μ-e scattering
questions on μ/e ID

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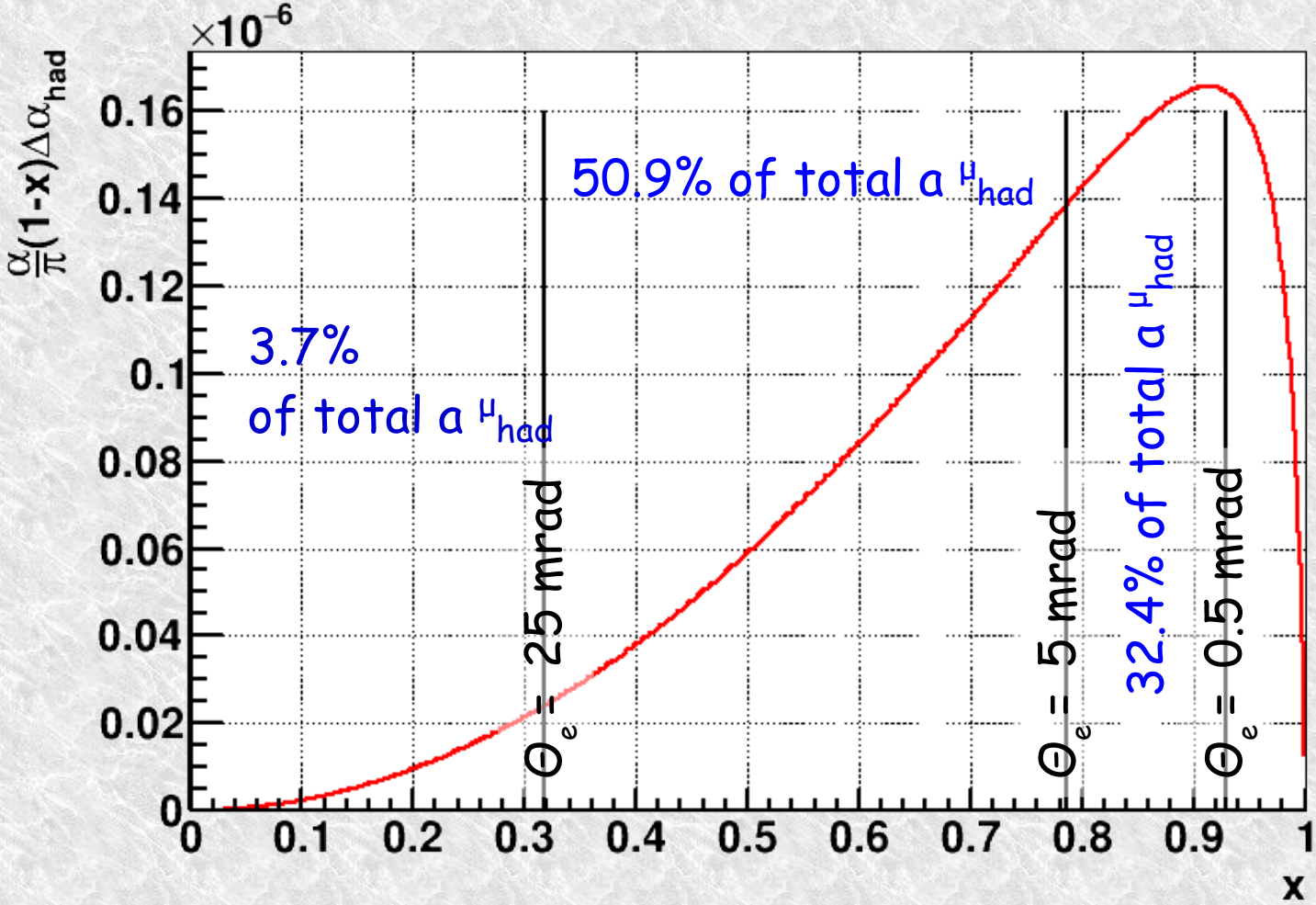
$a_{had\mu}$ from spacelike region

$$a_\mu^{had,LO} = \frac{\alpha}{\pi}\int_0^1 dx(1-x)\Delta\alpha_{had}[t(x)]$$



Θ_e = 0.5 mrad : x = 0.930, t = -0.138 GeV^2 , E_e = 135 GeV

Θ_e = 5 mrad : x = 0.786, t = -0.032 GeV^2 , E_e = 32 GeV

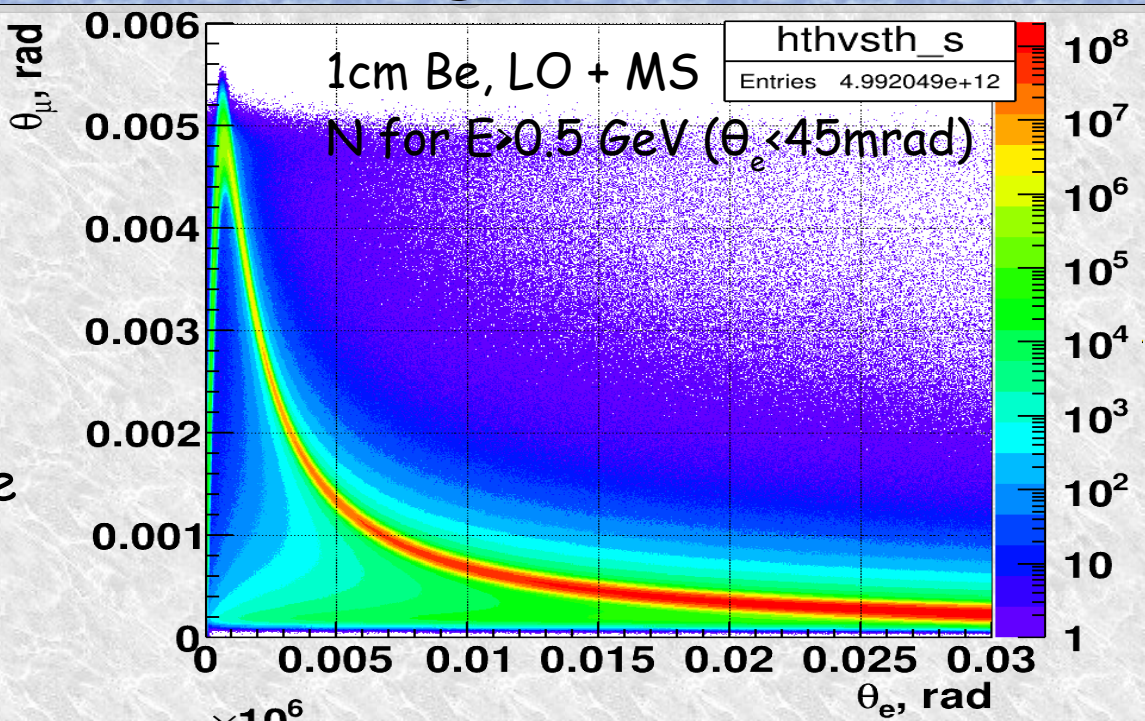
Θ_e = 25 mrad : x = 0.318, t = -0.0016 GeV^2, E_e = 1.6 GeV

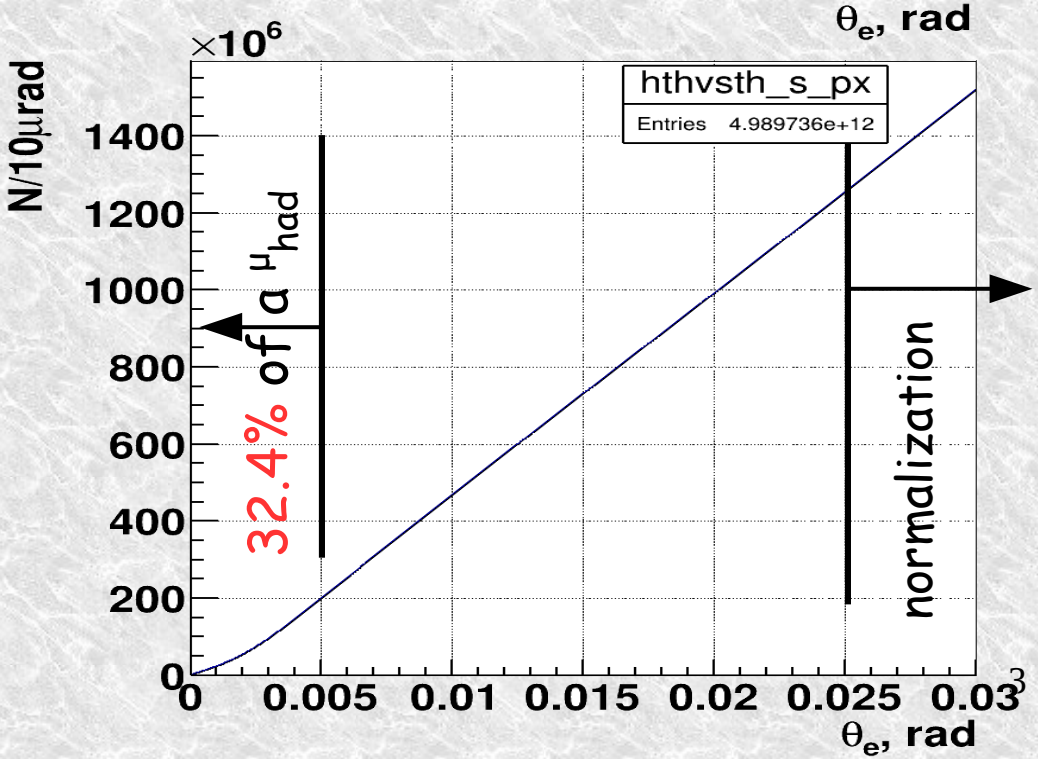
μe → μe scattering

Θ_μ < ~ 5 mrad ~ m_μ/m_e

Events with 1 of track is scattered
by angle > 5 mrad
are well defined for which track μ/e

