Electron-Muon Ranger (EMR) Step I Paper

François Drielsma

University of Geneva

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Structure of the EMR Step I paper

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

NB: This paper demonstrates the **capability of the EMR**

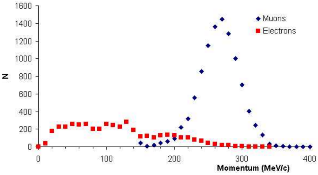
1. & 2. Electron-Muon Ranger

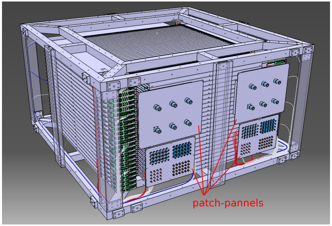
Pupose of the EMR in MICE:

- Reject the muons that decayed inside the cooling channel
- Redundant measurements of the trajectories and momenta

The EMR is fully active scintillator tracker calorimeter

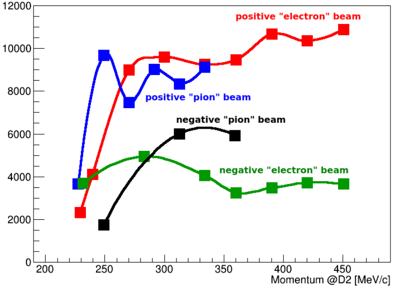
- 48 planes of 59 triangular scintillator bars
- Readout by multi-anode and single-anode PMTs





3.1. MICE beam settings and TOF selection

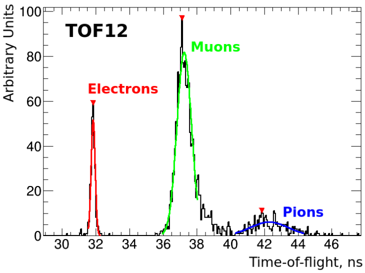
- One month of data taking in the MICE beam at Step I
- Array of beam settings ($e^{\pm}$, $\pi^{\pm}$) with momenta ranging from 230-420 MeV/c at D2



- PID from TOF dist.
- Momentum of muons from:

$$p_\alpha = \frac{m_\alpha c}{\sqrt{\left(\frac{c\mathrm{TOF}}{\Delta z_{12}}\right)^2 - 1}} \quad (1)$$

- For a beam with a setting of 230 MeV/c at D2:



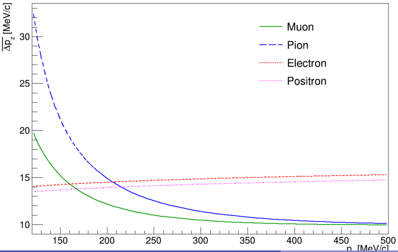
3.2 Energy loss before entering the EMR

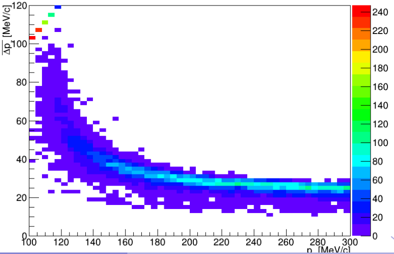
TOF2

- **MIP particles** lose $\sim$ 10 MeV/c in TOF (muons with $p_z > 2m_i c$)
- The **electrons** are all ultra-relativistic ($\beta\gamma > 100$) and lose $\sim$ 15 MeV/c

KL

- **MIP particles** lose $\sim$ 28$\pm$3 MeV/c in KL (muons with $p_z > 2m_i c$)
- The **electrons** are all ultra-relativistic ($\beta\gamma > 100$) and will shower in the lead of KL ($2.5X_0$)





Events in the EMR

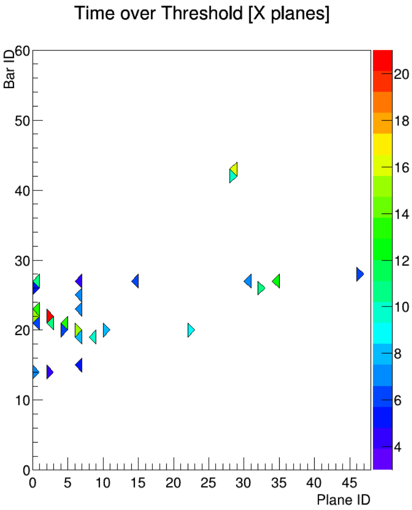


Figure: Electron shower

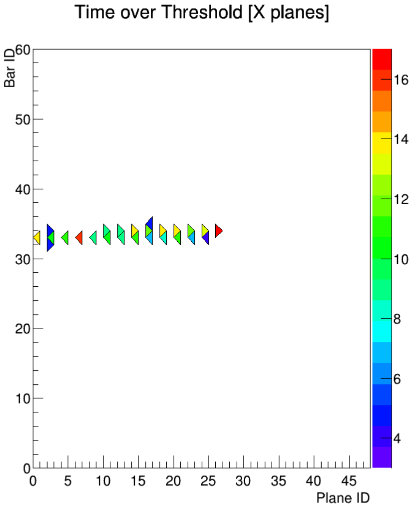


Figure: Muon track

3.3 Useful variables to discriminate electrons

For each beam setting (i.e. **momentum**) and each **event**, we measure:

1. Plane **density** ρ_p (*Longitudinal*)

$\rightarrow$ Measurement of the hit density in the active volume

$$\rho_p = \frac{N}{Z_x + Z_y} \tag{2}$$

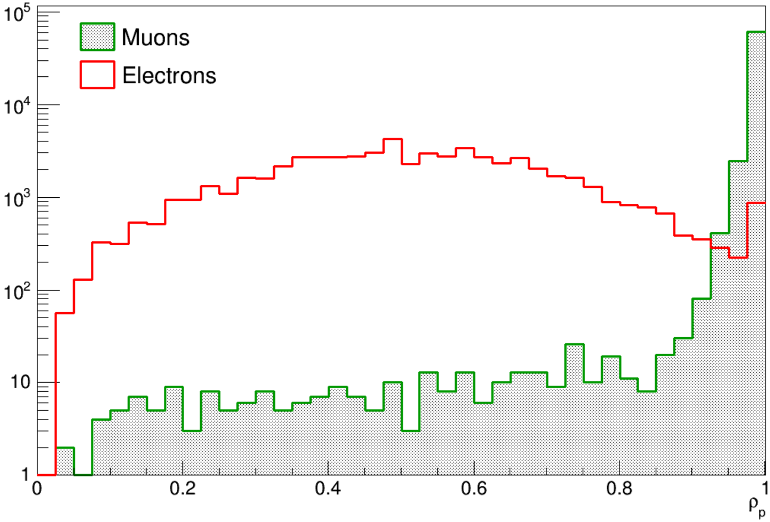
2. **Spread** in terms of χ^2 in the two projections (*Transversal*)

$\rightarrow$ Track / Shower spread of a particle

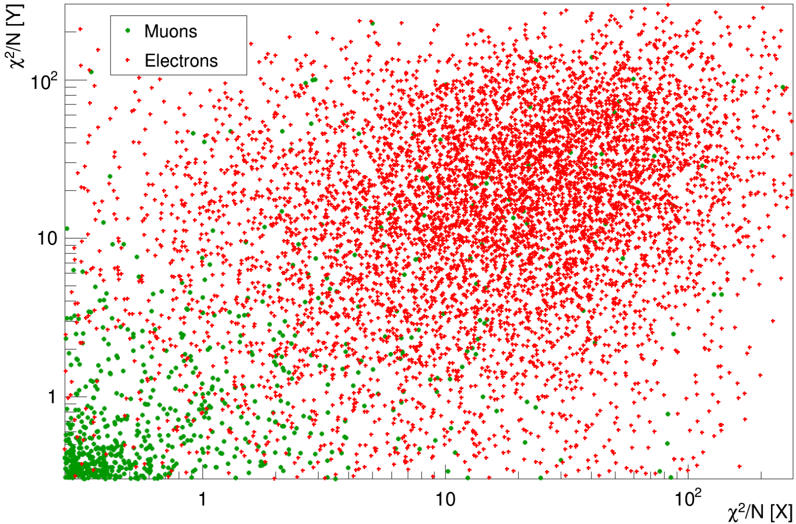
$$\chi^2/N = V_y(1 - \frac{V_{x,y}^2}{V_x V_y}) \tag{3}$$

The use of these variables as a combined test statistic will prove to be a strong tool to reject electrons and tag real muons in the detector as we will see in the following sections

Muon vs electron: Density (normalized)



