MuScat2: Ionisation cooling demo?

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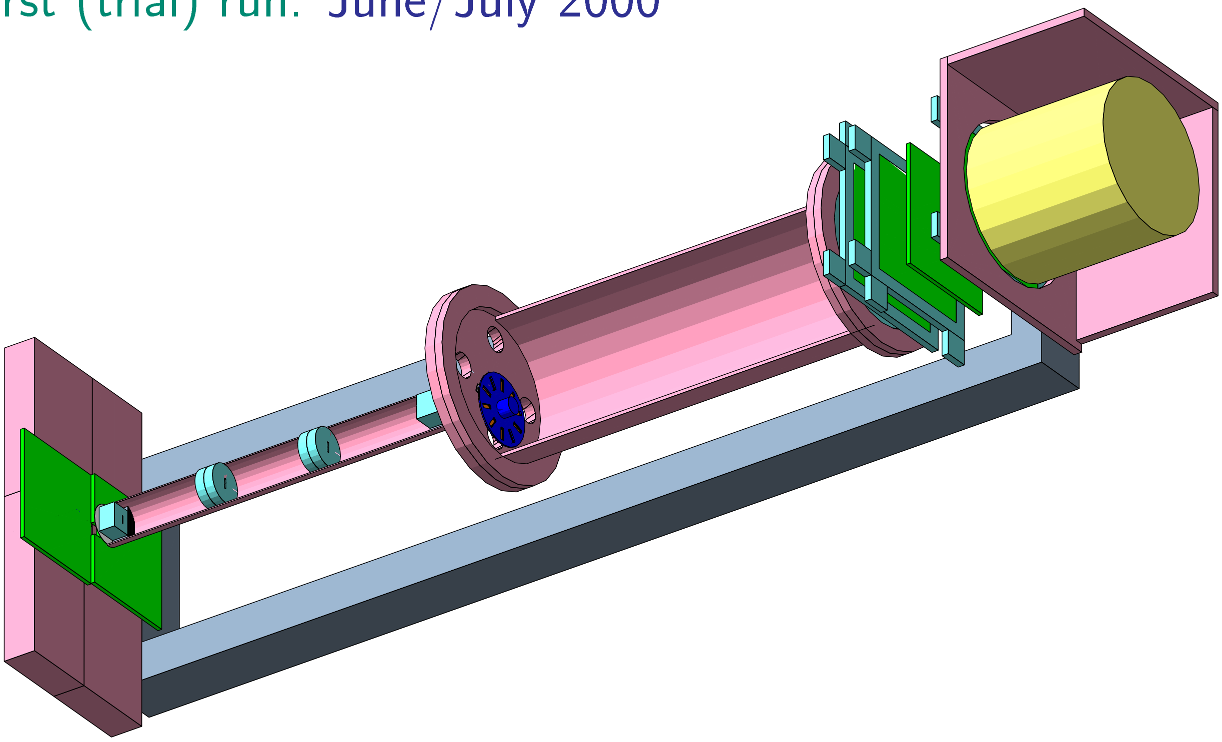
- Introduction
- Method
- Experiment and beam line
- Possible measurements
- HIMF
- Conclusions

Introduction

- MuScat: measure muon multiple scattering from
  150 to ∼200 MeV/c
- First (trial) run: June/July 2000



