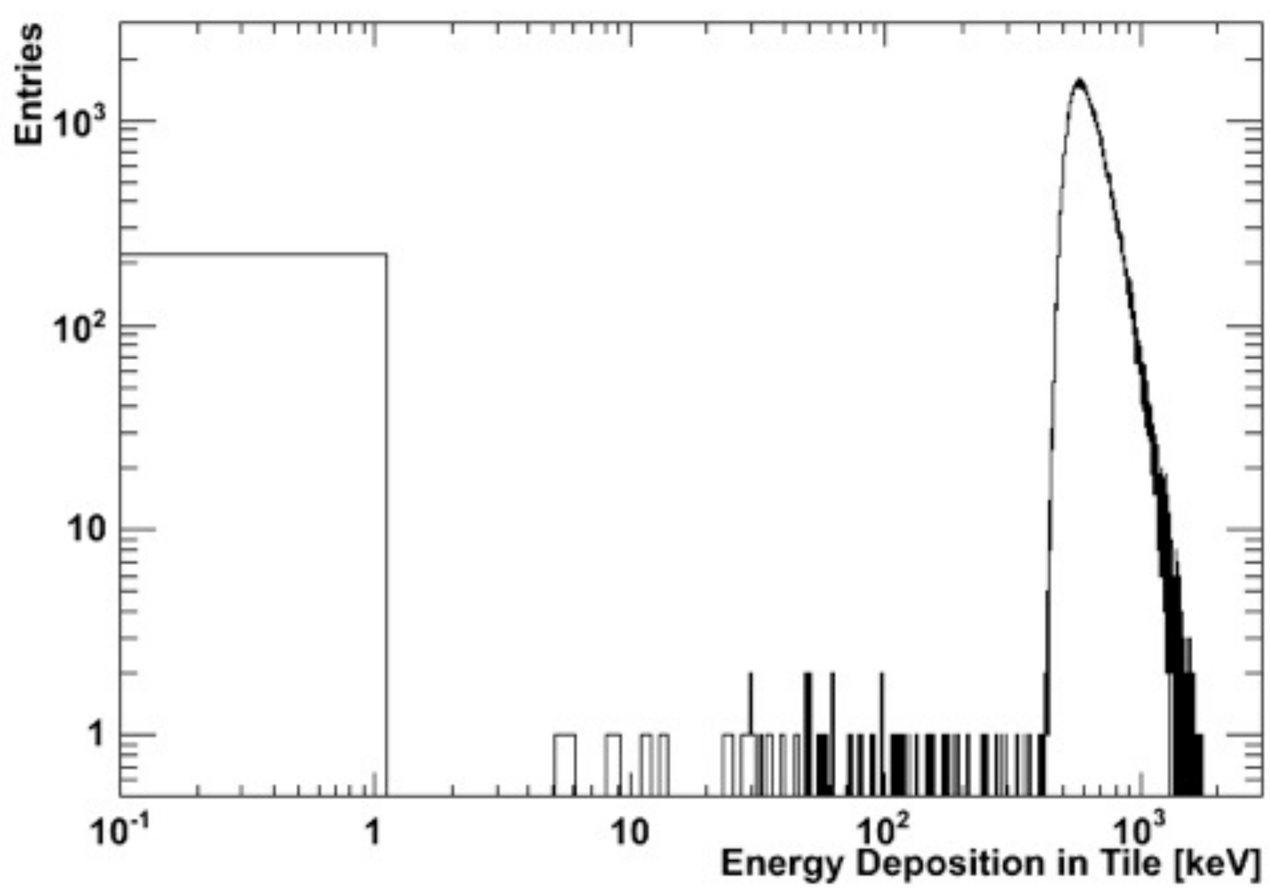
Conclusion

- Measurement system for large scale tile and SiPM quality assurance tests under construction
- First successful tests of readout chain