Θ_e = 0.5 - 5 mrad
gives 32.4% of total a μ_{had}

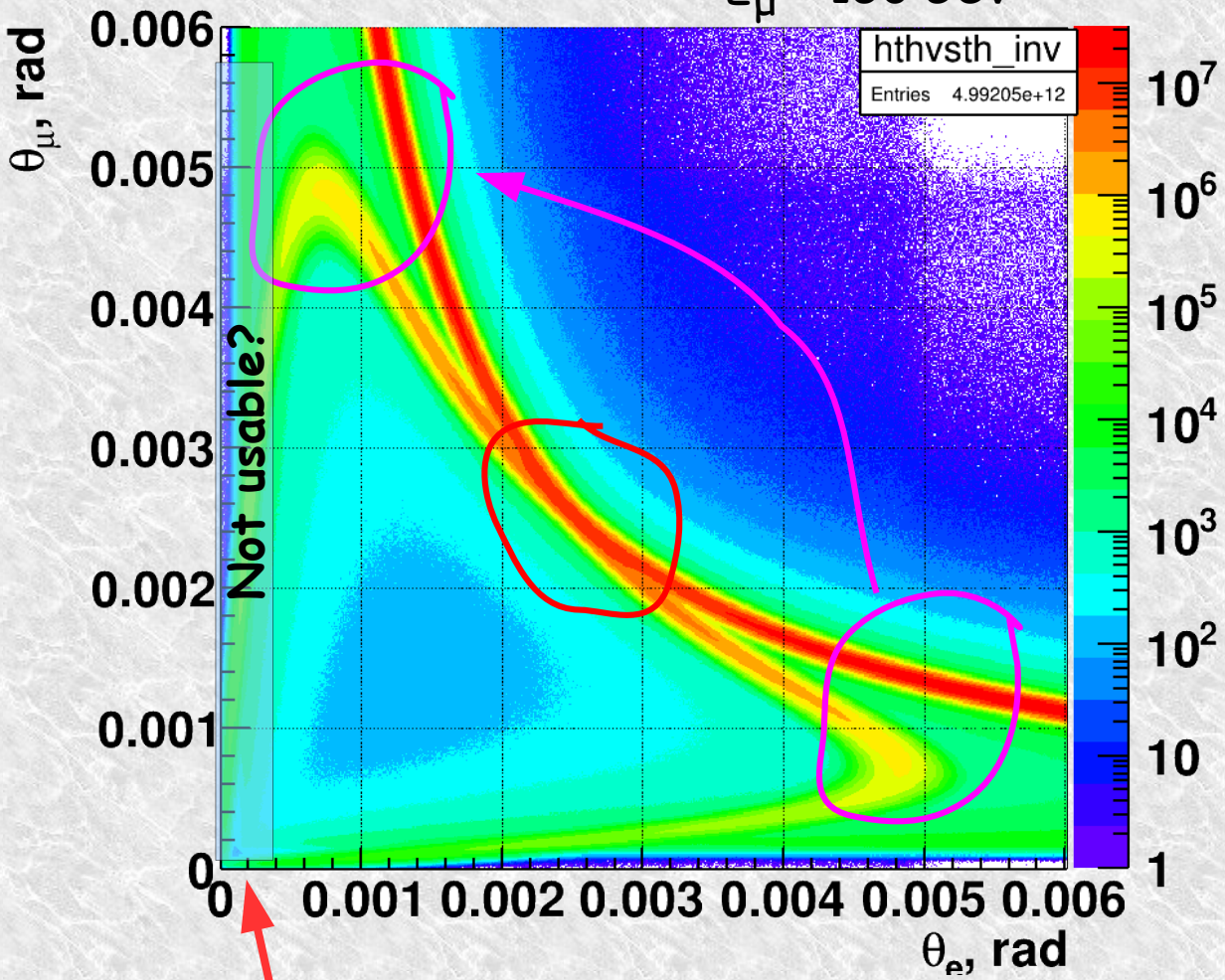




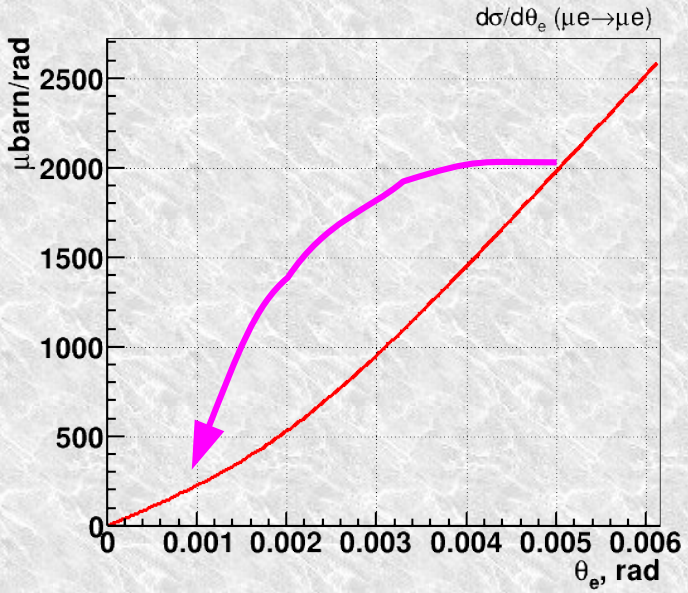
miss e/μ ID problem

μ/e can not be separated very well by tracking at 1-5 mrad

E_μ = 150 GeV



Number of events at
5mrad vs 1 mrad ~ 8.7/1
3mrad vs 2 mrad ~ 1.8/1.



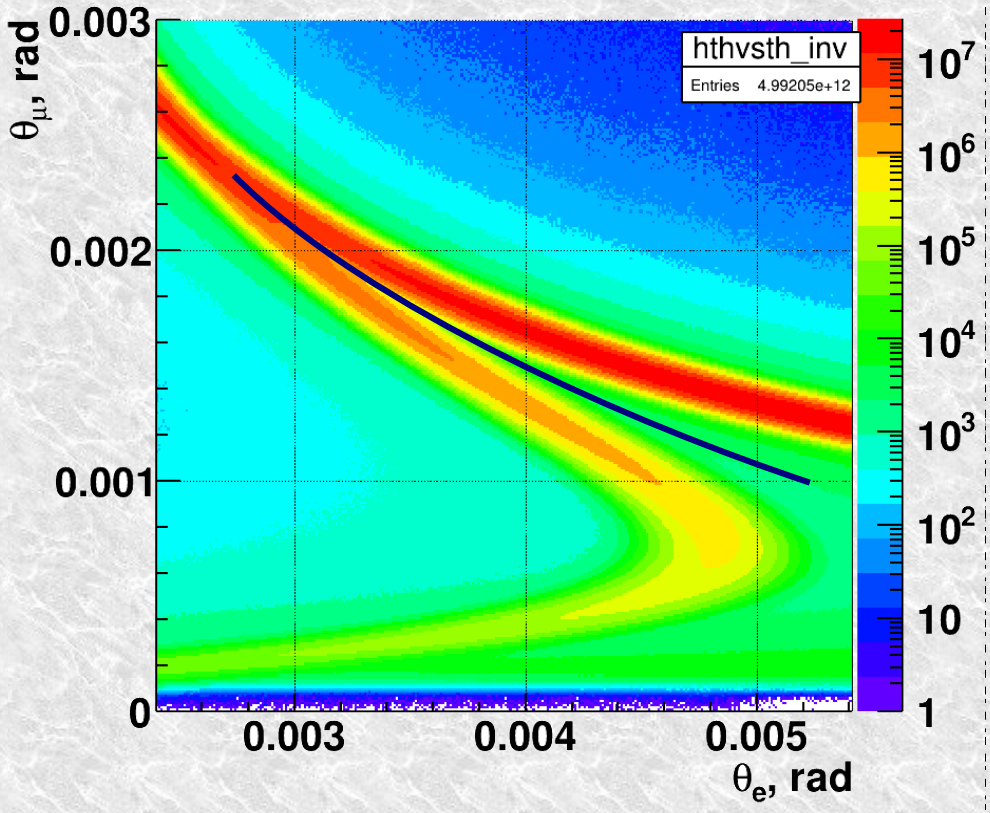
If we need 10 ppm cross-section than μ/e ID should be at $1./9 \times 10^{-5}$

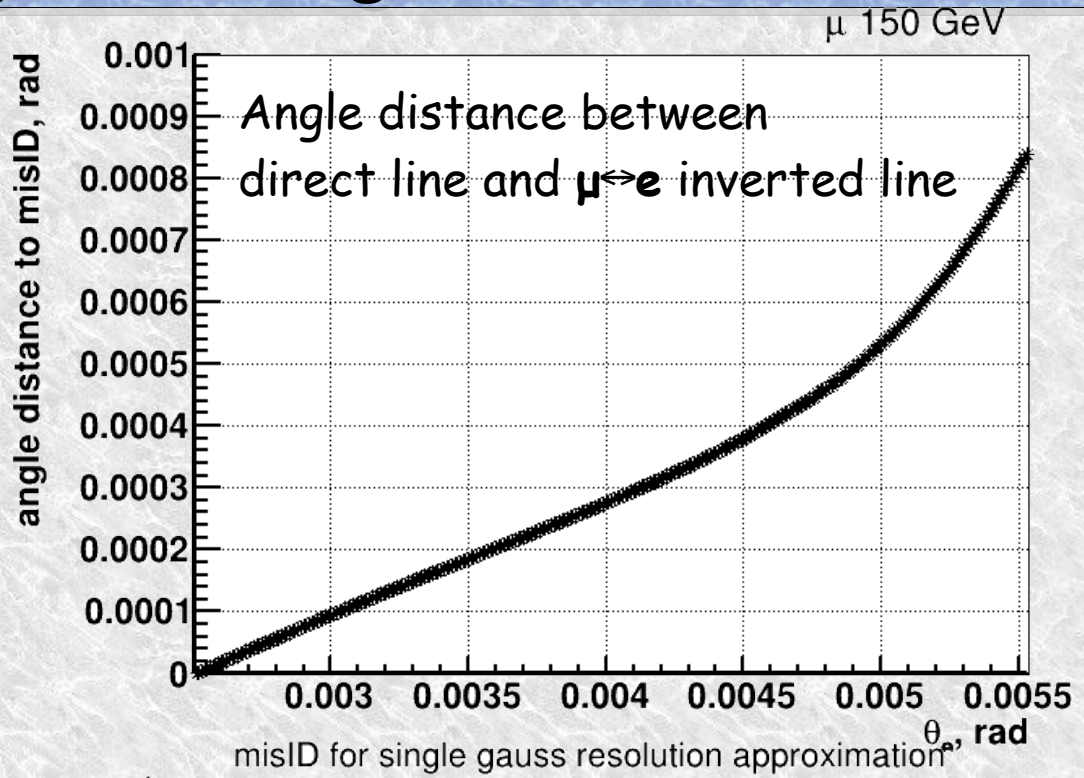
But look's like not….

