About a circular μ-beam test facility

Bruno AUTIN, CERN

1. Introduction
2. Injection
3. Accumulation
4. Phase rotation
5. Transverse cooling
6. Final remarks

Introduction

Linear vs Circular scheme

- Large acceptance
- Good transmission
- Accumulation
- Efficient use of components

Experience with μ - rings:

- g - 2 (CERN, BNL)
- conceptual studies for PRISM and FFAG machines

Injection

CERN g-2 scheme

" The perturbation, essential for injection into any circular machine, is here achieved by the shrinking of the orbits arising from the change of momentum in $\pi \to \mu$ decay and/or by the change in angle at the decay point which may result in a μ^- with smaller oscillation amplitude than its parent π^-.
The muons injected by this process are forward polarized on average.

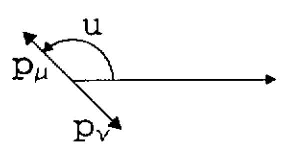
A pulsed magnetic horn was used around the target during part of the experiment to increase the forward π^- flux."

Novelty for a ν factory: FFAG ring instead of a weak focusing machine because of large acceptances.

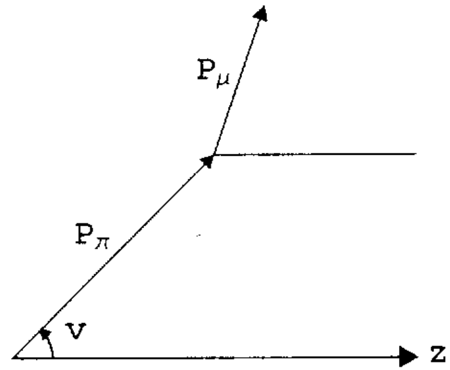
Decay process

$$\pi \rightarrow \mu + \nu$$

Center of Mass



Laboratory



Muon Energy-Momentum Vector

■ Center of mass

$$e_\mu = \frac{m_\pi^2 + m_\mu^2}{2\, m_\pi} = 109.778 \text{ MeV}$$

$$p_\mu = \frac{m_\pi^2 - m_\mu^2}{2\, m_\pi} = 29.7899 \text{ MeV/c}$$

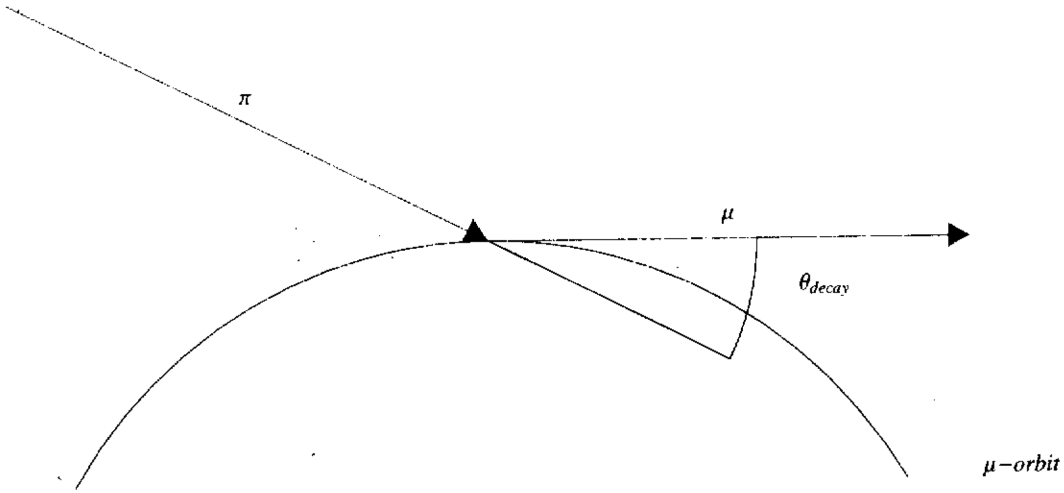
$$v_{\mu 0} = \begin{pmatrix} e_\mu \\ p_\mu \cos(u) \\ p_\mu \sin(u) \end{pmatrix}$$

■ Laboratory

$$v_\mu = \frac{1}{m_\pi} \begin{pmatrix} e_\pi\, e_\mu + \cos(u - v)\, p_\pi\, p_\mu \\ \cos(v)\, e_\mu\, p_\pi + (\cos(2\,v - u)\,(e_\pi - m_\pi)\, p_\mu + \cos(u)\,(e_\pi + m_\pi))\, \frac{p_\mu}{2} \\ \sin(v)\, e_\mu\, p_\pi + (\sin(2\,v - u)\,(e_\pi - m_\pi)\, p_\mu + \sin(u)\,(e_\pi + m_\pi))\, \frac{p_\mu}{2} \end{pmatrix}$$

