Electron-Muon Ranger (EMR)
Step I Paper

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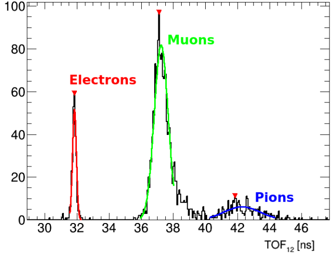
Structure of the EMR Step I note and paper

1. Introduction
   - Ionization Cooling, MICE ✓
   - Purpose of the EMR ✓
2. Electron-Muon Ranger
   - Structure of the detector ✓
3. Performance in the MICE Beam
   - TOF selection and particle tagging ✓
   - Correction for the energy loss in TOF2 and KL ✓
   - Useful variables for PID ✓
   - Efficiency of a simple test statistic ✓
   - Momentum reconstruction from the range ✓
4. Conclusions

Beam characterisation with TOFs

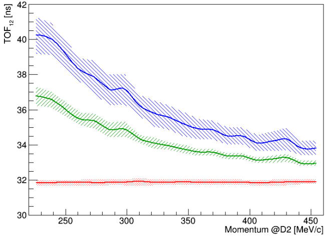
The *time-of-flight* structure of a beam setting exhibits a three peak structure with the first and second peaks composed of electrons and muons, respectively

→ Preliminary **particle ID**



Provided the particle mass, the TOF information allows for good momentum reconstruction between TOF1 and TOF2

→ Momentum **before** TOF2 and KL



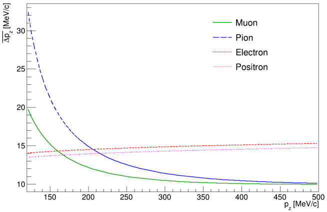
Momentum loss prior to the EMR

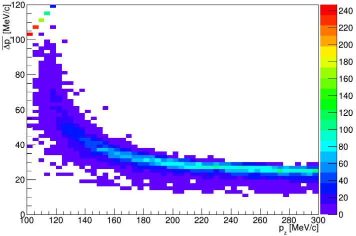
Energy loss in TOF2

- $\rightarrow$ $\sim 15\,\mathrm{MeV}/c$ loss through ionization for ultra-relativistic electrons and positrons
- $\rightarrow$ $\sim 10\,\mathrm{MeV}/c$ loss for MIP muons, $15\,\mathrm{MeV}/c$ for $150\,\mathrm{MeV}/c$ muons

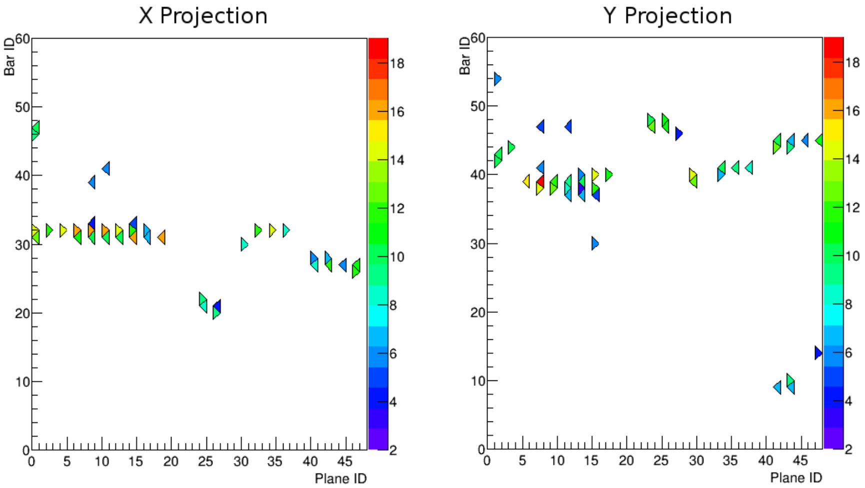
Energy loss in KL

- $\rightarrow$ electrons and positrons shower in the KL and multiple particles exit
- $\rightarrow$ $28 \pm 3\,\mathrm{MeV}/c$ loss for MIP muons, stop under $120\,\mathrm{MeV}/c$

