Overview

of

MICE detectors

MICE Collaboration Meeting
Friday 8 Feb 2002, Illinois Institute of Technology

V. Palladino

for the task force on Detectors

A. Bross, A. Blondel, P.Gruber, E. Mc Kigney, P. Janot, E. Radicioni,
M. Mezzetto, B.Osteria, D. Summers, L. Cremaldi, U. Gastaldi, L. Tortora
R. Edgecock, P. Zucchelli, G. Barr, M. Apollonio, K. Long, S. Tsamarias,
J.M. Rey, ...and more ......

Goal of detector system

Measure **precisely** enough

all parameters … in and out

X, Y, P_x, P_y, P_z, t in
X, Y, P_x, P_y, P_z, t out

of each muon of a sample

large enough

….. to measure an **order 1 %** reduction

of muon emittance

$$1 - R = 1 - \frac{\varepsilon_{final}}{\varepsilon_{in}} = \text{few to } 20\ \%$$

to **order 0.1 %**

beam T_μ typically 200 MeV (P_μ 280 MeV/c)
spread ± 10%
50 mm* 200 mrad rms emittance in each proj.

Experimental Layout

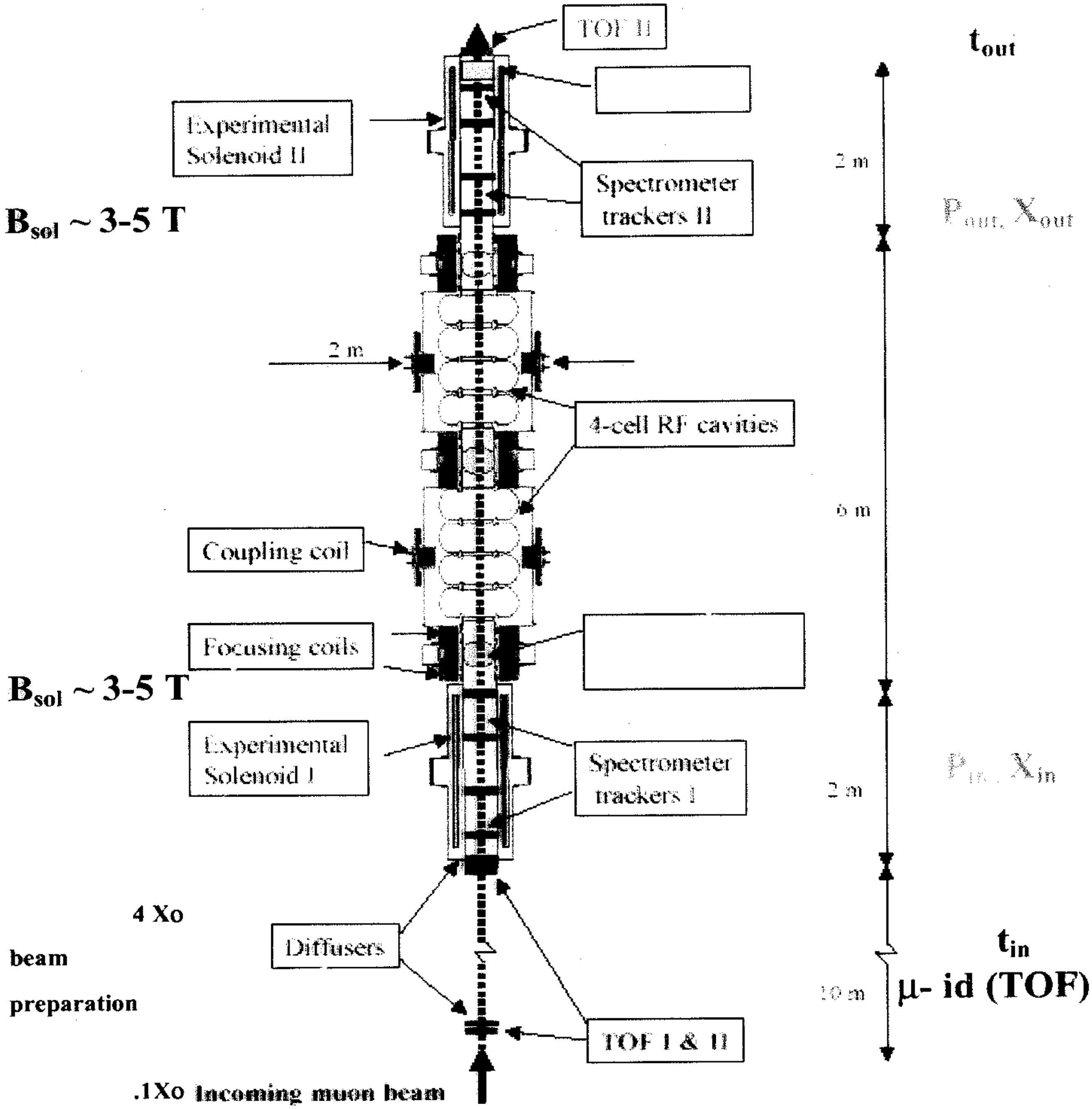


Figure V.1: Overview of the International Muon Ionization Cooling Experiment (top view)

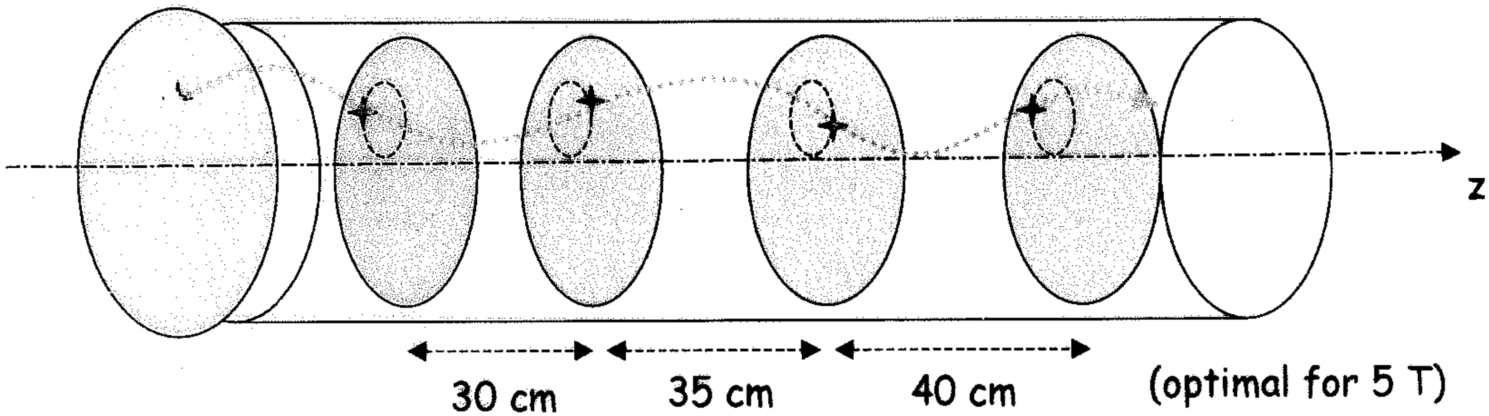
300 mm diameter
up to 10^7 μ/sec

Emittance Measurement: Improvement (I)