θ_e < 0.5 mrad can't be used at all?

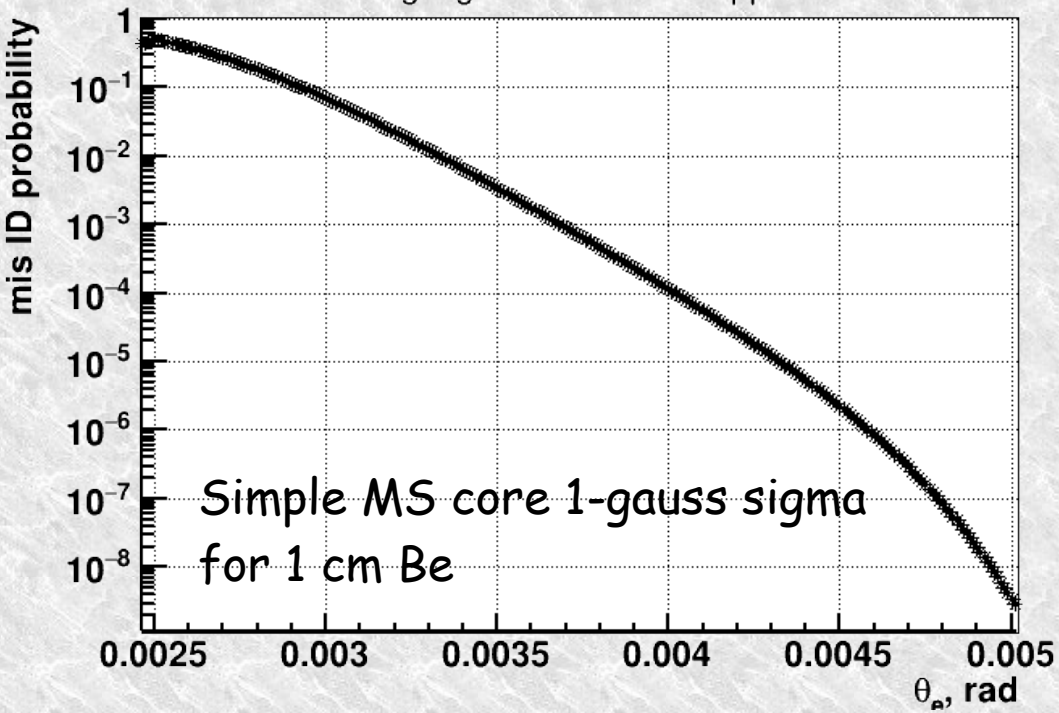
Similar to events with low scattering angle muon and high angle electron : huge background from low momentum electron

Separation by tracking itself





misID for single gauss resolution approximation



Θ = 4.5 mrad

d = 0.4 mrad → σMS ~ 0.06 mrad → ~10^{-5}

Θ = 3. mrad

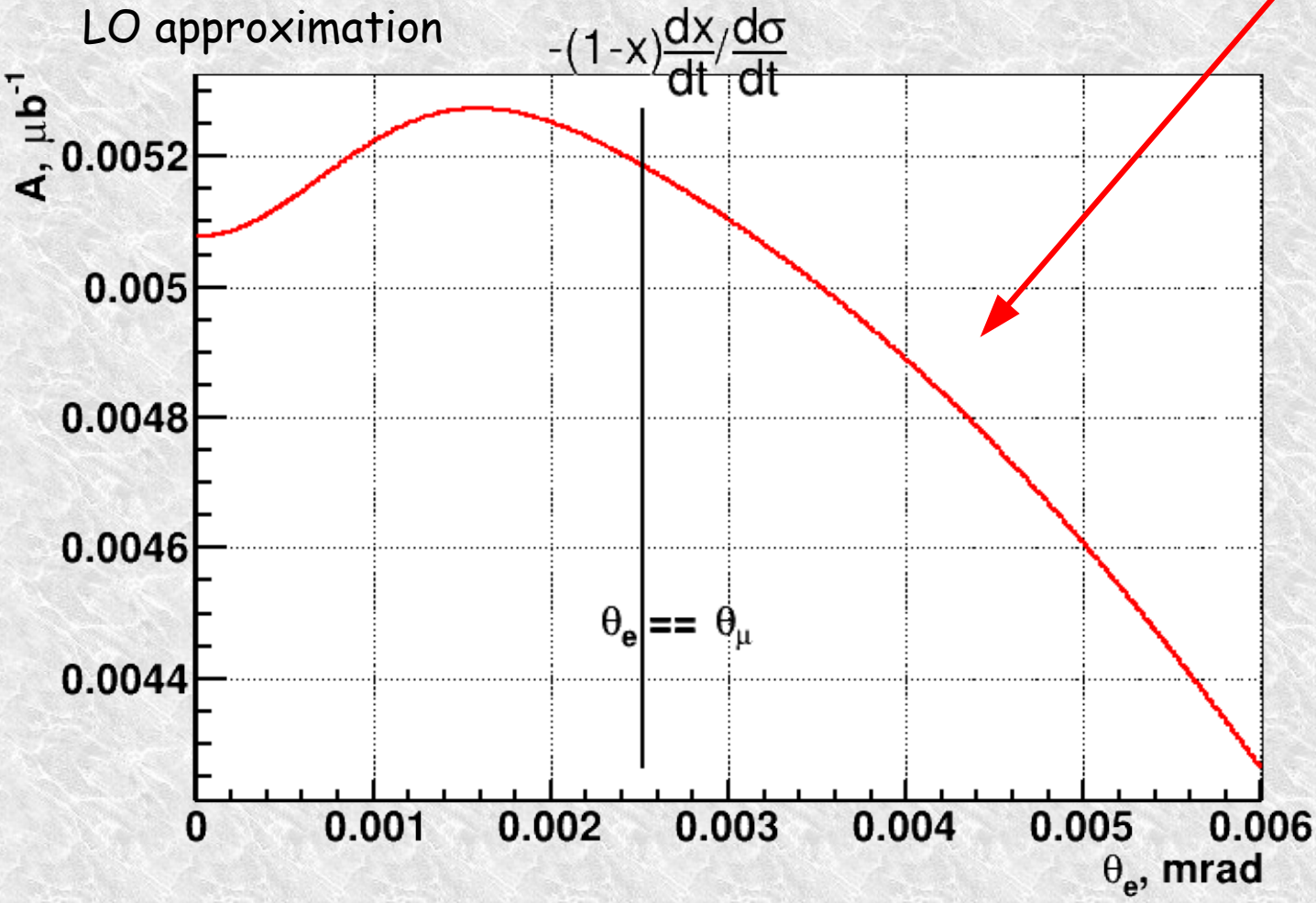
d = 0.1 mrad → σMS ~ 0.03 mrad → ~10^{-1}

with tails it will be more worst
+ momentum beam spread

$a_{had\mu}$ summing (E beam = 150 GeV)

$$a_\mu^{had,LO} = \frac{\alpha}{\pi}\int_0^1 dx\,(1-x)\,\Delta\alpha_{had}[t(x)] = \frac{\alpha}{\pi}\sum dt\,(1-x)\,\frac{dx}{dt}\,\frac{\Delta N}{d\sigma/dt\;2\,Ldt}$$

LO approximation



Normalization function is not very fast changing

	ΔA/A
1. ⇔ 5. mrad	0.133
1.2 ⇔ 4.5 mrad	0.104
2. ⇔ 3. mrad	0.029

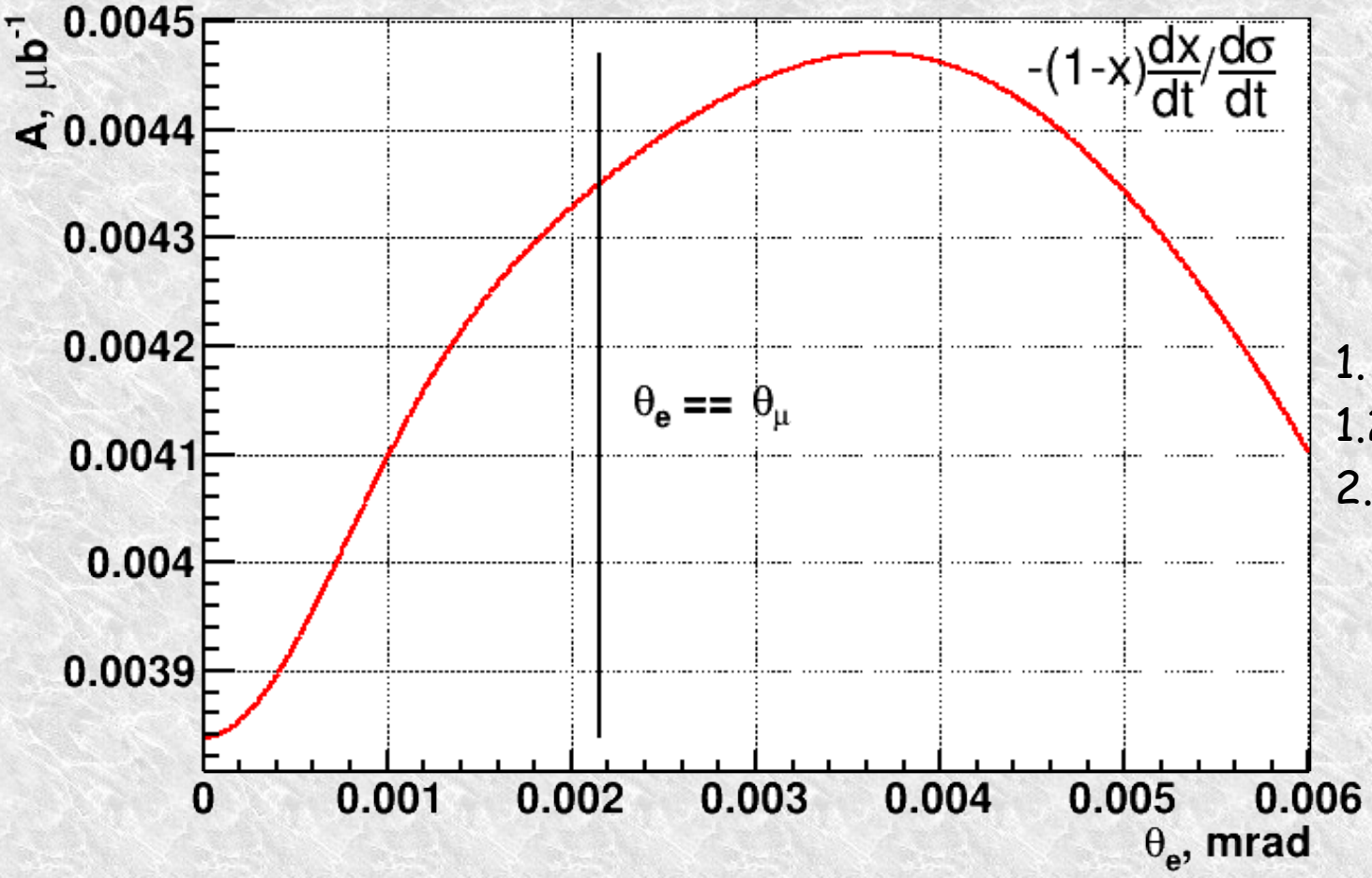
mis ID 5.→ 1. mrad affect a_μ^{had} with 10% (not factor x10)