Muon Storage

■ Elementary process



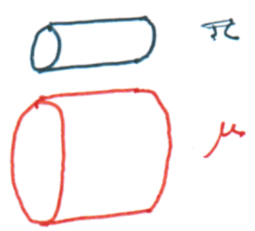
$$p_\mu = \sqrt{v_{\mu 1}{}^2 - m_\mu{}^2} \qquad \theta_{\text{decay}} = v_{\mu 3} \,/\, v_{\mu 2}$$

Accumulation

Non Liouvillian injection allows

increase of phase space density or accumulation

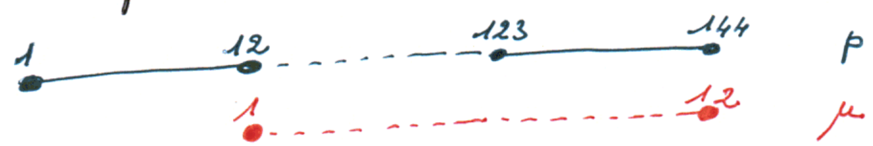
Configuration of π and μ bunches at the origin of the ring (end of target)



Constraints :

- μ - ring circumference multiple of p - bunch spacing
- Isochronicity ?

Time compression :



A good feature for a muon collider

For a ν factory, azimuthal stacking of several beams.

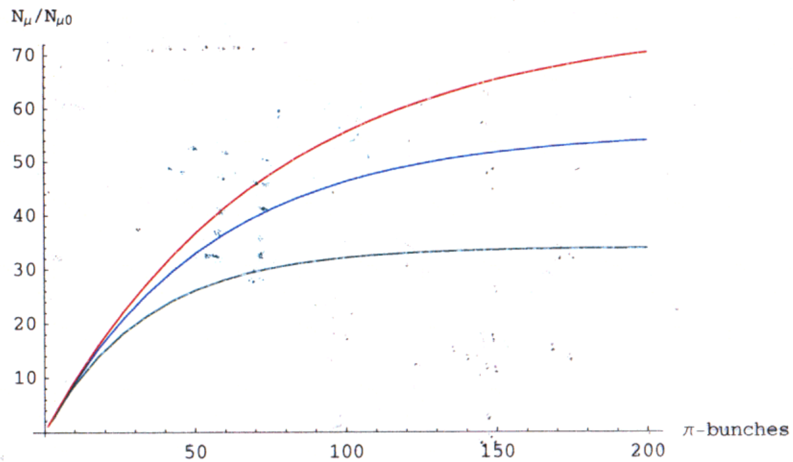
Competition with μ decay : →

■ Accumulation factor

After N injections of π bunches separated by the distance L

$$N_\mu / N_{\mu 0} = e^{-kL} \frac{e^{-NkL} - 1}{e^{-kL} - 1}$$

$$k = \frac{m_\pi}{p_\pi \Lambda_\mu}; \quad L = 32\,\text{m}; \quad T_\pi\,[\text{MeV}] = \{100,\ 200,\ 300\}$$



Phase rotation

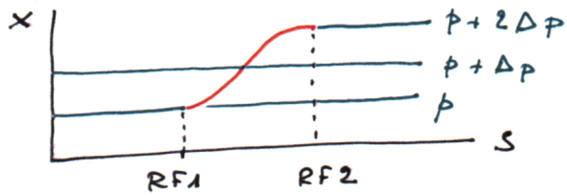
PRISM simulations show that non linearities of phase rotation depend more on RF wave ($h=1, 5$) than on particle kinematics.

However, much larger corrections of energy are needed for a ν - factory.

Constraints:

The RF kicks must not increase ϵ_h

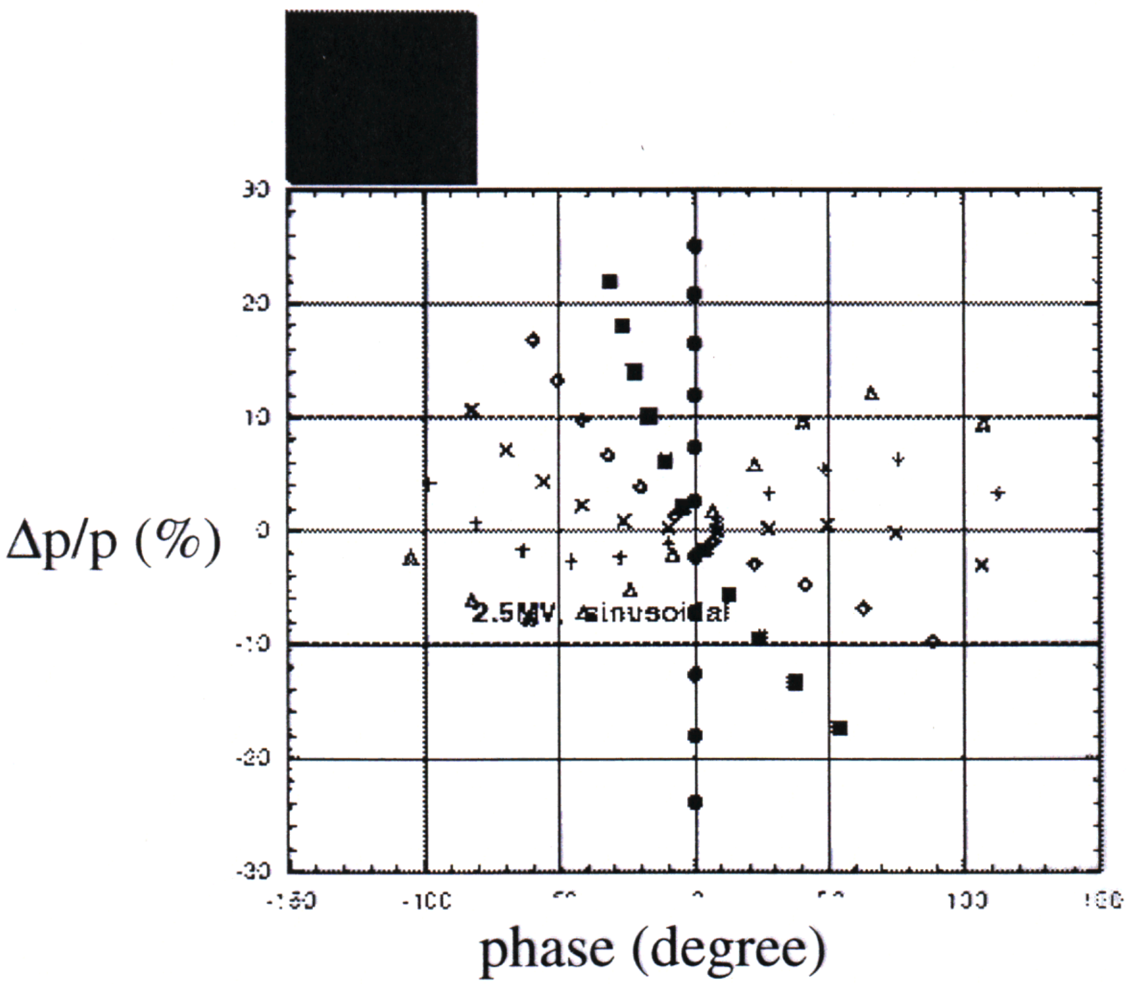
1. RF cavities in zero - dispersion
   How to maintain $D=0$ for $\frac{\Delta p}{p} \sim \pm 50\%$
   Extra space for D-suppressors.
2. Phase shift between cavities $\sim \pi$



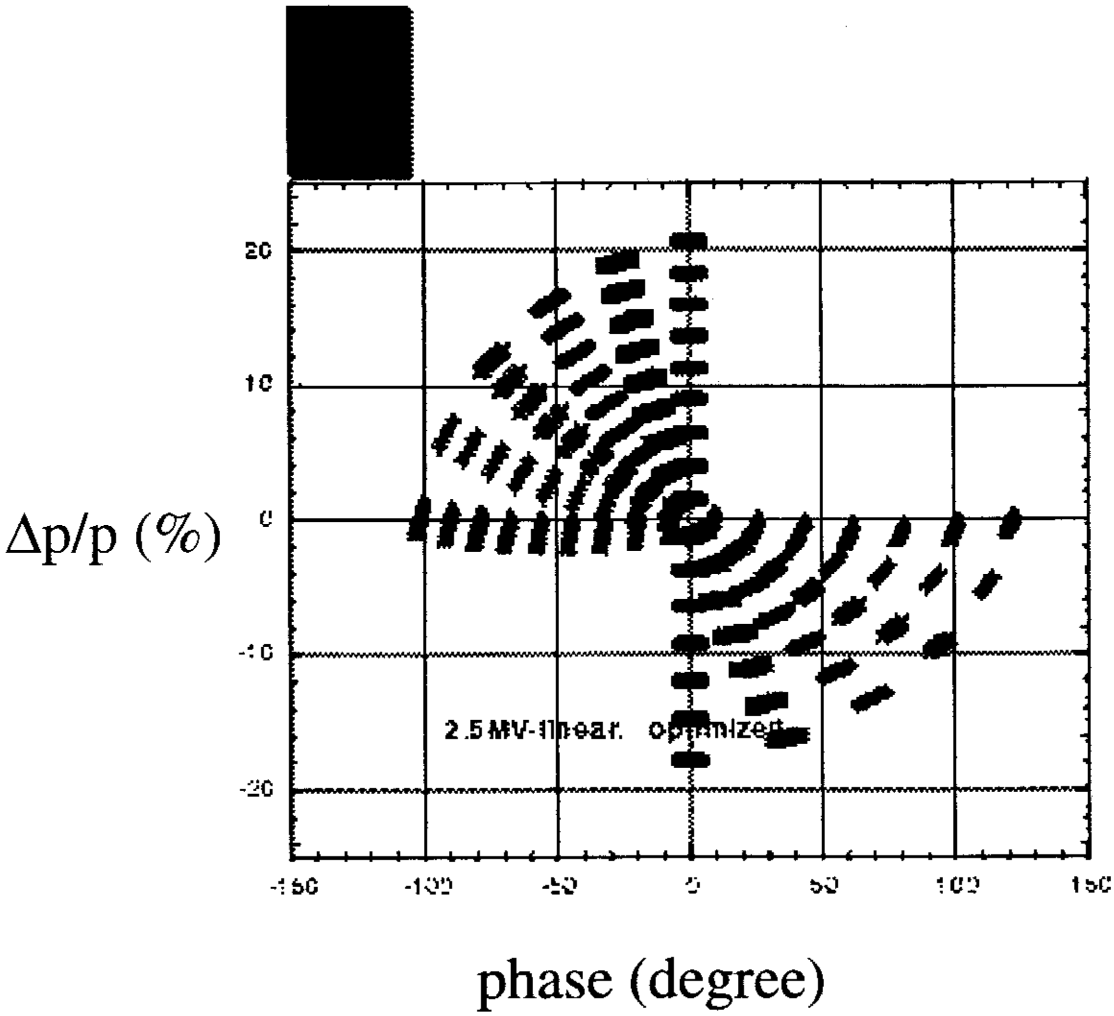
$\Delta\mu \sim \pi$ for large $\Delta p/p$ may be satisfied by the zero chromaticity condition