- The previous (minimal) design leads to reconstruction ambiguities for particle which make ~ a full turn between the two plates (only two points to determine a circle)

- It also leads to reconstruction efficiencies and momentum resolutions dependent on the longitudinal momentum, which bias the emittance measurements.

Solution: Add one plate, make the plates not equidistant



To find p_T and p_Z, minimize:

$$\chi^2_{p_T} = \sum_{i=1}^{4}\left[\left(\frac{x_i - x_0 - R\cos\phi_i}{\sigma_i}\right)^2 + \left(\frac{y_i - y_0 - R\sin\phi_i}{\sigma_i}\right)^2\right] \quad \text{and} \quad \chi^2_{p_Z} = \sum_{i\neq j}\left(\frac{R\Delta\phi_{ij} - \frac{p_T}{p_Z}\Delta z_{ij}}{\sigma_{R\Delta\phi_{ij}}}\right)^2$$

Summary of Detector requirements

π rejection <1%

.1 % at PSI: <10% in beam * <1% after TOF

TOF to ~70 ps or less

π/μ separation to 1% or better
timing wrt RF (5°/360°/200 Mhz=70 ps)

tracking

precision to ~200 μm/point

$\sigma(P_\mu)$ ~ few Mev/c
$\sigma(\theta_\mu)$ ~ few mrad
$\sigma(X_\mu)$ ~ order 100 μm

robust to bkgnd x-rays from RF cavity

major worry, potential killer !!!!!!!!!!