- Main problem: Delay-line chambers

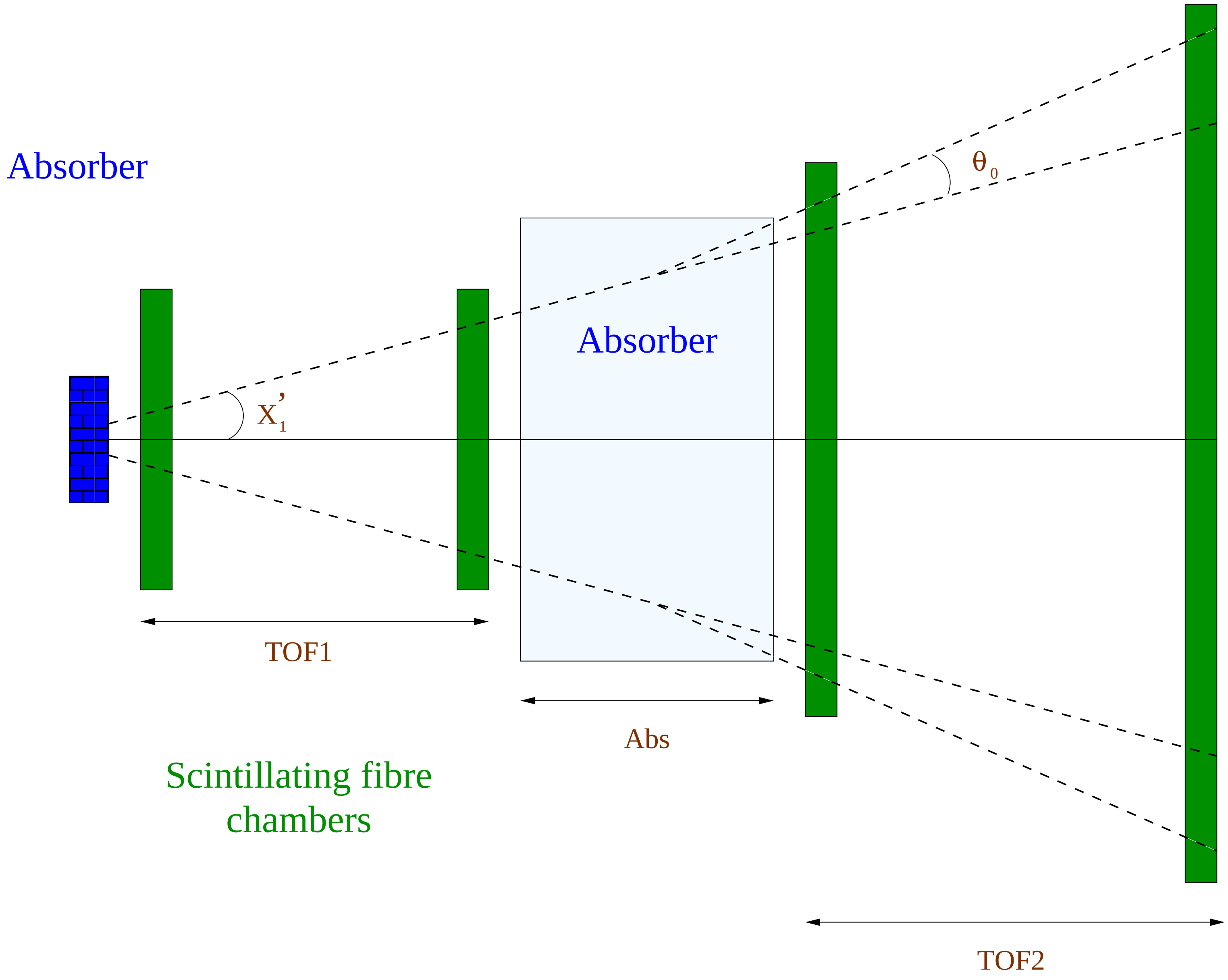
  $\Longrightarrow$ replace with scintillating fibres (Ed McKigney)

  $\sigma_x \sim 200\mu$m

  $\sigma_t \sim 150$ps

- MuScat2: cooling principle demo

Schematic of the detector



Method

- Normalised 2-d transverse emittance:

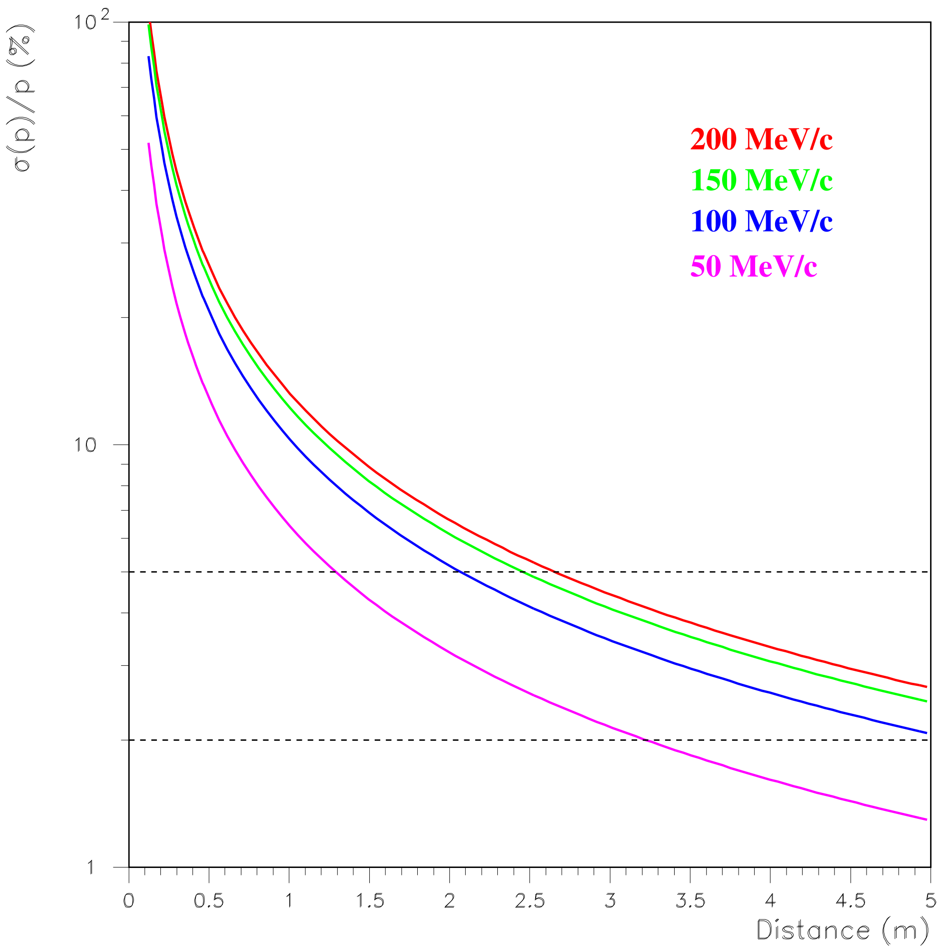
$$\epsilon_N^2 = \frac{1}{m_\mu^2 c^2}\left(\langle x^2\rangle\langle p_x^2\rangle - \langle x p_x\rangle^2\right)$$

- In a single particle experiment, looking for change in "emittance", i.e. effectively a change in X'

- Easy to do, but resolution important

- Momentum:

$\sigma_p \sim 2 - 5\%$
at 100 MeV/c



- Position: negligible in comparison

Detector requirements

- Cooling must be bigger than heating $+ 5 \times$ error

$$\Longrightarrow \text{minimum } X_1'$$

- If

$$\text{“raw” cooling} = \frac{\Delta(\beta\gamma)}{\beta\gamma}$$

$$\text{heating} = \theta_0 \text{ (rms)}$$

then

$$\epsilon_2 = \epsilon_1 \frac{(\beta\gamma)_2}{(\beta\gamma)_1} + \text{heating}$$

$$X_2' = X_1' \frac{(\beta\gamma)_2}{(\beta\gamma)_1} + \theta_0$$

- Now

$$X_2' = X_1' - \underset{\uparrow}{20} \text{ mrad to measure cooling}$$

$\sim 5\times$ contribution from
3% momentum measurement

$\Rightarrow$ $$X_1'(\text{min}) = \frac{(\beta\gamma)_1}{\Delta(\beta\gamma)}(\theta_0 + 20) \text{ (rms)}$$

- Note: (1) beam size $= 4 \times X_1'$
  (2) $(\beta\gamma)_1 \longrightarrow$ TOF1 length
  (2) $(\beta\gamma)_2 \longrightarrow$ TOF2 length

Some examples

p_1 MeV/c	TOF$_1$ (3%; 100ps)	Abs cm	p_2 MeV/c	TOF$_2$ m	Heating mrad	Cooling %	X_1' mrad	Width m
100	2	70	39	1	56	80	95	1.4
100	2	40	70	1.4	42	47	132	2.0
200	3.5	40	186	3.3	16.5	10.4	351	10.1(!)