Backup



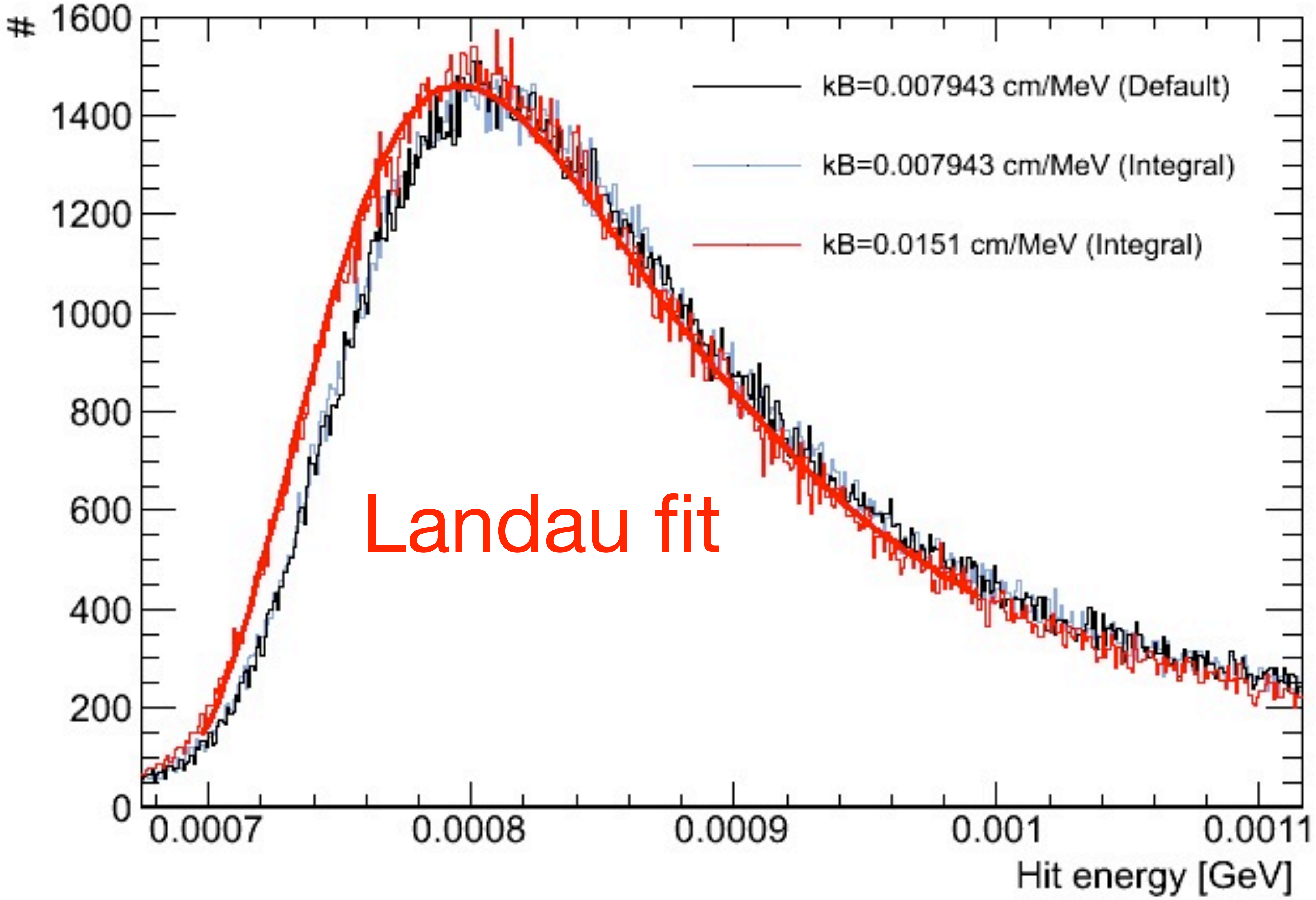
large trigger tile (50x50)cm
Uniformity may be a problem,
not simulated jet
large collimator
idea: one trigger for all tiles
not realistic



small trigger tile (3x3)cm
small collimator

MipPerGeV (GeVPerMip)

80GeV muon, hit energy distribution



	GeVPerMip [keV]
Default kB = 0.007943cm/MeV	816
Integral kB = 0.007943 cm/MeV	816
Integral kB = 0.0151 cm/MeV	806

Result: Only small influence since muon = mip (small dE/dx -> no quenching)

Visible energy fraction