e rejection to <1%

need e-identifier beyond kin cuts (20%)

DAQ

up to few thousand muons/sec
(1% because of in-out correlation)

Trigger, timing and μ–ID by TOF

Two planes, ~ 10 m apart, in front
$t_\pi - t_\mu \sim 1400$ ps (280 MeV/c)

One plane at the back

3-fold (2-fold) coincidence

Baseline: fast conventional scintillators
(Milano, Napoli, Padova)

10 1 cm*10 cm*2 cm thick BC-420
8 2.5cm*40 cm*2.5 cm BC-404
8 2.5cm*40 cm*2.5 cm BC-404

1 R4998 Hamamatsu PMT/slab/end
(20 mm diameter, 0.7ps rise, 160 ps transit)

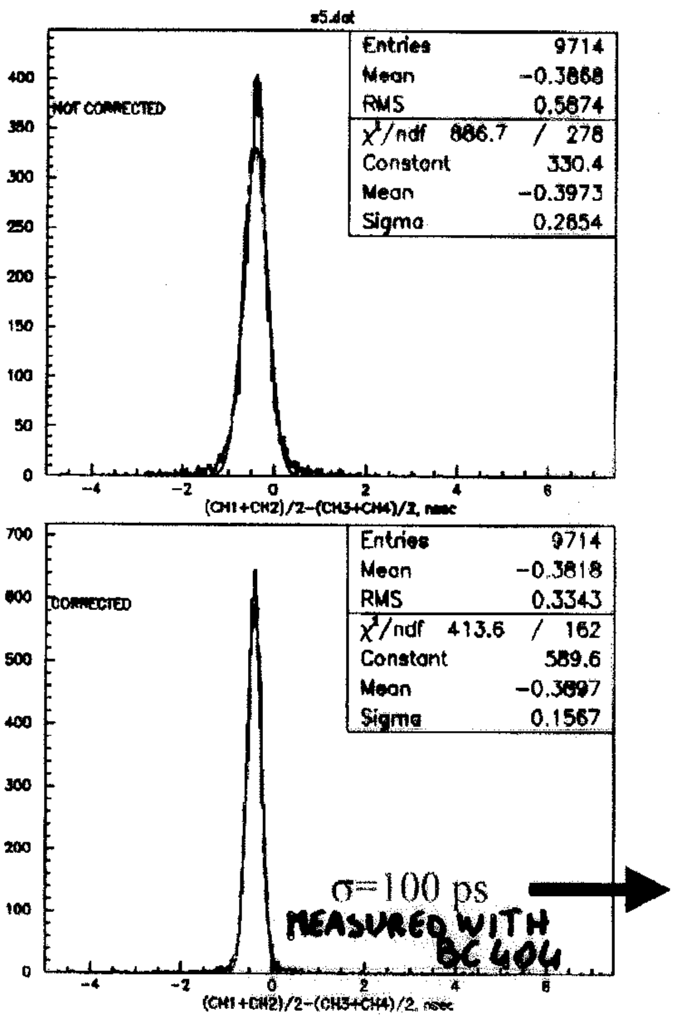
see next
about 75 KEuros (+HARP)