Requirement 10 ppm in N(Θ) spectra precision reduced by 1./(ΔA/A)

→ 10^{-4} μ/e ID for a_μ^{had}

3×10^{-4} for θ_e = 2 ⇔ 3 mrad

$a_{had\mu}$ summing (E beam = 210 GeV)

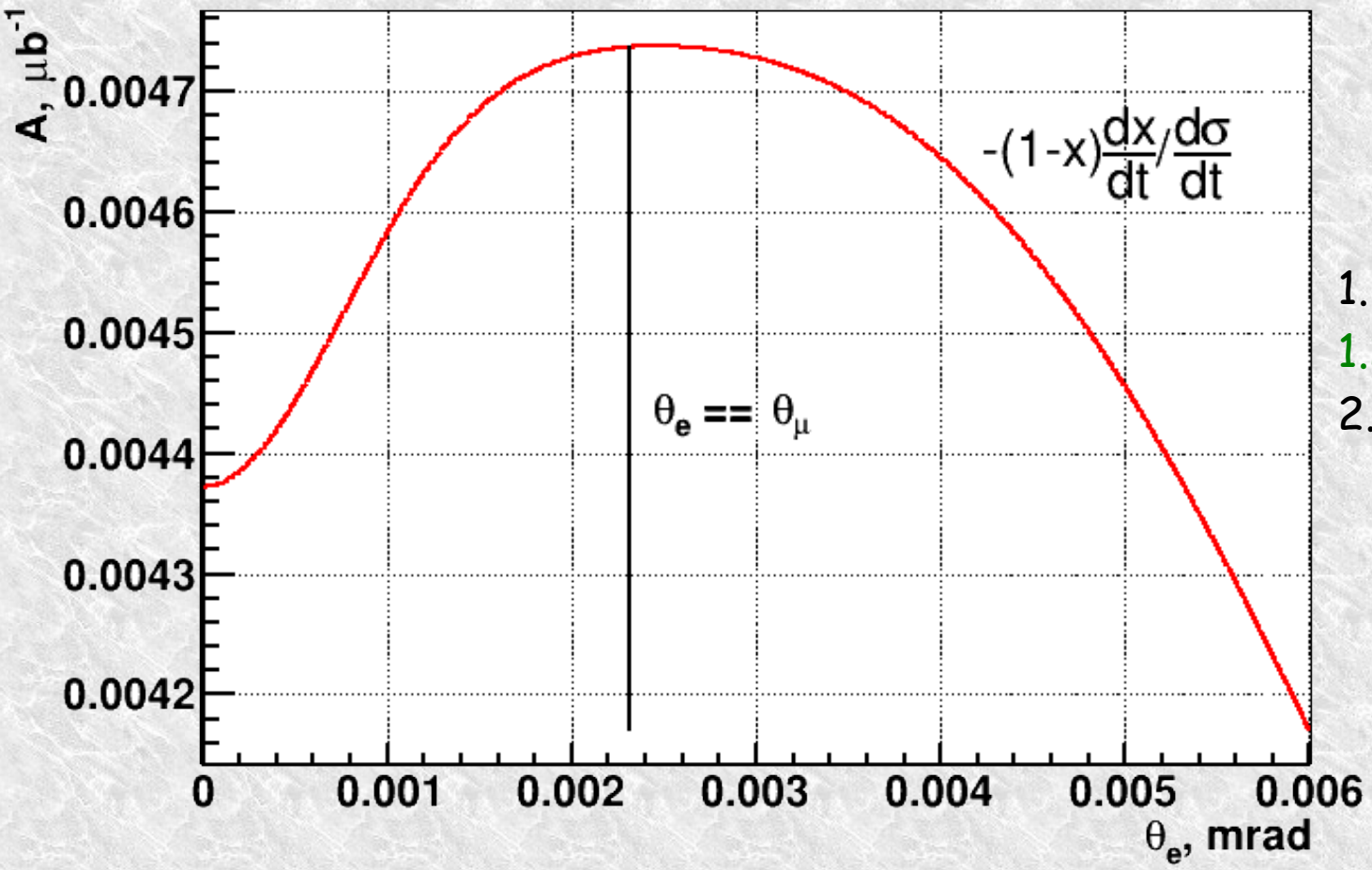


		ΔA/A
1.	⇔ 5. mrad	-0.067
1.2	⇔ 4.5 mrad	-0.059
2.	⇔ 3. mrad	-0.026

$a_{had\mu}$ summing (E_{beam} = 180 GeV)

Normalization function more symmetric over $\theta_e = \theta_\mu$

~180 GeV muon beam looks like most suitable for μ/e ID problem



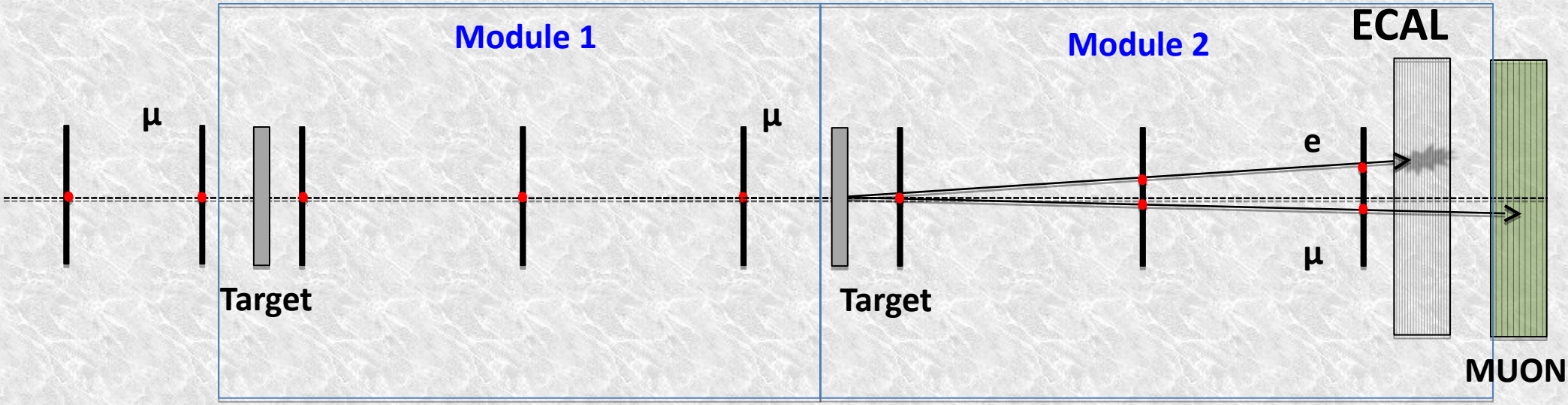
		ΔA/A
1. ⇔ 5.	mrad	0.029
1.2 ⇔ 4.5	mrad	0.015
2. ⇔ 3.	mrad	0.00016

~10^{-3} μ/e ID for a_μ^{had}

"180" GeV
can be optimized better

e/μ ID by calorimeter

Ecal + Muon system can be used after last modules…

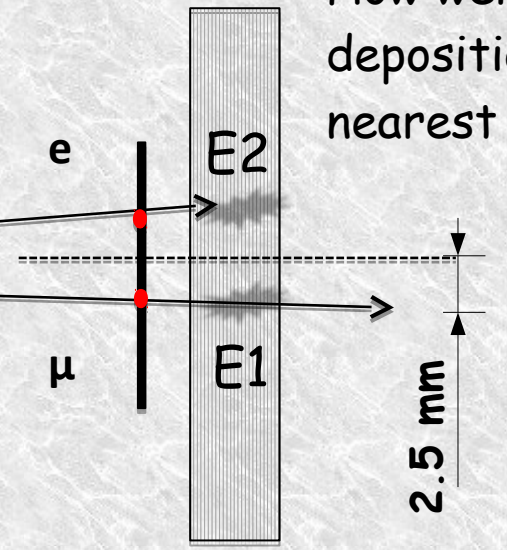


Calorimeter ID

Angle between μ vs e ~ 5 mrad
→ 5mm/1m distance
between impact point at calorimeter

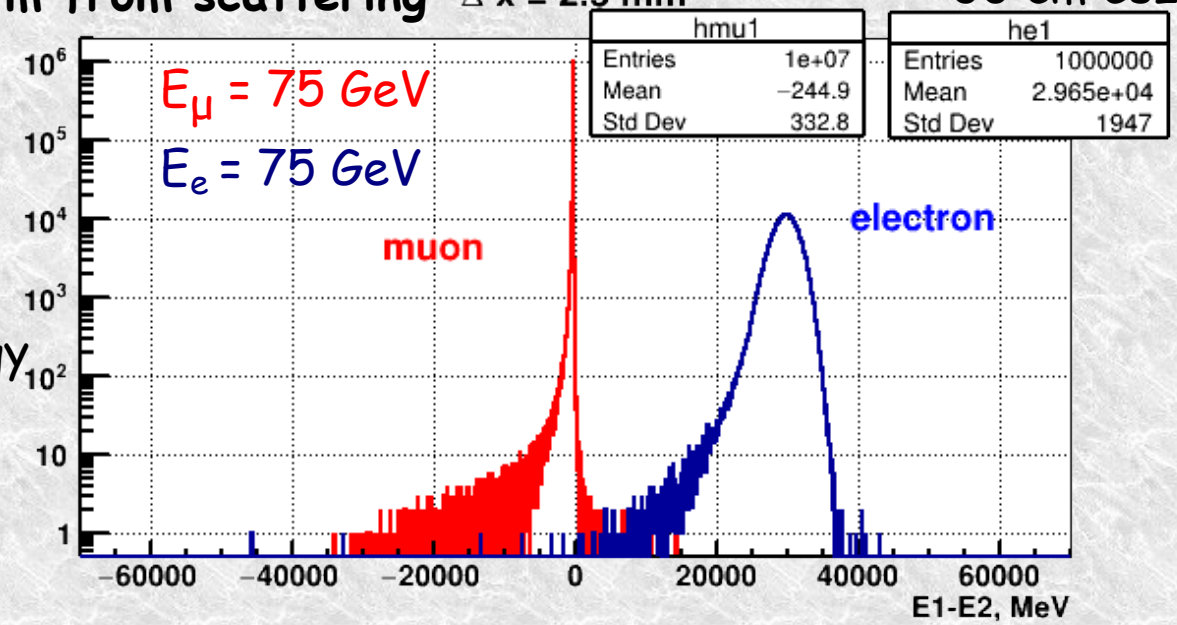
ECAL

How well separated energy deposition between nearest particle?

