



ν STORM

Beam Instrumentation

First ideas

Lars Sjøby on behalf of the
CERN Beam Instrumentation Group

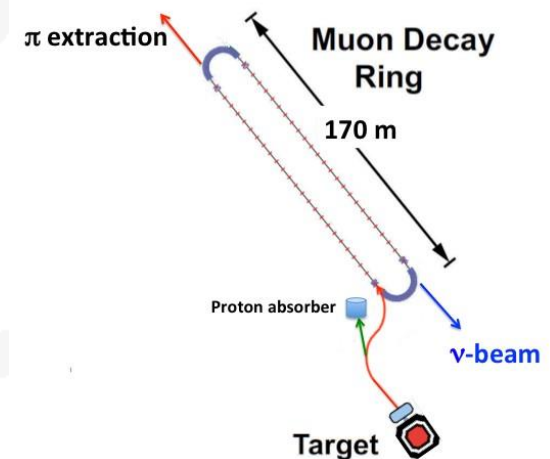
Overview

- **Specifications and beam parameters**
- **Beam observables:**
 - Intensity
 - Beam position
 - Beam profile
 - Tune
 - Beam loss
 - Energy
- **Summery**

Beam parameters

| Parameter | Value | Comments |
|-----------------|--------------|--------------------------|
| Muon energy | 3.8GeV | |
| Total intensity | 1 - 5E11? | Muon |
| Pulse length | 10.5 μ s | From SPS |
| Bunch frequency | 200MHz | Before injection |
| Nb of bunches | 233-2100? | Phase at injection? |
| Bunch length | 1-4ns? | Has to be simulated |
| Bunch intensity | 5E7-2E9? | More precise data needed |
| Rev. frequency | 851kHz | T = 1.17 μ s |
| Bunch current | 2-80mA ? | Injection scheme? |
| Average current | 14-68mA | At injection |
| Circumference | 350m | |
| Beam size | 30cm | Diameter |
| Aperture | 40-60cm | |
| Beam life time | 100 turns | |
| Vacuum | 10E-7 | |

1. Continuous multi turn (~9 turns) injection.
2. No RF
3. Injecting on top of circulation bunches **NOT** foreseen yet, i.e. 200MHz plus any frequency above is possible.
4. Structure in beam unknown for the moment



What is asked for

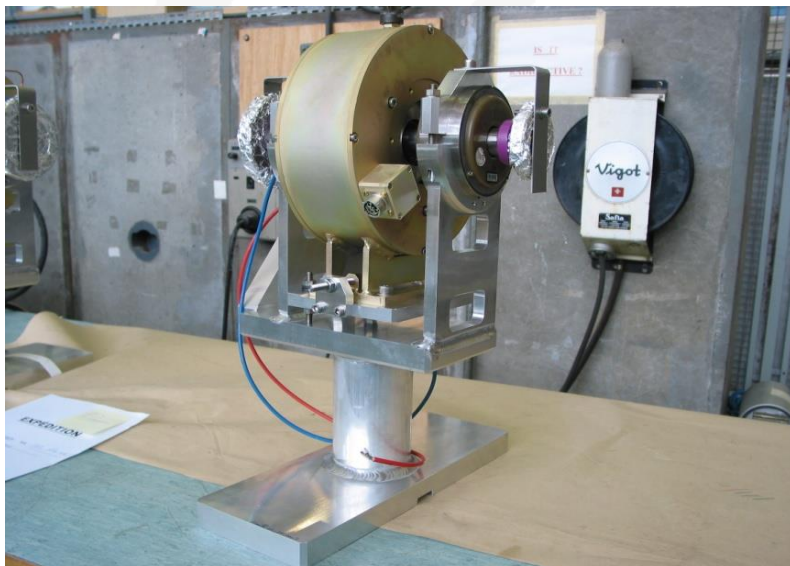
More complete specifications are needed 😊

| | Resolution | Accuracy | Quantity | Comments |
|---------------|------------|----------|----------|--------------------|
| Intensity | 0.1% | 1% | 1 | |
| Beam position | 1cm | ? | ? | |
| Beam profile | 1cm | ? | ~15 | Destructive is OK? |
| Tune | ? | ? | 1 | |
| Beam loss | ? | ? | ? | Ring tuning |
| Energy | ? | 1% | 1 | |
| Energy spread | ? | ? | 1 | |

- Turn by turn measurements are requested
- 1us time resolution? or synchronized to revolution frequency?