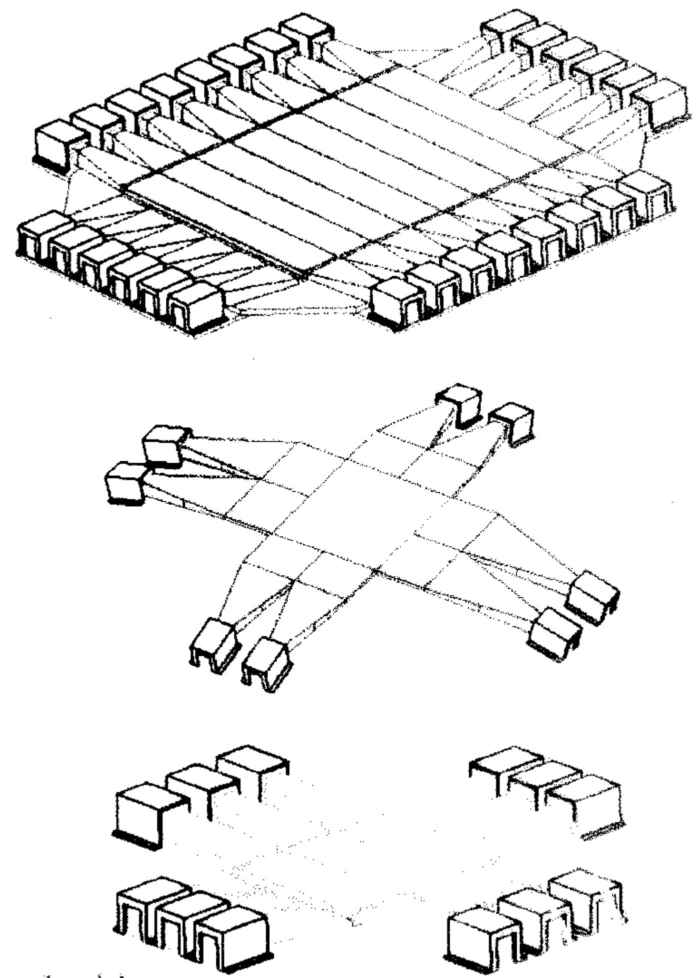
Alternative: ultra-fast Cherenkov radiators
(Fermilab)

see next
about 100 K$

PAMELA TOF SYSTEM

40x4x0.7 cm^3 BC408 slabs





Can be improved with:

- Thicker slabs (0.7 → 2.5 cm)
- Faster plastic (BC408 or BC420)
- Faster PMT (R5900 → R4998)

Published resolutions of TOF systems based on plastic scintillators of similar dimensions

Exp.	Dimensions (cm)	Plastic	PMT	Resolution (ps)
BESS	$95 \times 10 \times 2$	BC-408	R6504s	50
ISOMAX	$10 \times 2 \times 1$	BC-420	R2083	47
NA49	$8 \times 3.4 \times 2.5$	BC-408	XP2972	59
NA49	$48 \times 2.4 \times 2.5$	BC-408	R3478	70
NA52	$10 \times 1 \times 1$	NE110	XP2020	90

Ultra-High Precision TOF Detector based on Cerenkov Radiators
(A.Bross, Fermilab)

MgF2 Cerenkov radiator **disk perpendicular to the beam.**

CsI photocathode deposited on the back side of the MgF2 radiator.

Micro-channel plate (MCP) or micro-sphere plate structure amplifies up to 10^ 7.

Anode structure with a 50 Ohm output connector maintains pulse fidelity.

For a **2 mm thick** radiator, expect a signal of 30-40 pe.

Preliminary measurements with the first detector head (33 mm diameter)

very good pulse response.
single pe initiated pulses rise time 300 ps
rise time jitter between 15 and 30 ps
In the initial phases of this work we have used

plan to test a **superconducting TDC** (4 ps least count)

for ICE, use a mosaic of micro channel plates for coverage
anode segmentation ie # of TDC's will follow from backgrounds rate

(commercially available) general purpose MCPs drive costs, about $25 USD/cm^^2

(75 K$ for 30 cm diameter)

adequate for a 30 ps timing resolution

Note on μ–ID

TOF adequate if beam clean
if not (RAL π/μ ~ several 10%?)

…dedicated Cerenkov system (Mississipi)

+ redundancy desirable …

PROGRESS on MC SIMULATION of PID

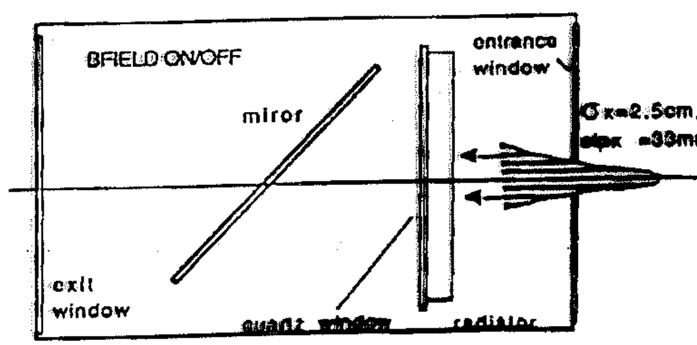
L.Cremaldi, P.Rubinov, D. Summers

U.MISSISSIPPI 5-15-99

4x

- MUCOOL GEANT PID Simulation

1/2 mm - entrance window
1.00cm - fc-72 Cv radiator
1/2 mm - quartz window
30 cm - He gap
1/2 mm - glass mirror
1/2 mm - exit window