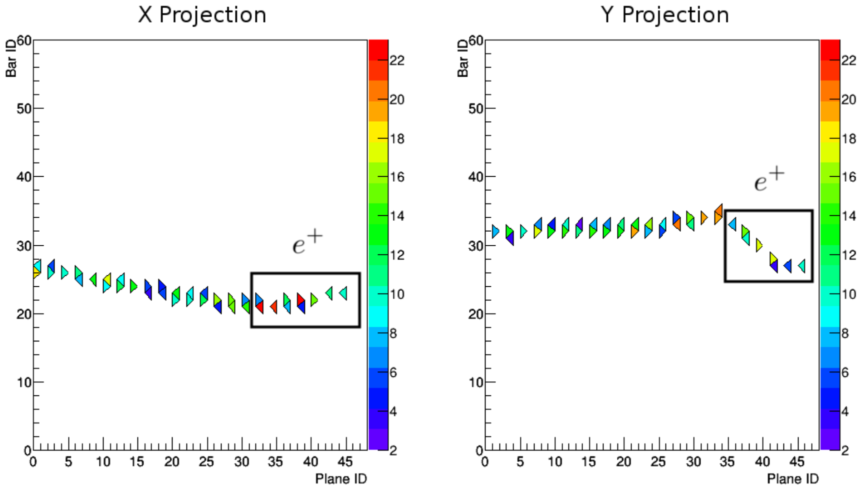




Electron shower *ToT* profile (450 MeV/c @D2)



Muon decay *ToT* profile (250 MeV/c @TOF$_2$)

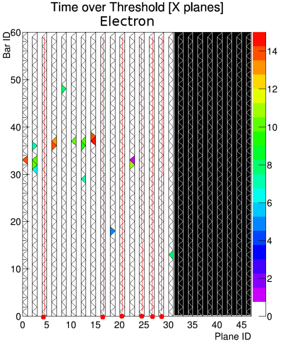


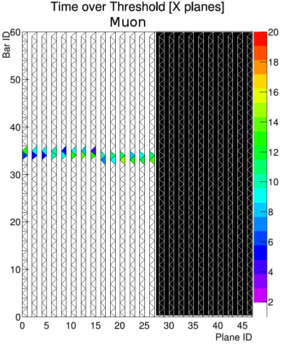
Definition of the Plane Density ρ_p

The plane density is defined as the percentage of the planes that record a signal on the path of the particle or its shower, i.e.

$$\rho_p = \frac{N_x + N_y}{Z_X + Z_Y} = \frac{N}{Z_X + Z_Y} \tag{1}$$

with N_i the number of planes hit in the iz proj. and Z_i the most downstream plane in the iz proj. N is the total amount of planes hit.