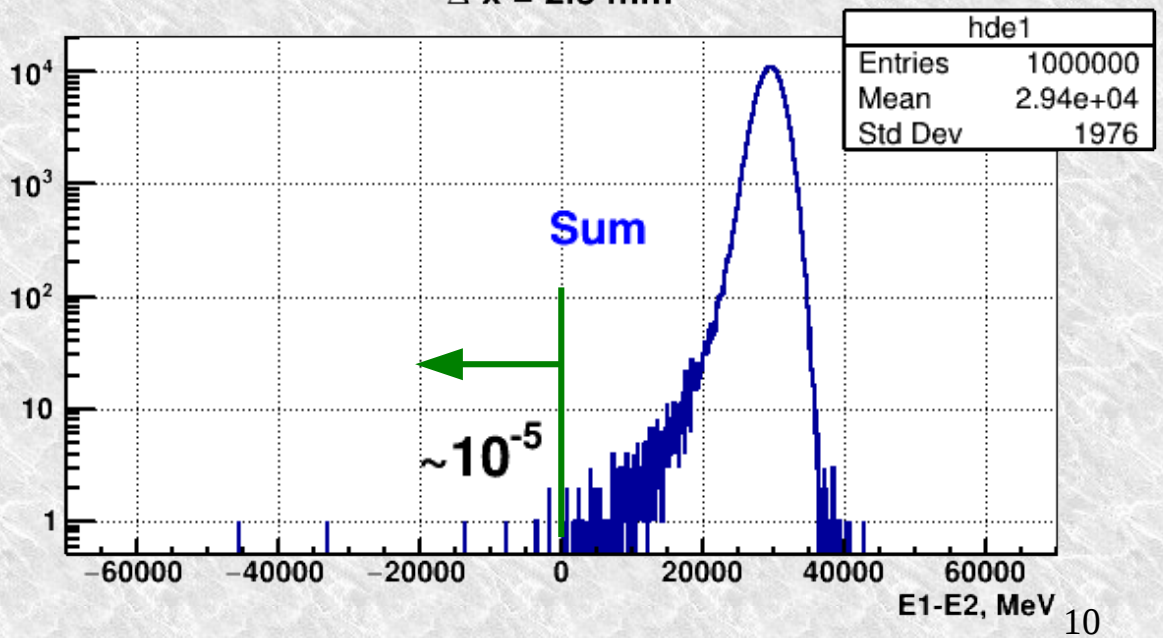


1m from scattering Δ x = 2.5 mm

30 cm CsI



Δ x = 2.5 mm



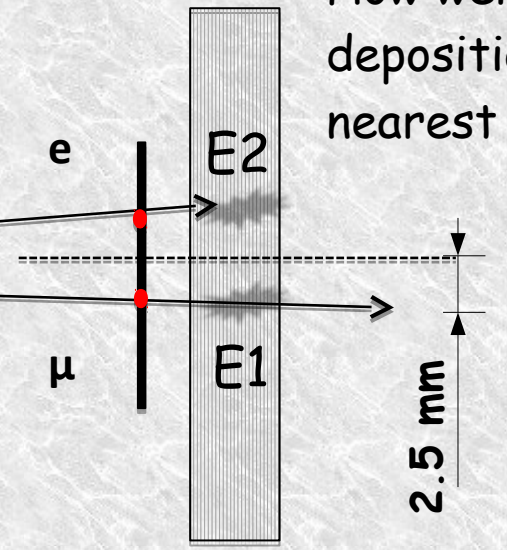
But everything is limited by size of crystals….

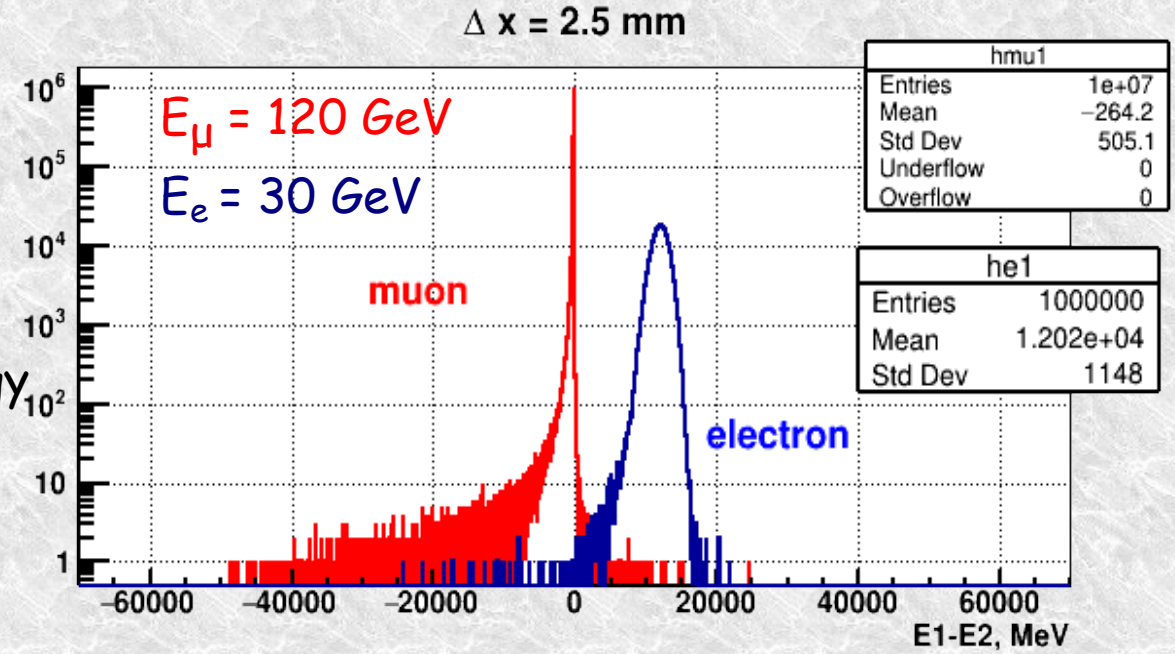
Calorimeter ID

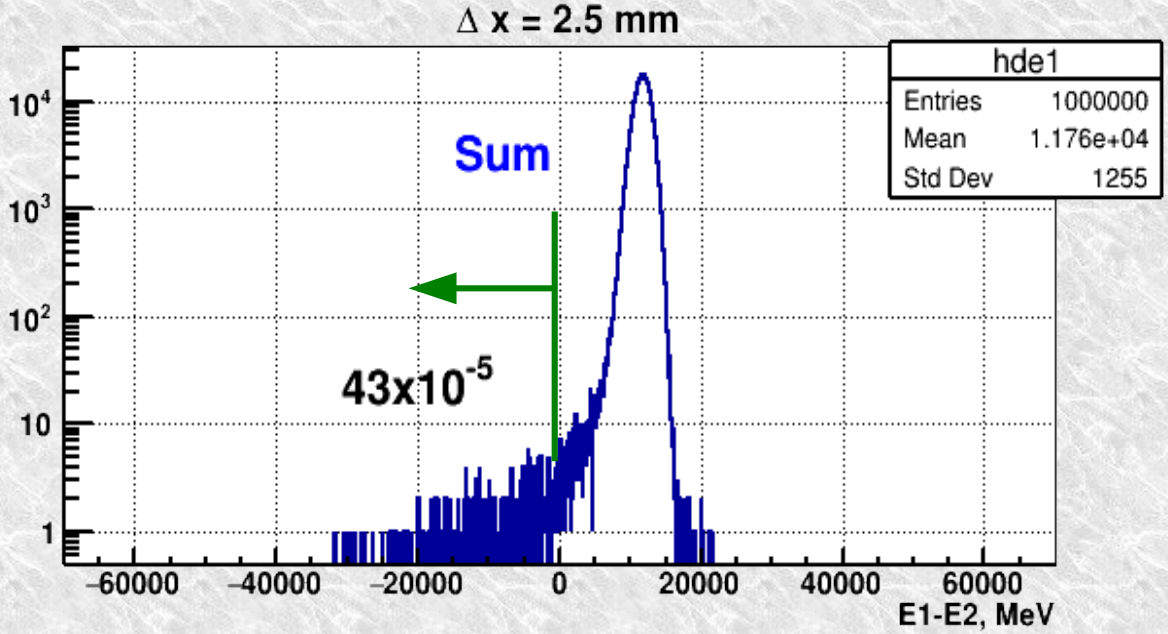
Angle μ out vs e ~ 5 mrad
→ 5mm/1m distance
between impact point at calorimeter

ECAL

How well separated energy deposition between nearest particle?