- P_{inc} = 180 MeV π, μ, e (No decays)
- n = 1.244 ΔZ=1CM OF C6F14 (FC72)
- Features:

-dλ/λ² spectrum
-chromatic dispersion
-1/2 PE noise
-Q(λ) PMT quantum efficiency
-T(λ) quartz transmission

- <NPe>= 0.5/cm π

<NPe>= 18/cm μ $\varepsilon_\mu \approx .98 \rightarrow r_e^{misid} \approx 4\times10^{-3}$, $r_\pi^{misid} < 10^{-5}$

<NPe>= 45/cm e

- NEAR FUTURE- DECAYS IN FLIGHT
REFINEMENT OF CONSTANTS

Detector Solenoids

L >≅ **1 full turn** of helix, at typical muon momenta

(1 m for 200 MeV/v at 3 T)

L + 2 D for uniformity …. **2 meters or so**

NB uniformity non crucial
(1% ok, mostly CPU wise)

diameter D

single coil …….. take signals out
.. bend radius ~100 fiber radius
bore D up to **600 mm**
J. M. Rey

split coils, feedtroughs ?

bore of somewhat smaller D

Stray fields ….. flux return, in fact !!!

Lab safety

Readout (PMT's …..

open ……

Tracking in the solenoids

>3 stations for x, θ, P

as thin as possible $\theta_{MS}/\theta_{COOL} \leq 10\%$
min X-ray conversion
0.4 % X_0 ~ 1.5 mm plastic Sci
(last plane!)

fast (well below 100 ns)

robust to RF X-rays (major scare !!!!!)

two options in LOI

1D (SciFi)

MUSCAT like SciFi's (multiplex)
+MAPMT's ~700 K$
see E. Mc Kigney
(IC College, RAL, Trieste)

D0 like SciFi's
+VLPC's ~1000 K$
see A. Bross (Fermilab)

2D (pixels) at least station closest to RF?
500 μm, 300 μm thick
ALICE-like (P. Jarron) ~1400 K$
... not quite mature yet ...
(Geneva, ETH, Strasbourg)