Intensity measurements

- L4 Beam Current Transformer

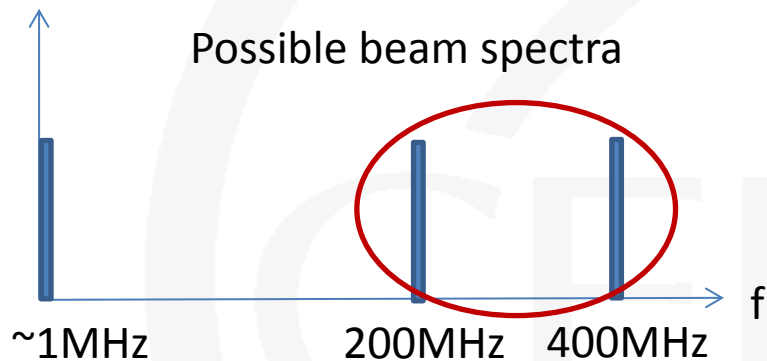


| Parameter | |
|---------------|---------------|
| Time constant | > 100ms |
| Bandwidth | 10MHz |
| Droop @ 500us | 0.5% |
| Resolution | ~10 μ A |
| Rise time | 35ns |
| Cost | 75kCHF |



LEIR Semi-fast BCT [100us/div]

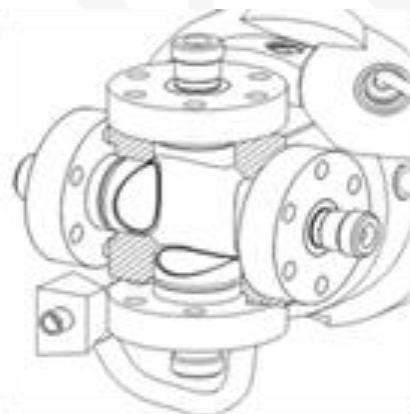
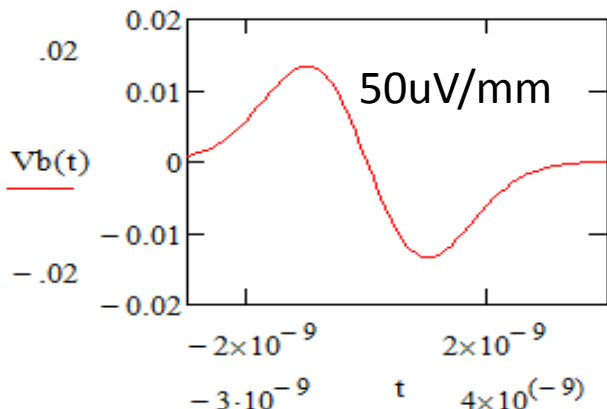
Beam position measurements



Button Pick-ups

- Simple design ☺
- Cheapest solution ☺
- Big buttons needed ☹

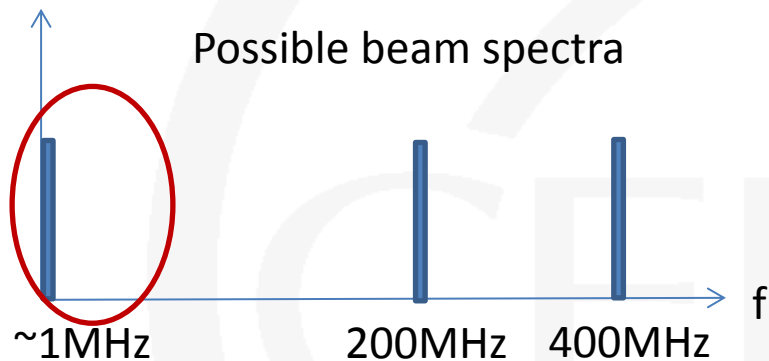
- Bunch length 4ns (4σ)
- Bunch intensity $5E8$
- BW=200MHz
- **Button diameter 10cm**