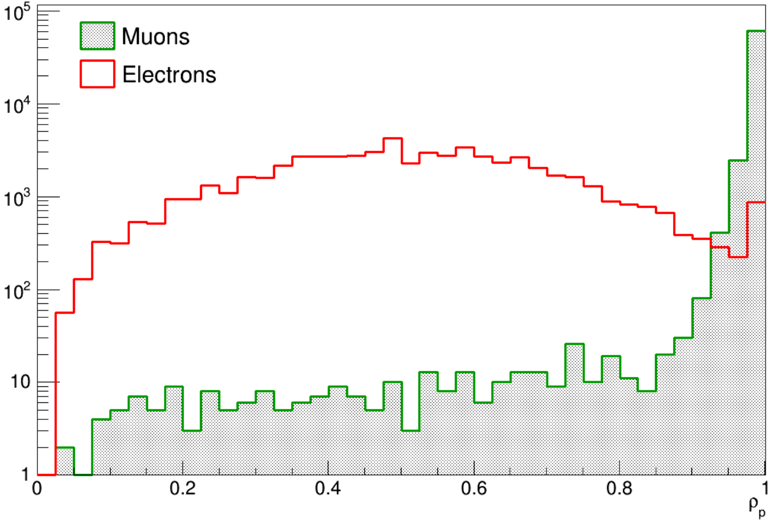




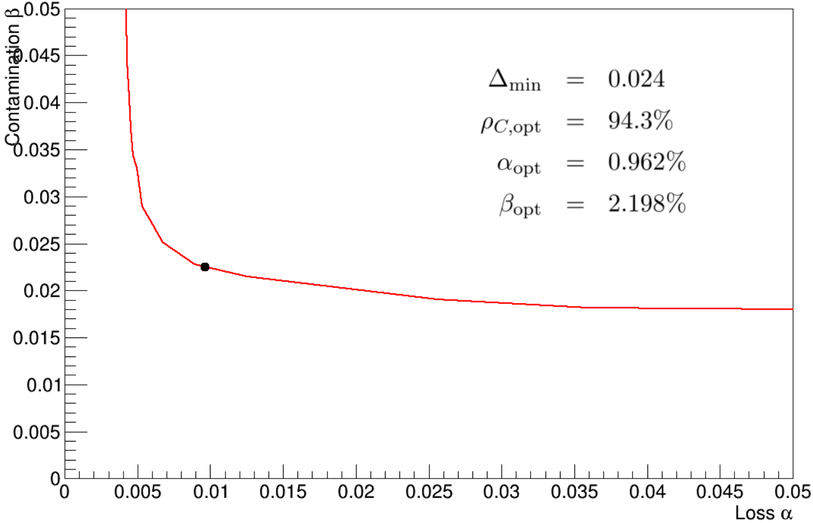
Electrons: 9 planes hit over a span of 15, $\rho_p = 60\%$;

Muons: 14 planes hit over a span of 14, $\rho_p = 100\%$.

Muon vs electron: ρ_P (normalized)



Plane density: separation efficiency



Spread in terms of χ^2/N in the two projections

One way to express that angular spread of an electromagnetic shower is to fit it with a line a evaluate its χ^2 normalized to the amount of hits N:

$$\chi^2/N = \frac{1}{N}\sum_i \frac{(y_i - (ax_i + b))^2}{\sigma_i^2} \tag{2}$$

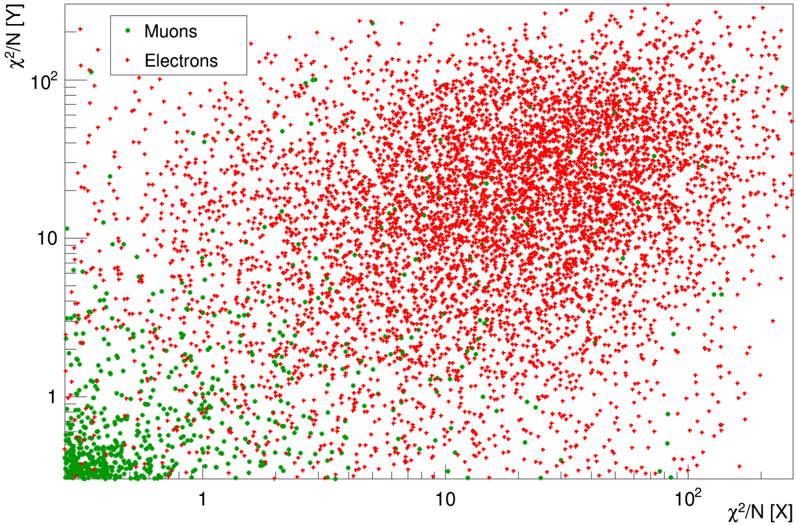
For a given array of hits (x_i, y_i), the exact value of this parameter is expressed in term of the spread $\sigma_y^2 = E\left[(y-\overline{y})^2\right]$ as:

$$\chi^2/N = \sigma_y^2(1-\rho^2) \tag{3}$$

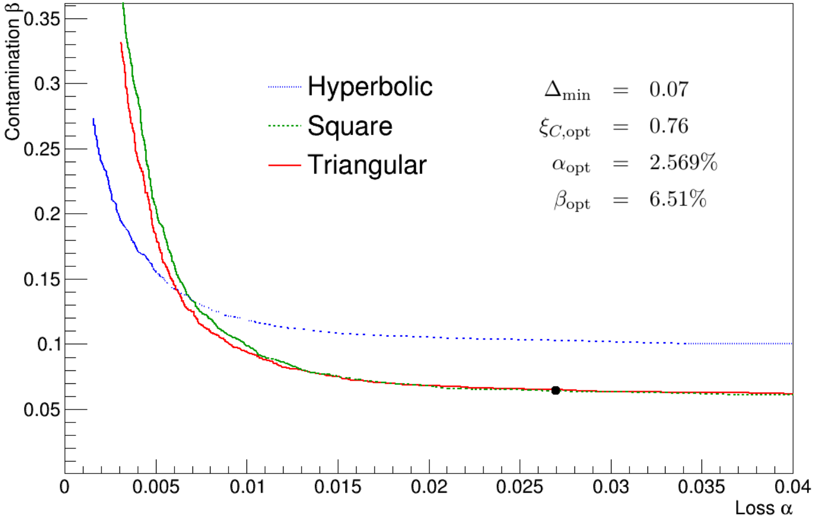
with $\rho = \texttt{Cov}(x,y)/\sigma_x\sigma_y$. This is exactly what we want as:

- Electrons have a significant spread σ_y and the hits they produce are weakly correlated ($(1-\rho^2)\rightarrow 1$), so that $\chi^2/N \rightarrow \sigma_y^2 \gg 1$
- Muons have a small spread σ_y (centre of the detector) and are strongly correlated (line, $(1-\rho^2)\rightarrow 0$), so that $\chi^2/N \ll 1$

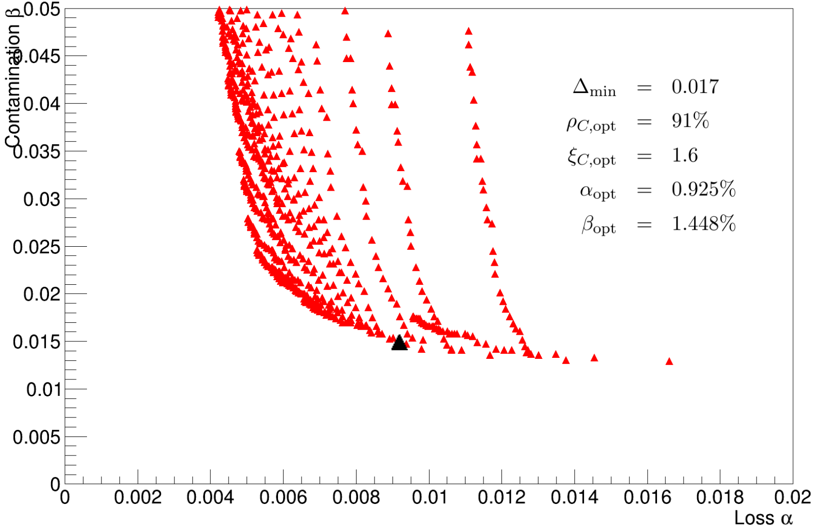
Muon vs electron: χ^2/N in the two projections