+ recently TPG (TPC+GEM) being revisited
see U. Gastaldi

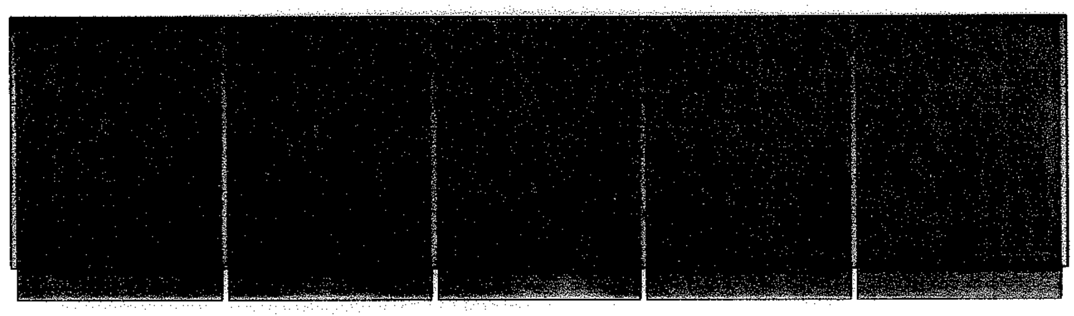
ALICE pixel ladder

⇒*ALICE silicon pixel ladder*

⇒*Consists of 5 readout chips bumped on a silicon detector of 70,72 mm x 16,8mm*

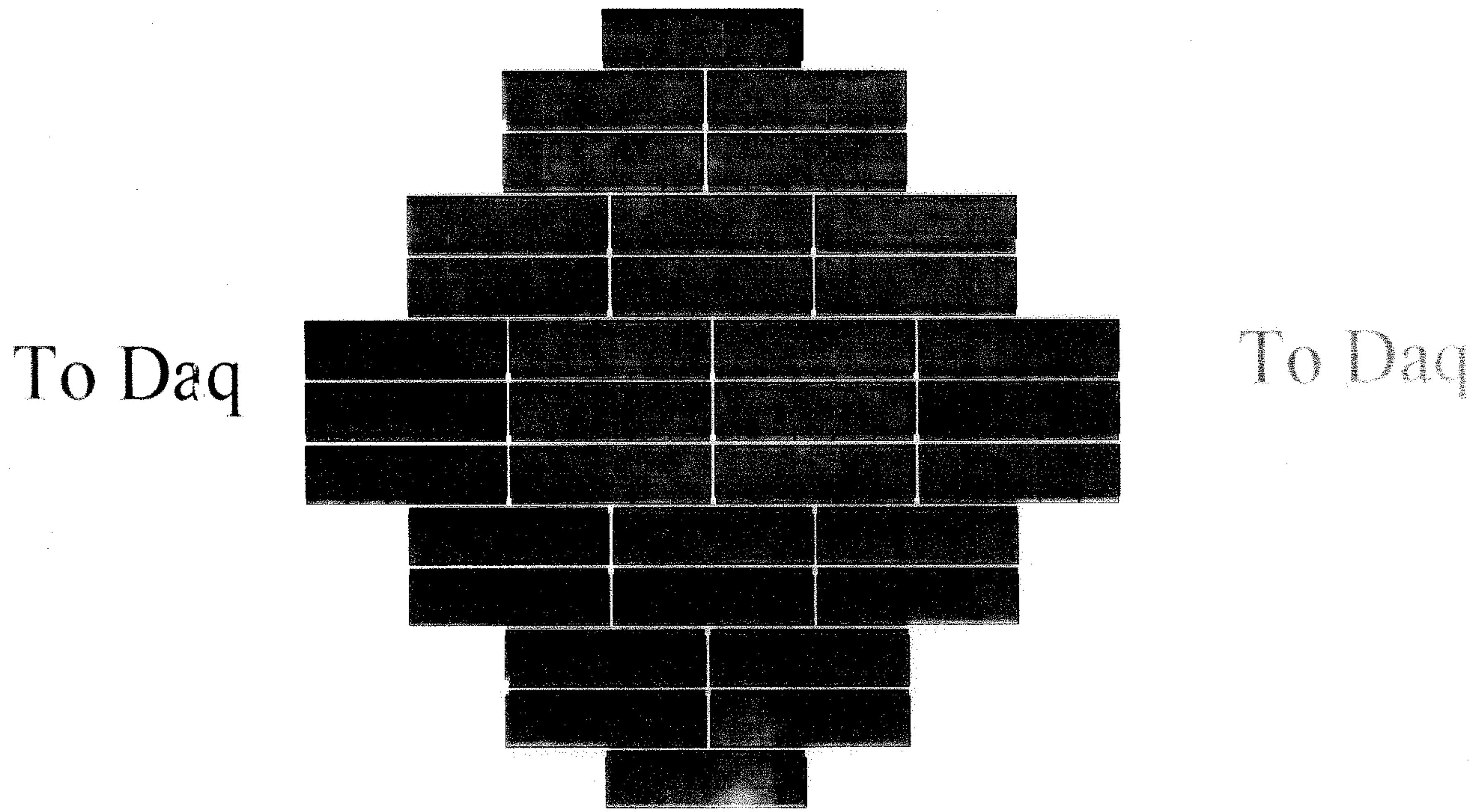
⇒*detector thickness: 150 micron - thinned*

⇒*chip thickness :200 micron - thinned*



Octagonal construction

based on ALICE pixel Stave : diameter 29 cm



Conclusions

- **3 solutions of Muon Cooling Project tracking system**
  - ALICE pixel based
    - **ready made solution no development**
    - **thick: not the best for minimum radiation length and X-ray rejection**
    - **20 % dead area**
  - MCM-D ALICE based
    - **100% full coverage**
    - **uncertain technology development**
    - **thick: not the best for minimum radiation length and X-ray rejection**
  - A-Si:H layer on VLSI wafer
    - **the best possible X-ray rejection**
    - **offers the hardest detector**
    - **technology not mature**
  - RF cavity test
    - **Proposal to use MEDIPIX (already used for CLIC test)**
      - Contact M. Campbell, B. Mikulec EP-MIC-FE

e- identification

needed

can use $\langle P_\mu \rangle > \langle P_e \rangle$

$\langle \theta_\mu \rangle < \langle \theta_e \rangle$

$\langle \chi^2_\mu \rangle < \langle \chi^2_e \rangle$

but ~ 20 % e survive

size

$\sigma_\mu \sim \sigma_e \sim$ **60 mm at the end**

Cerenkov (~.1 %)

viable … low β_e **… low c/n …**

… but β_μ **stays below it**

n-1 = 0.005 already ok (1-3 m)