LHC buttons D=25mm

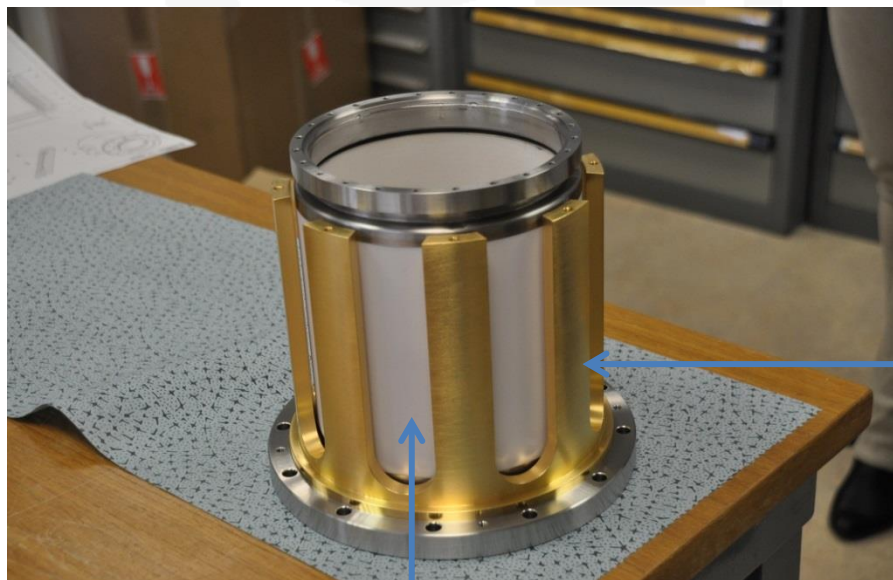
Single turn resolution $\sim 10\text{mm}$ with $S/N=10$
Cost $\sim 10\text{-}15\text{kCHF}$...depending on quantity

Beam position measurements



Inductive BPM

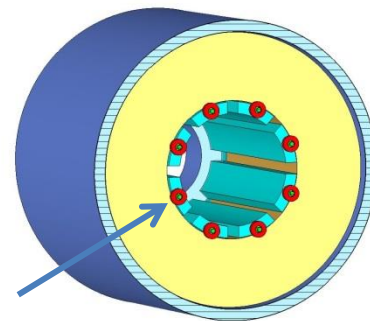
- Sensitive ☺, captures all image current
- Less sensitive to beam loss ☺
- Intensity measurement ☺
- Big ceramics, costly ☹



Ceramic chamber

$I_{\text{average}}=50\text{mA}$
 $N=25$
 $BW=200\text{MHz}$

$$R_T = \frac{V_{\Sigma}}{I_B} = \frac{R_S}{2n}$$



Electrodes

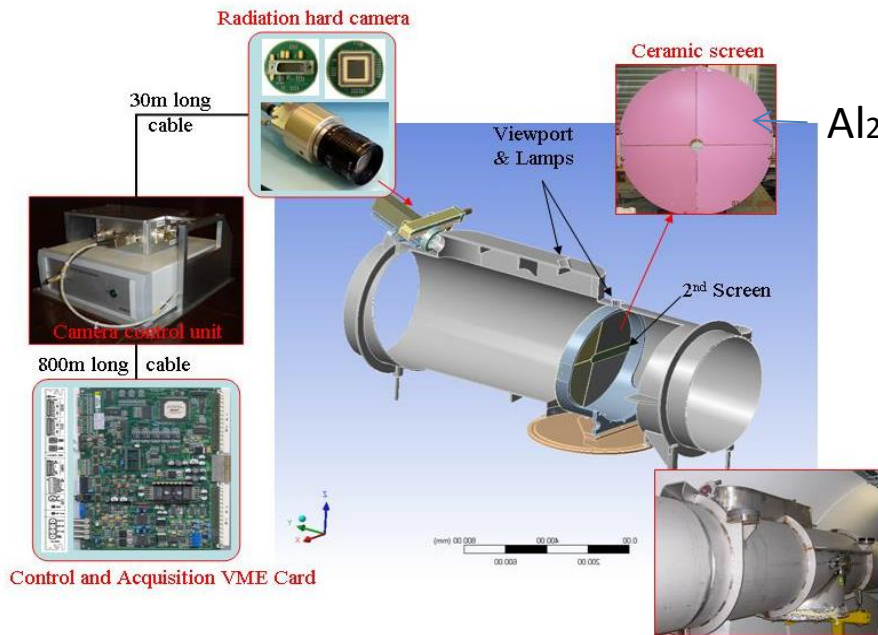
Current transformers

Single turn resolution $\sim 1.5\text{mm}$ with $S/N=10$
Cost $\sim 35\text{kCHF}$...depending on quantity

Profile measurements

- Only non destructive device is the Ionization Profile Monitor (IPM) but not enough time / intensity to ionize gas and obtain a profile.
- Other detectors based on ionization (MWPC, IC, GEM) are destructive (and complicated)
- No synchrotron light
- Wire scanners too slow
- **SEM strips and Scintillation screens are options**

A LARGE **FIXED** SCINTILLATING SCREEN FOR THE LHC DUMP LINE



Al₂O₃..CRO₂ screen

Standard CERN MTV system but In/out mechanism has to be added.