Normalised χ^2: separation efficiency



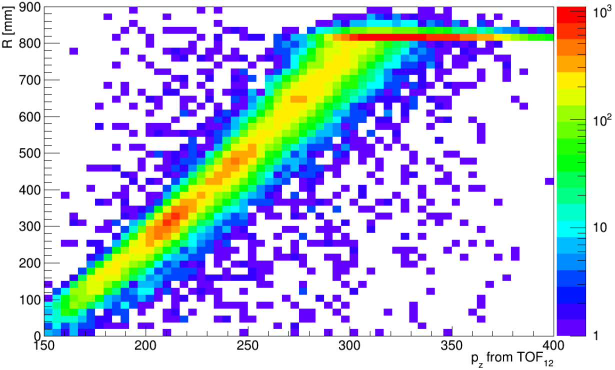
Combined separation efficiency



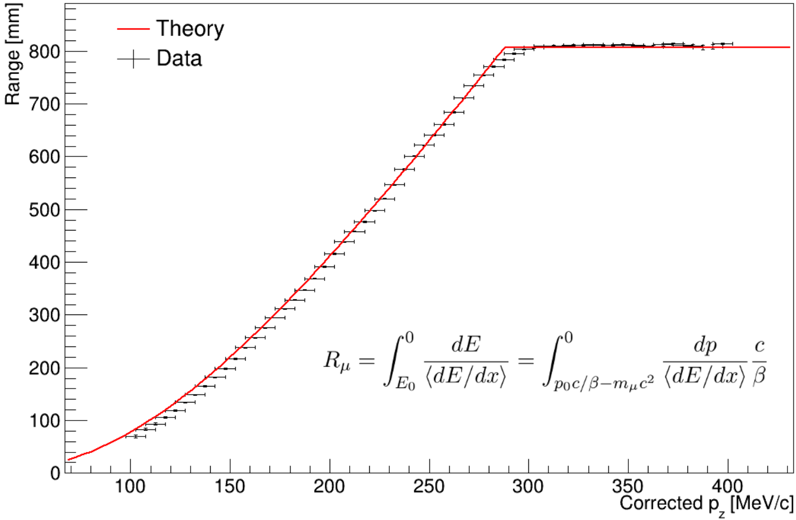
Definition of the Range of muons R

The range is defined as the distance the particles travels through the EMR before it stops. Given that z_N is the z coord. of the last bar hit,

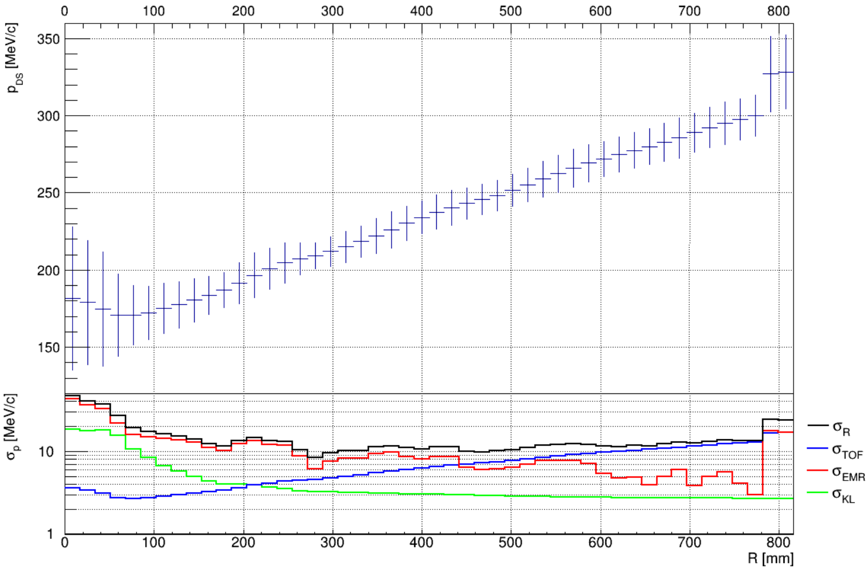
$$R = z_N \sqrt{1 + (\tan^2\theta_x + \tan^2\theta_y)} \quad (4)$$



Comparaison with the CSDA range



Uncertainty on the range reconstruction



Conclusions

EMR Paper: Status

Task	Person	Timescale
Plots post CM42 comments	François Drielsma	< 1 week
Improvements to range-momentum analysis	Francois Drielsma, (Alain Blondel)	~ 3 weeks
Write up long form (MICE Note) version of new analysis	François Drielsma	~ 3 weeks
MICE Note → Wise People	François Drielsma	< 1 week
MICE Note digested	Alan Bross, Ludovico Tortora	~ 2 weeks
MICE Note comments received and implemented → return to Wise People. Publish MICE Note (on wiki/notes page)	FD, AB, LT	Iterative
Paper drafted	François Drielsma	~ 4 weeks
Paper → Wise People	Alan Bross, Ludovico Tortora	~ 2 weeks
Comments received and acted on.	François Drielsma	Iterative
Paper → Collaboration	François Drielsma	2 * 1 week iterations
Paper → Publish, reviewer comments, etc.	François Drielsma	...