(Greece, Trieste) *Louvain*

Pb-Sci em calo (<1%)

also viable … long. & transv. profiles

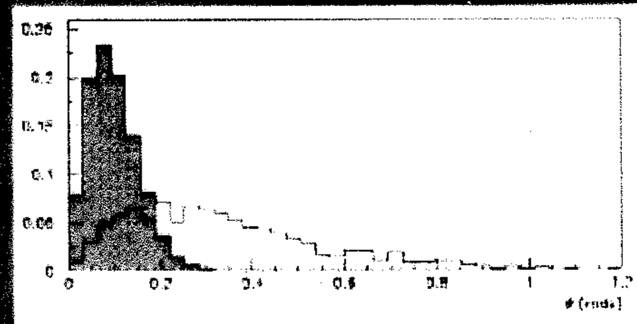
… deposit

(Rome)

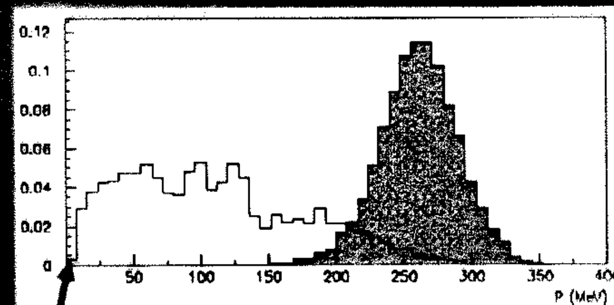
30-50 K$ for either device

Identification strategy

- Particle properties as obtained by P.Janot fast simulation
  - Simulation features as described on Thursday 25th
  - ~10000 muons
  - ~4000 electrons
- Kinematical properties
  - Transverse position distribution $\sigma x \approx \sigma y \approx 6$ cm
  - Momentum and direction from the fast simulation (P.Janot)



- Electron and muon spectra
  - Due to the big mass difference, beta for muon and electrons is not overlapping
  - → A threshold cherenkov detector seems appropriate



Electron identification

- Detector response
  - Quantum Efficiency QE=15%
  - Collection efficiency 80%
  - Poisson fluctuations
- Scan of refractive indices
  - $(n-1) = 10^{-4} \rightarrow 10^{-1}$
  - Corresponding to gaseous radiators
    - Nitrogen taken as a reference

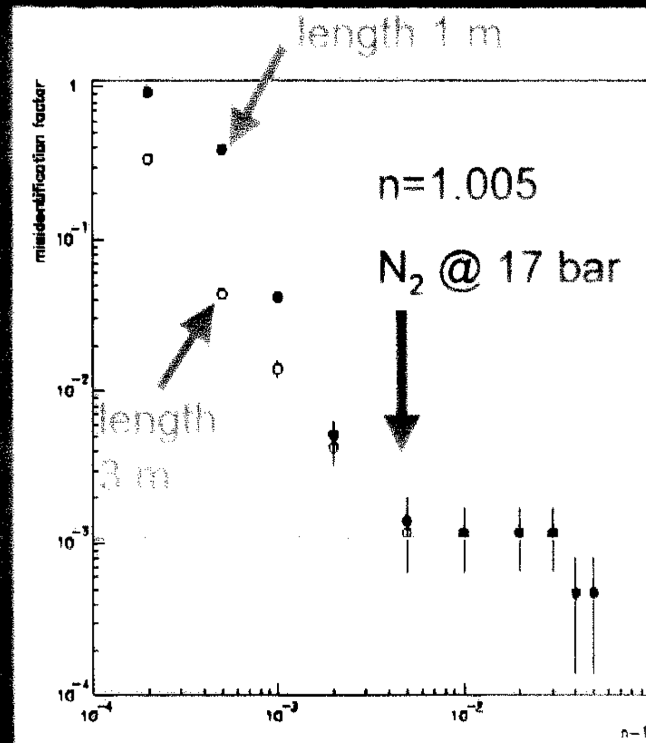
Muons have an effective threshold of n=1.06