Muon vs electron: Normalised χ^2



3.4 Test statistic

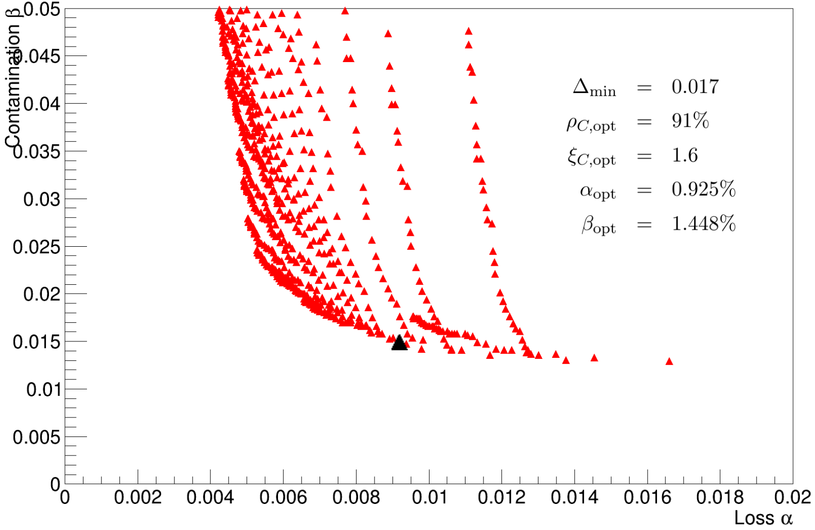
The plane density ρ_P is efficient to reject the electrons at all momenta. Even if it performs well on its own, adding a cut on $\xi = \chi^2_X/N + \chi^2_Y/N$ improves the rejection without reducing the acceptance.

Hypothesis testing :

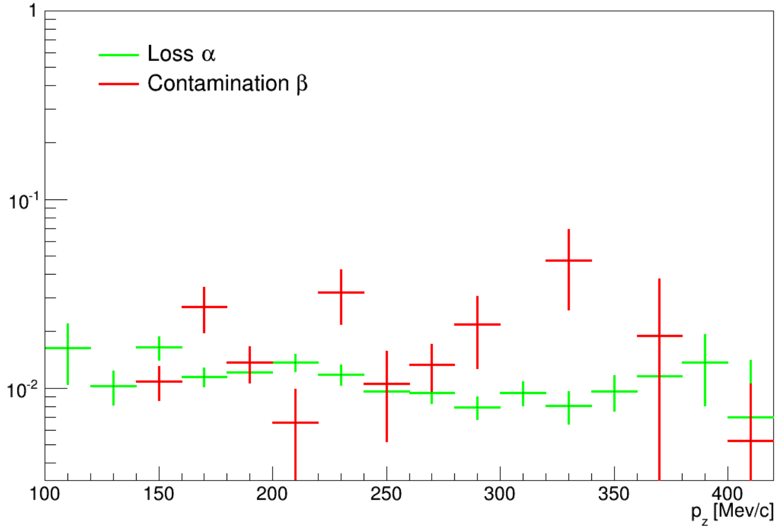
- H_0 is the null hypothesis, the particle X is a muon. H_1 is the alternative, i.e. X is an electron.
- $\alpha = p(X \in w|H_0)$ is the **loss**, the probability that X is tagged as an electron, given that X is a muon (w the critical region)
- $\beta = p(X \in (W - w)|H_1)$ is the **contamination**, the probability that X is tagged as a muon, given that X is an electron (W the space)

$\rightarrow$ In the (α, β) space, the best choice of cut is the one that minimizes $\Delta = \sqrt{\alpha^2 + \beta^2}$, the distance from the origin.
$\rightarrow$ The real contamination is in fact $R_e\beta$ with R_e the abundance of electrons in the beam, i.e. $R_e = N_e/N_\mu$ (= 11.7% in the test beam)

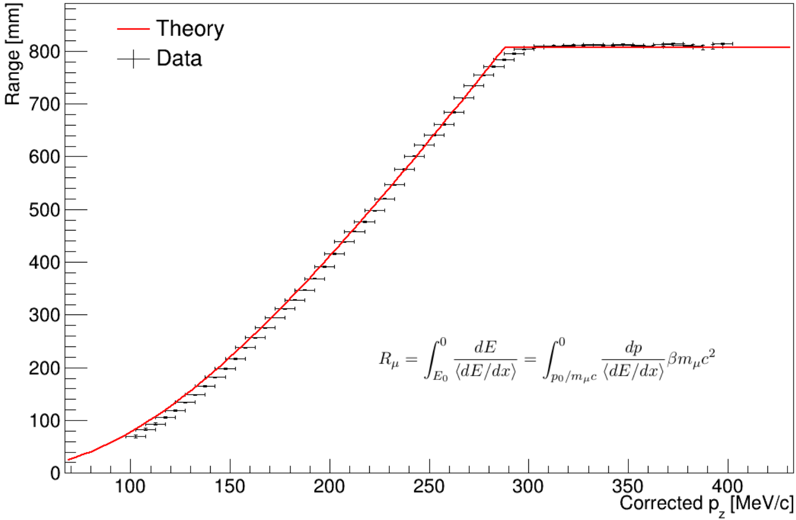
Optimal cut and efficiency



Rejection power at different momenta



3.5 Momentum reconstruction from the range



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 (very close)	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	...

http://mice.iit.edu/micenotes/public/pdf/MICE0466/MICE0466.pdf