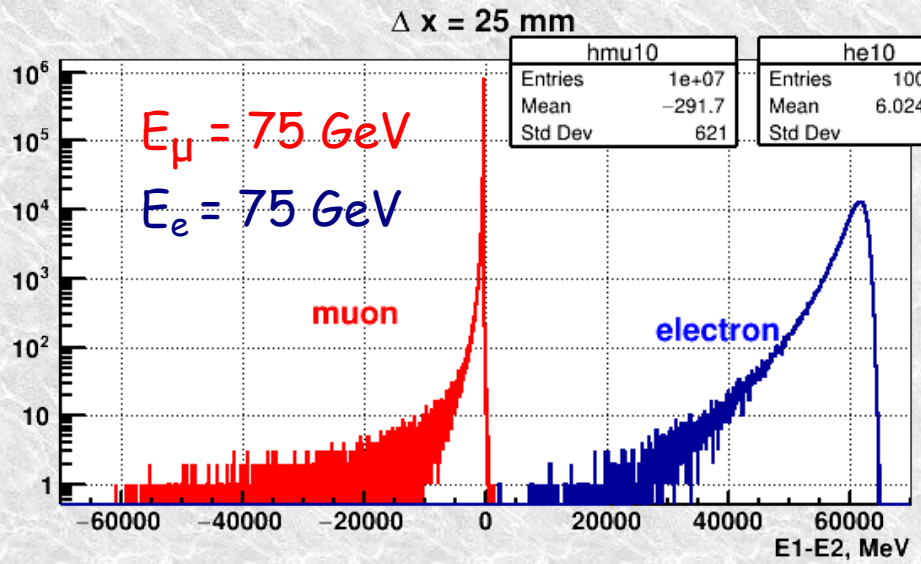


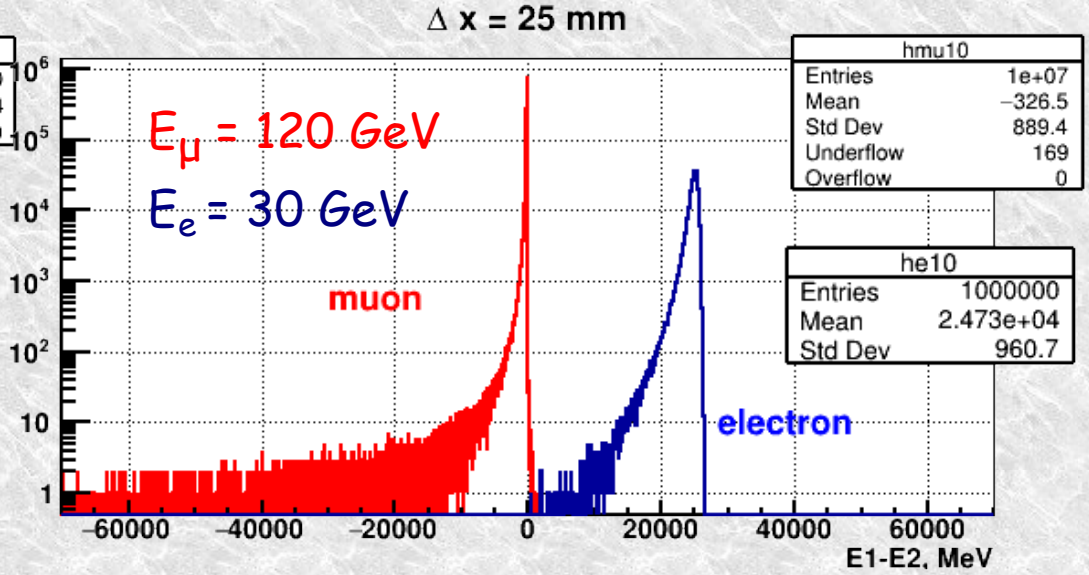
But everything is limited by size of crystals….
We should to put calorimeter far away – 10m after last target?

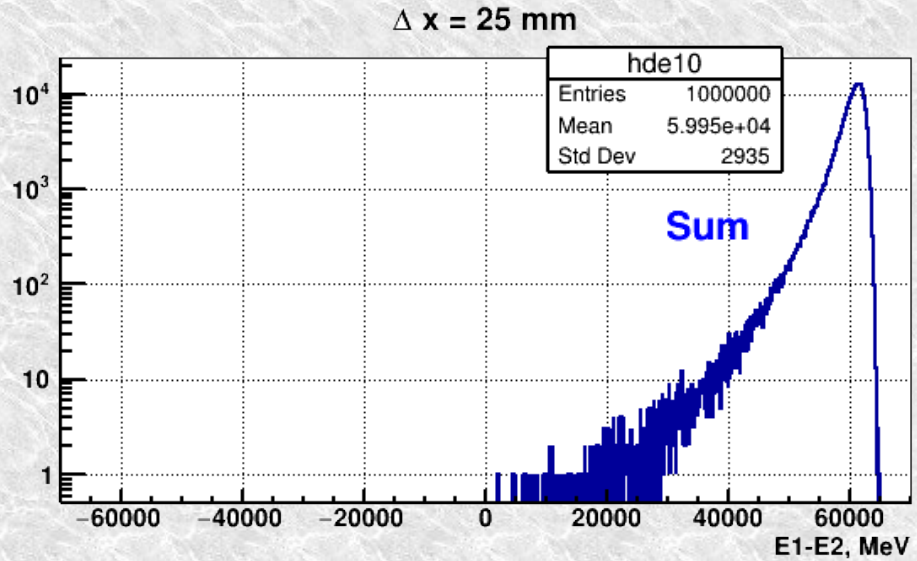
Calorimeter ID

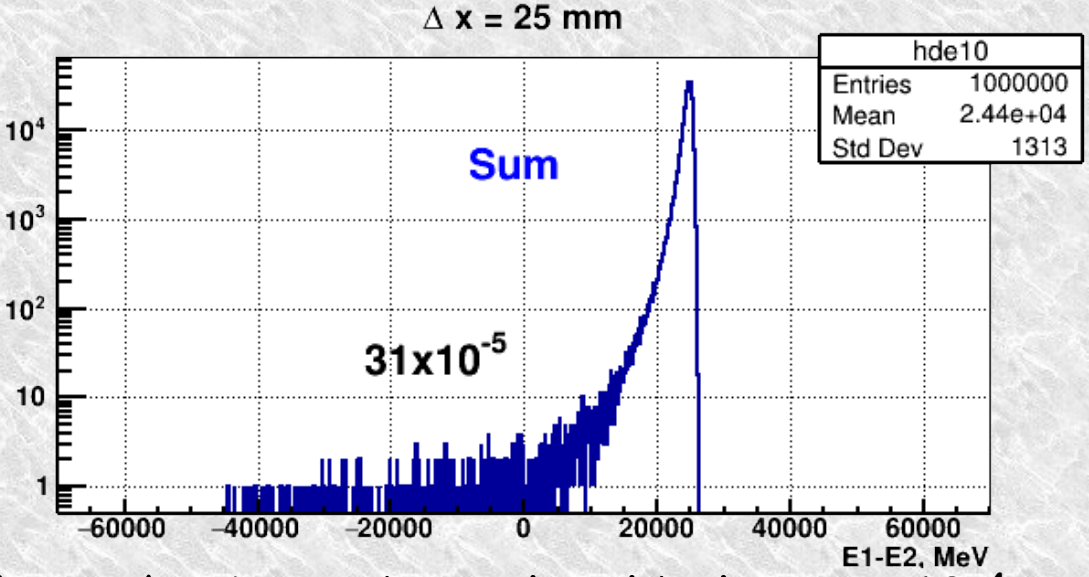
30 cm CsI

10m from scattering → 5cm spacing









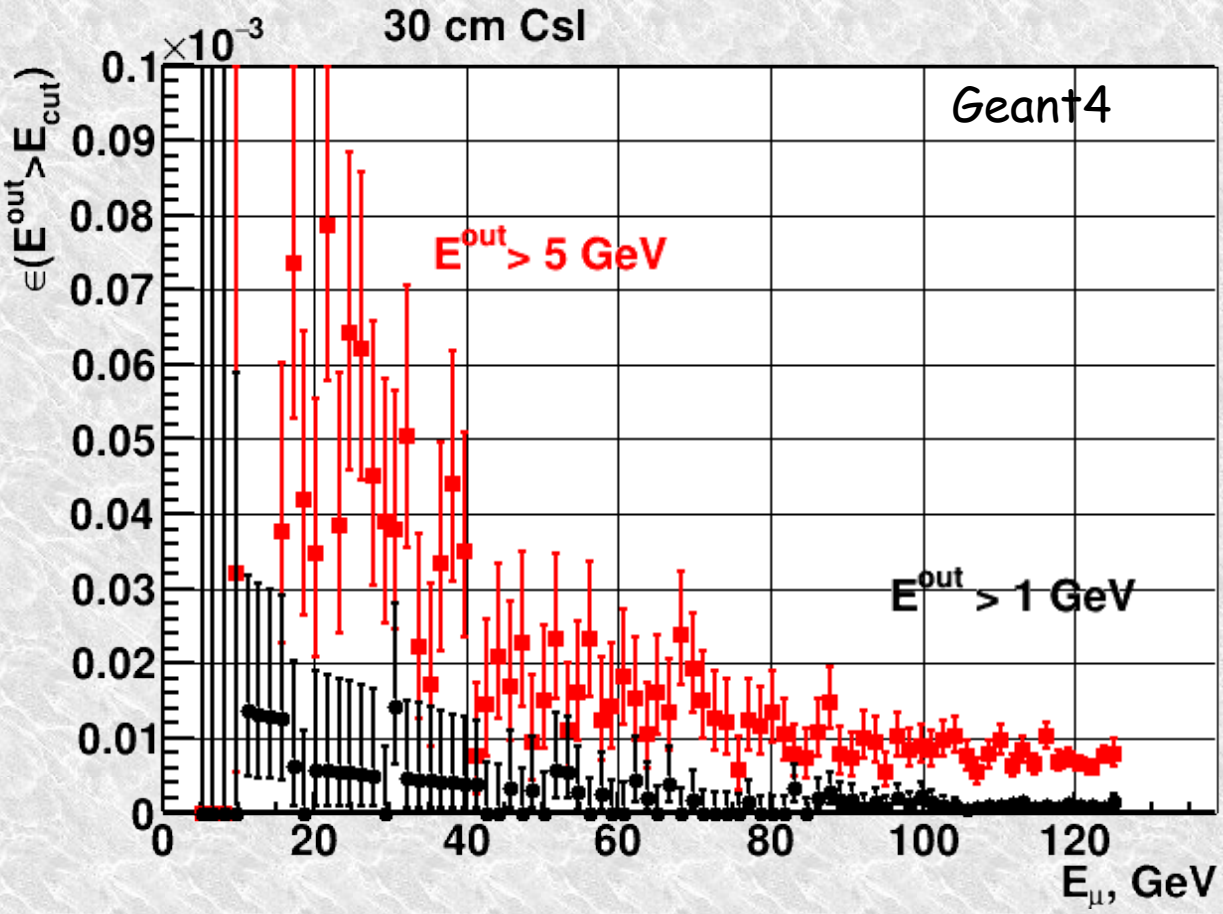
If detection element is small enough then μ/e ID can be at level below < $3x10^{-4}$