- Ckov effect negligible for most of the points

Electrons vary from a few photoelectrons (@ low n) up to about 1 thousand of ph.el. (@ n=1.1)

Electron identification

→ Detection of >= 3 ph.el

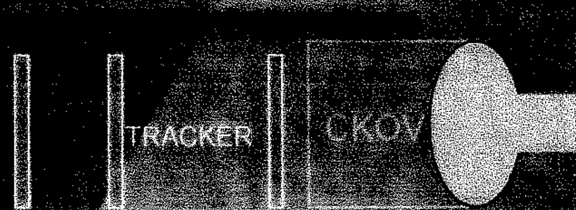


electrons mis-identification probability

Some design ideas

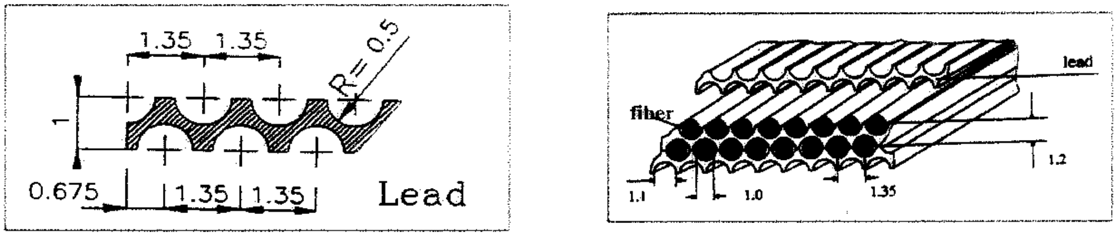
- Just after the channel
  - after the TOF

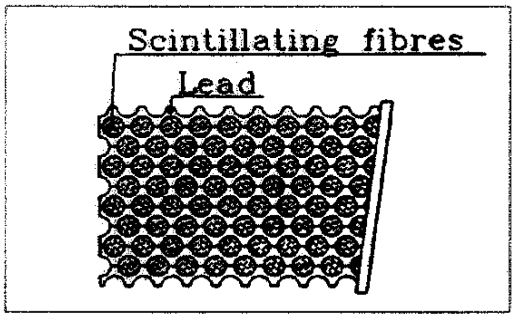
- One Phototube option



- Inside the channel?
  - Before the TOF

electromagnetic calo





Density ≈ 5 g/cm^3

Sampling fraction for mip ≈ 15%

Radiation length ≈ 1.5 cm

Fig. a : The Construction Technique of KLOE EmCal

e/μ separation from range/profiles & deposit
48cm*48cm 16 cm thick (full containment)

Pb-SciFi (1mm) a la KLOE

deposit linear with kin. energy
1 mip = μ = 27 MeV electron

can tell e, if not too soft
up to 300 MeV or so

expect <1% e survival

Bari

DAQ, rates etc (at PSI)

50 MHz p from cyclotron $< 5\ 10^7$ p/s

run at .1 μ/p

RF-on duty cycle ~ $5\ 10^{-3}$

a) 100 μs live @ 50 Hz
b) 500 μs live @ 10 Hz

~20% μ "in time" with Rf
~20% μ within channel

< 1000 "events"/sec

~1% on $\frac{\varepsilon_{final}}{\varepsilon_{in}}$ in seconds

~.1% in minutes

DAQ... continued

nost data from trackers

multiplexed MUSCAT option
0.5 Kbytes/event

⇒ **present design**
(6 VME crates, event-building
over switched Gbit-Etherne Network)
can take up to 10^5 events/sec

.. quite a margin ...

TDC's, ADC's add little

but buffers limited, favour 100 μs live @ 50 Hz

100 K$ for computer cluster
220 K$ for readout hardware

... rent? ... re-use? ...

No road stoppers in sight

Conclusion

baseline detector scheme exists

with few alternatives and variants

X-ray answers eagerly expected

revisit .... while deciding

host beam
background condition
solenoid design
stray B fields
....

not a driving cost ... 1200-1900$ or €