Phase Rotation Simulation at FFAG(1)

- non-linear relation on energy vs. time at low energy
- in case of sin-wave rf
  - *after 5 turns*



Phase Rotation Simulation at FFAG (2)



Technical Challenges of Neutrino Factories

Bruno Autin, CERN

Introduction

Neutrino flux depends on

Muon intensity I_μ:	10^{21} integrated $< I_\mu < 10^{22}$ per year (10^7s)
Muon energy E_μ:	10 GeV $< E_\mu <$ 50 GeV
but almost not on muon beam divergence:	$\delta\theta_\mu << \gamma_\nu^{-1}$

Transverse cooling

The interaction of the π's with the absorbers may be a problem. If so,

1. Permanent absorber just before the target

or 2. "Rain" of LH_2 using CELSIUS technique adapted to μ-bunches.

<u>Schemes to be studied:</u>

a. Simultaneous phase rotation and cooling

b. Cooling after phase rotation

<u>Observation of cooling</u>: beam profile measurement after 1 turn, 2 turns, ..., n turns.

<u>Typical ring</u>

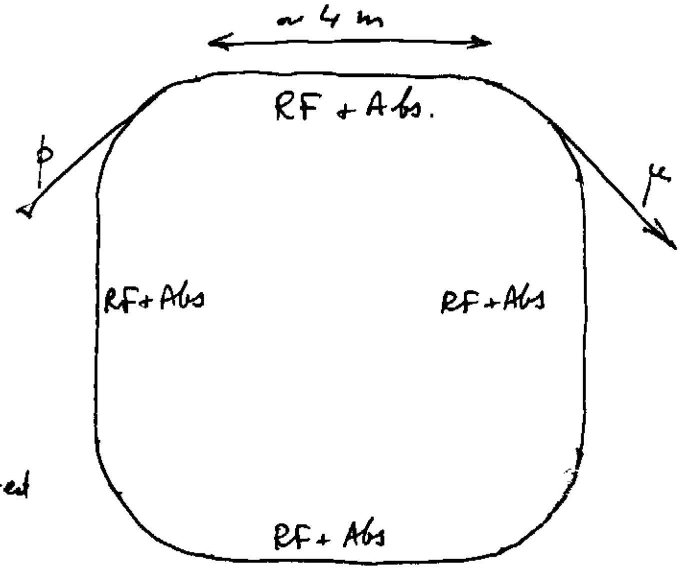
Circumference: 32 m

E_{in} = 100 – 300 MeV

FFAG

A. Lombardi's approach to phase rotation and cooling adapted to a ring (to be proven!)

$\Delta E \sim 8$ MeV/turn



Final remarks

1. Can FFAG's match the various constraints on:
   - acceptances
   - isochronicity
   - chromaticity ?

2. How many muons can be stored?

3. If answers to 1. and 2. are satisfactory, then the various manipulations needed in the front end of a ν - factory may be implemented with their technology and diagnostics in a rather economic way.