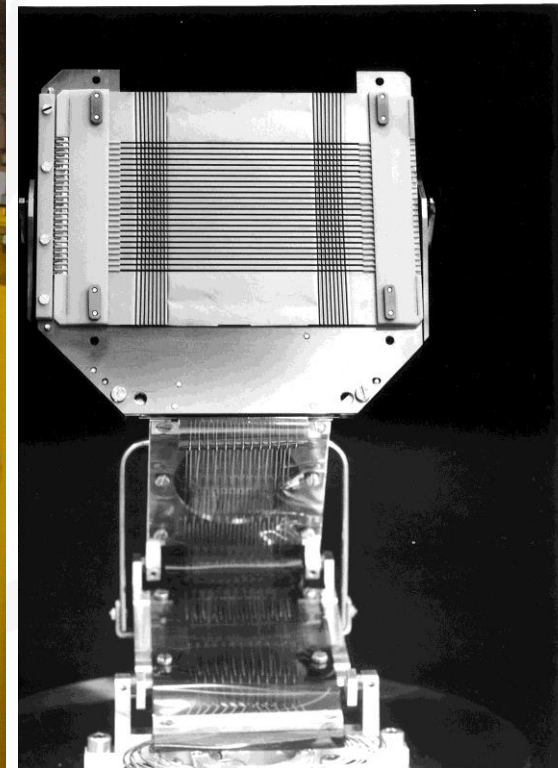
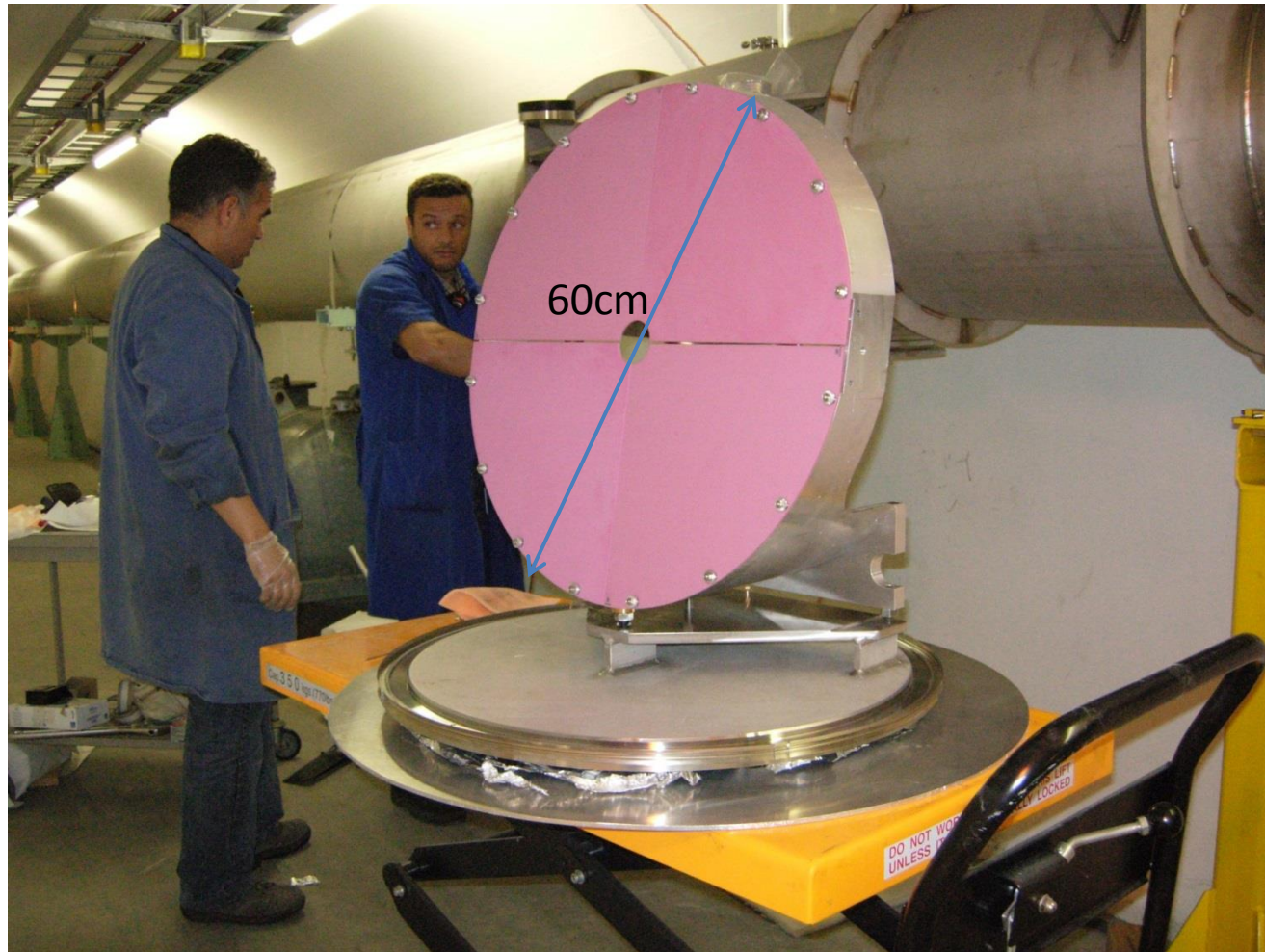
Cost ~50kCHF