Sliced calorimeter with shower profile can help to improve this number further

muon system

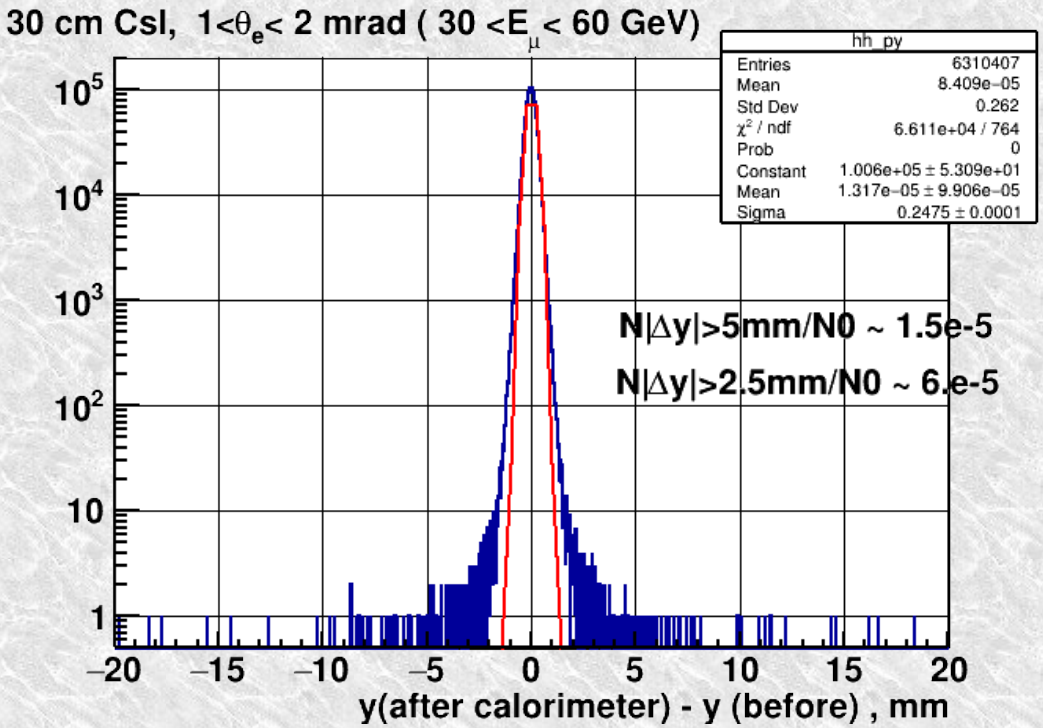
At which level muon will survive in calorimeter?

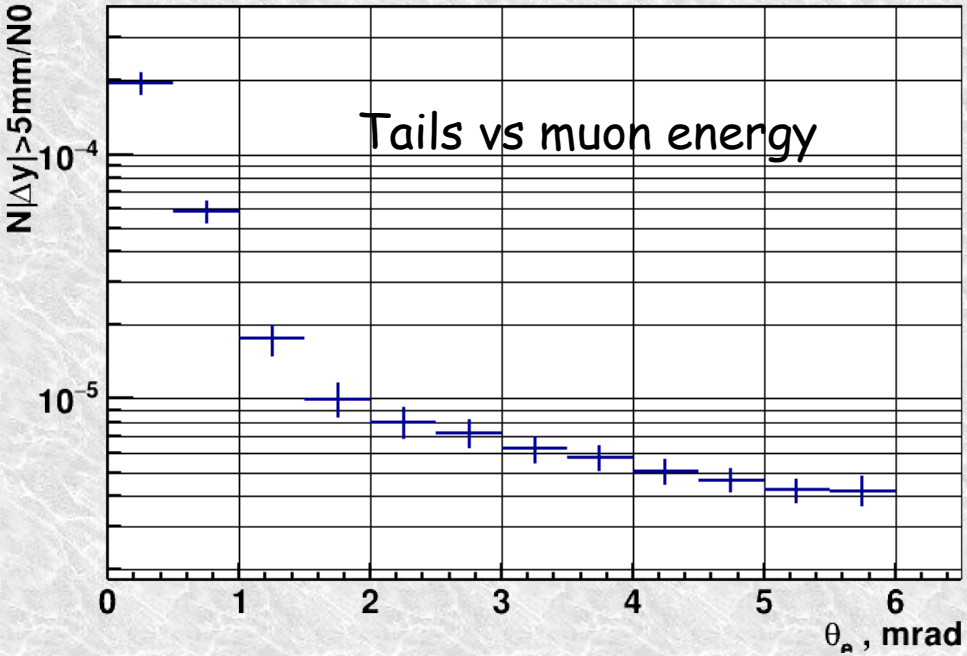
Inefficiency to lose muon after 30 cm of CsI



Muon will pass calorimeter with inefficiency ~ few 10^{-5}

Muon after calorimeter





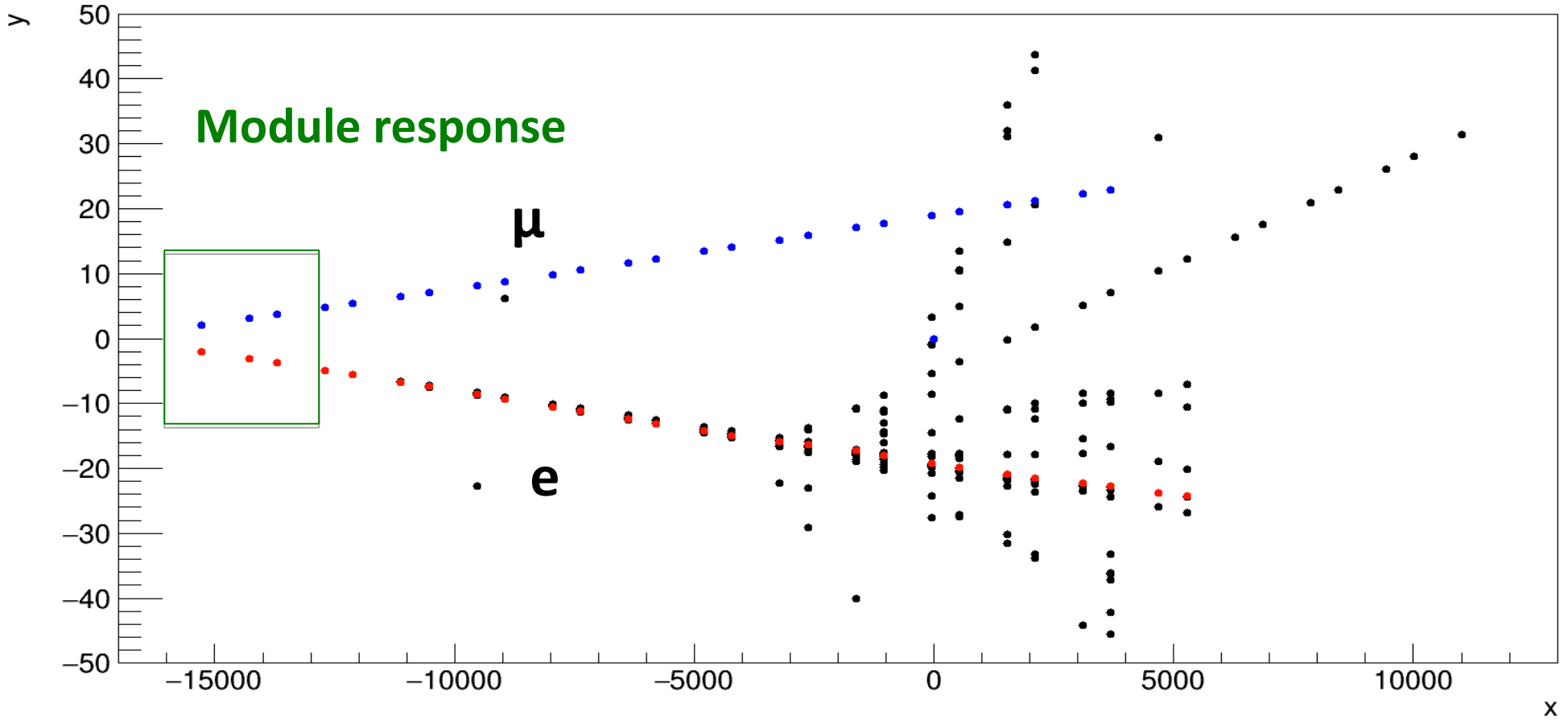
Output position of muon after 30cm CsI ~ 0.25 mm (should be compared to 5 mm distance between μ/e)

Tails ~ 10^{-5}

Muon crossing of calorimeter can gives ID at level ~ 10^{-4} ?