Conclusions: $>$ 100 MeV/c difficult/out of the question!

$\leq$ 100 MeV/c also difficult - large detectors and absorbers - but may be possible

Further study required

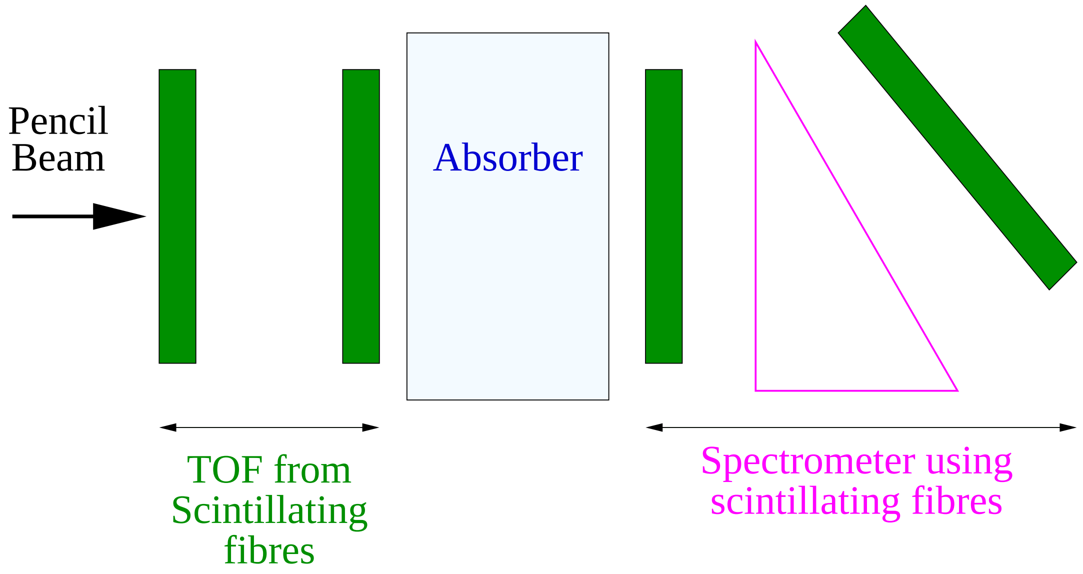
Another possibility - Straggling

- Need: 1% momentum measurement
- Need: "flat" Bethe-Bloch region
- Need: "medium" length absorber to have a measurable effect but "constant" dE/dx

p (MeV/c)	E_{kin} (MeV)	ΔE/cm (MeV/cm)
200	120.0	0.30
150	78.0	0.35
100	39.0	0.47
50	11.0	1.08
20	1.9	4.68

straggling of a few percent

- Possible detector:



- Further optimisation required

HIMF - High Intensity Muon Facility

- Protons from ISIS: 1 bunch in 50

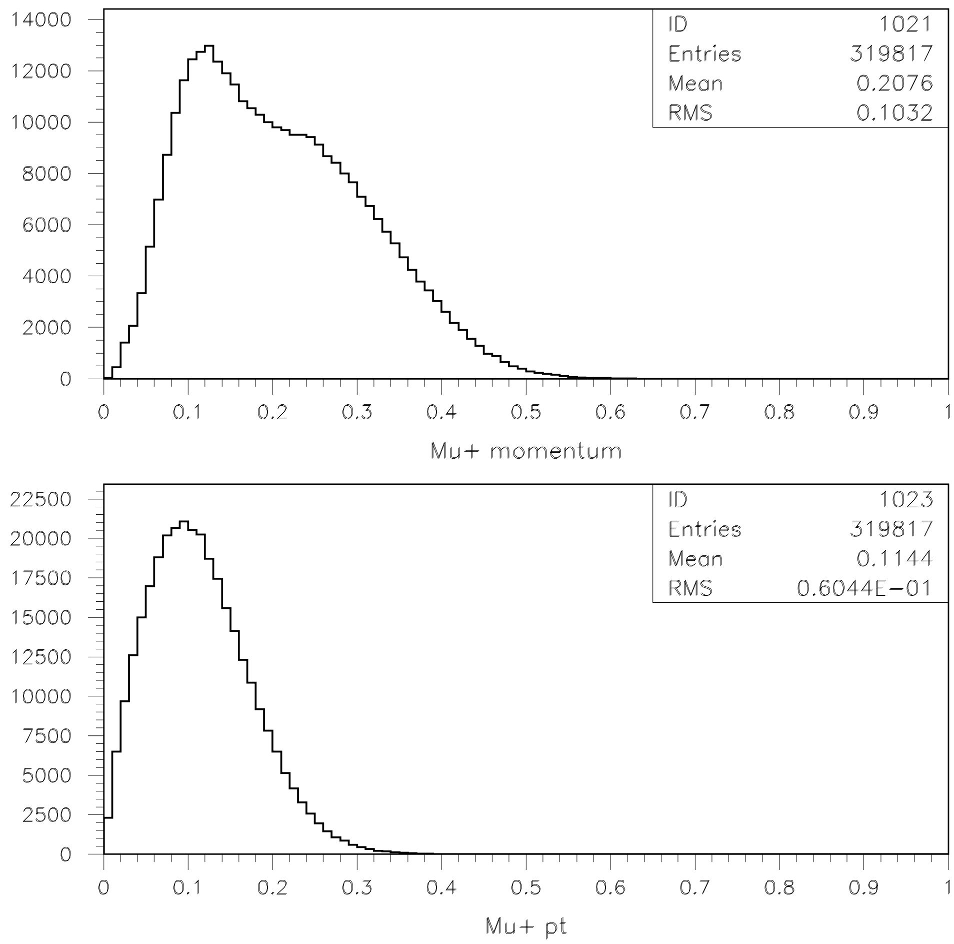
  $= 2.5 \times 10^{13}$ p/s at 800 MeV/100ns bunch

- But: simulations by Chris Prior show it is possible to compress bunch length to ~7ns with 50% of intensity - tested

  $\Longrightarrow 10^{13}$ p/s in 7ns bunch

- Pion and muon production simulated with MARS:

  carbon target 10cm long, 2cm radius; 7.5m decay length



For 10^7 protons $\Rightarrow$ 0.03 μ/p

$\Longrightarrow 3 \times 10^{11}$ μ/s

- Assume: can catch 25% of pions and all decay muons with $p_l > 0.$ and $p_t < 120.$ MeV/c

- Muon rate/s in $\pm$1% momentum bins:

Momentum bin (MeV/c)	Muon rate/s $\times 10^8$
50	1.0
100	3.3
150	4.5
186	3.5
200	3.5
250	2.1
300	5.3
350	3.8
400	2.3

$\Longrightarrow$ many muons possible!!

- Additional advantage: beam in large experimental hall

- Funding being investigated - international support required!

Potential HIMF Hall

Conclusions

- A cooling demonstration experiment using scintillating fibre detectors for momentum and position measurement is difficult, but not impossible
- If it's useful, a straggling measurement is easier
- ISIS can be used to make proton bunches of ~7ns length with 10^{13} protons per bunch
- This gives muon bunches with $\pm 1\%$ momentum spread and $\sim 10^{8}$ muons per bunch
- A large experimental hall is available for:
    - o Target tests
    - o Capture tests
    - o A cooling experiment
- Sources of funding are being investigated
- Support is required!