Events throughout the detector

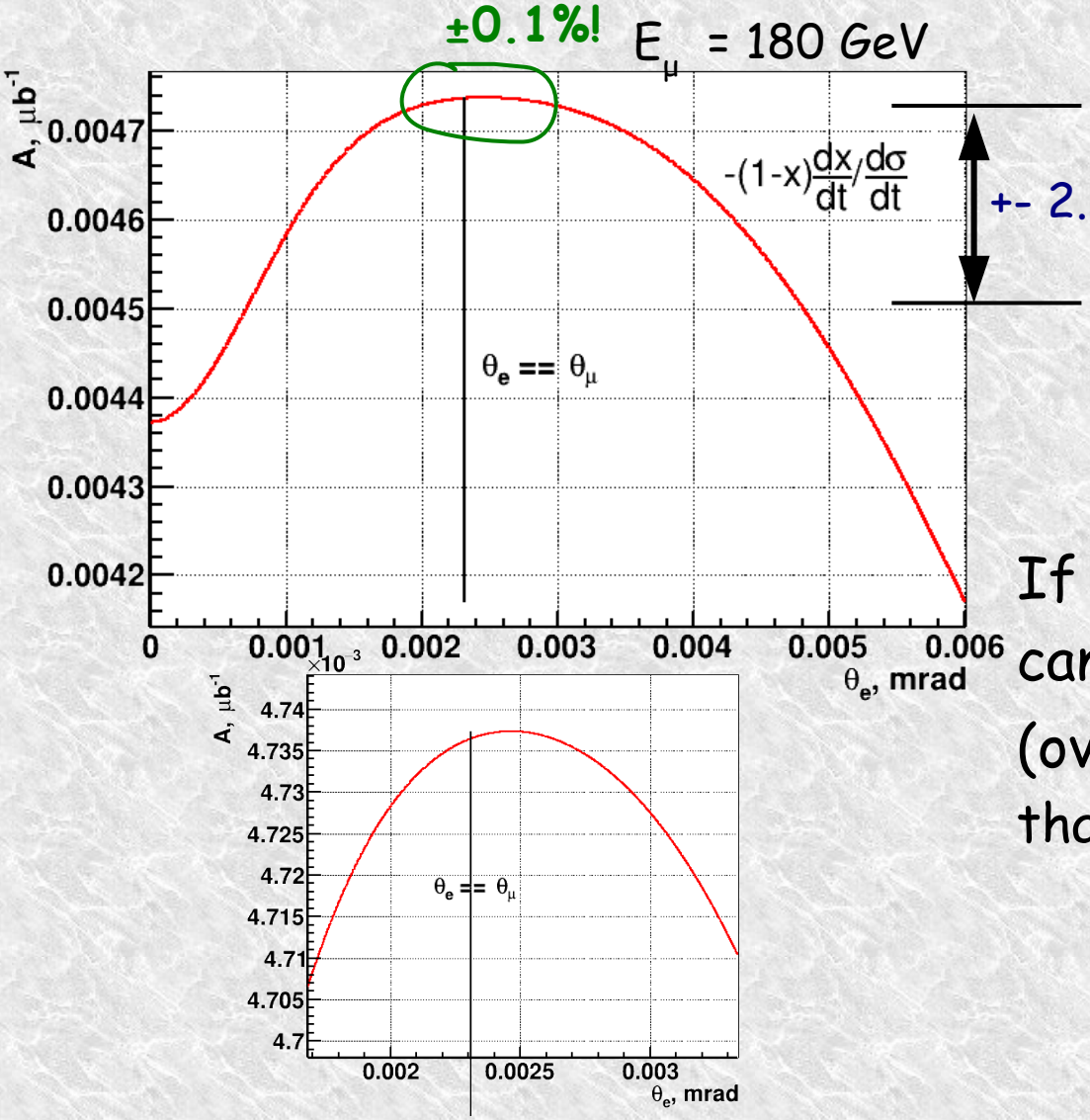
PID capabilities



Muon/electron will pass ~ 40 targets (~1-2 X/X0) before reaching calorimeter
muon can be easily tracked up to calorimeter → calorimeter still usable

$a_{had\mu}$ without any μ/e ID

$$a_\mu^{had,LO} = \frac{\alpha}{\pi}\int_0^1 dx(1-x)\Delta\alpha_{had}[t(x)] = \frac{\alpha}{\pi}\sum dt\,(1-x)\frac{dx}{dt}\frac{\Delta N}{d\sigma/dt\,Ldt}$$

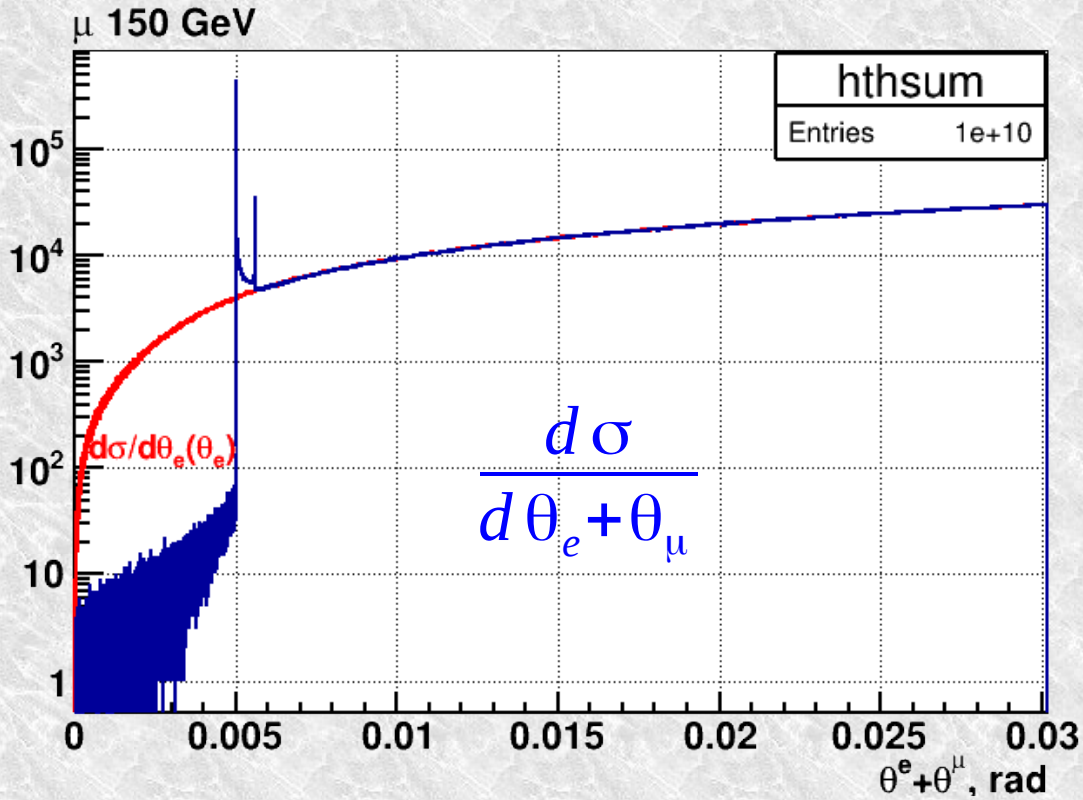


Without any μ/e ID,
just by counting events of excess over prediction (with only lepton VP)
→ δa ~ 2.5% for part at θ_e < 5 mrad
(5% for μ beam 150 GeV)

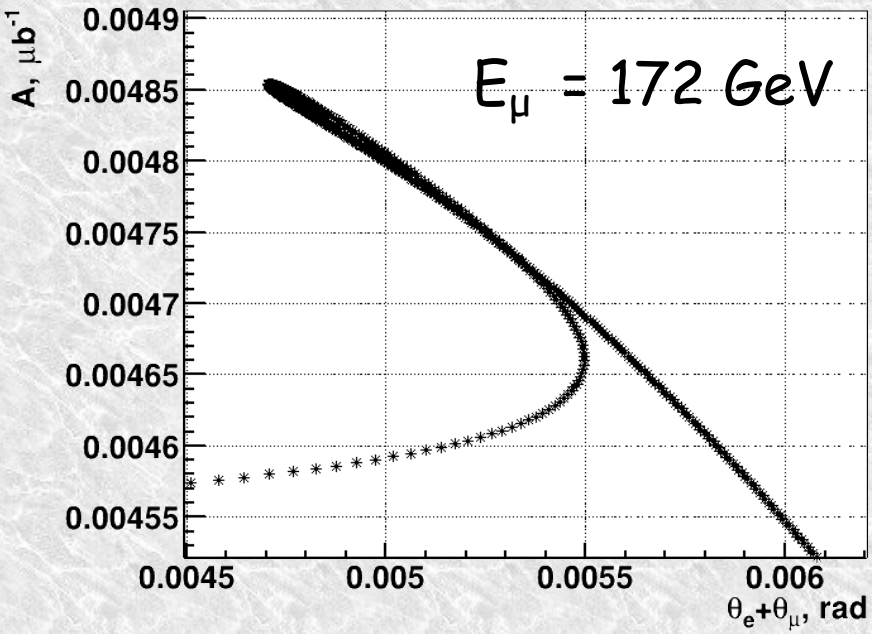
From most problematic region
2 ⇔ 3 mrad : δa ~ 0.1%

If the Normalization function can be symmetric over $\theta_e = \theta_\mu$
(over change of μ ⇔ e angles)
than it is not necessary to have any μ/e ID

$a_{had\mu}$ without any μ/e ID



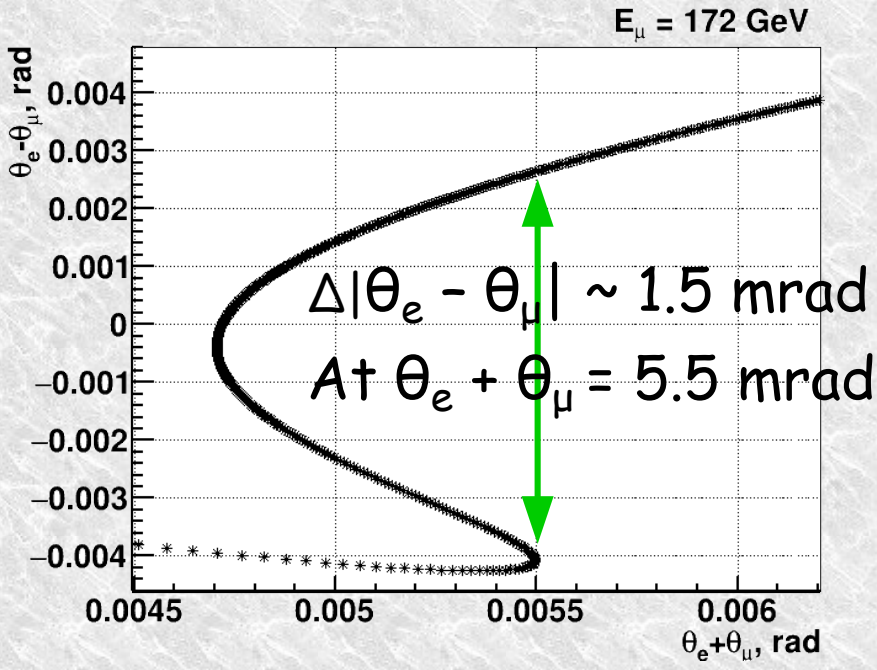
Change of Normalization coefficient to amu << 1%



With proper E_μ

Probably it will be enough to use just angle between final e - μ:

Spectra vs $\theta = \theta_e + \theta_\mu$



Summary

Calorimeter + Muon system can be solution for μ/e ID
(can gives level of ~ 10^{-4}?)

Effect of miss μ/e ID can be greatly reduced
by choosing proper energy of muon beam
in LO approximation with E_{beam} = 172 GeV : we don't need it at all

but anyway we need it to study low energy electron background
scattered because of MS