Profile measurements

Power full in/out mechanism needed!

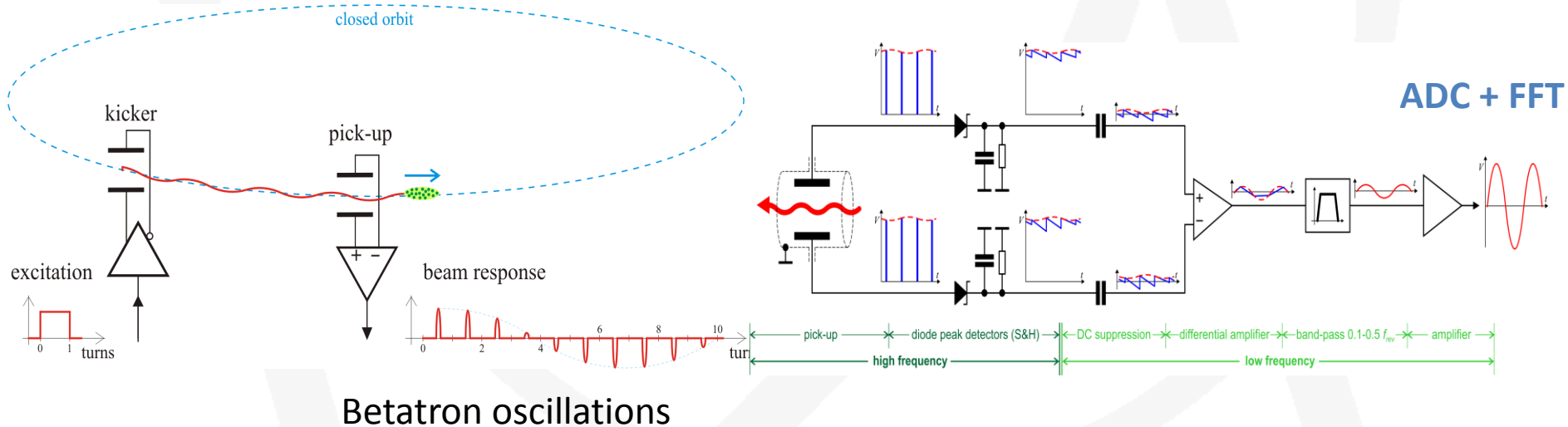
Resolutions of 1 cm is possible

SEM strips $L \sim 10\text{cm}$



Tune measurements

- Will use existing BPM(s)
- Based on known BBQ technique
- Required resolution? : Determines number of PU's needed.
- Excitation probably not needed (injection coherent oscillations)



Cost ~10kCHF

Ionization Chamber

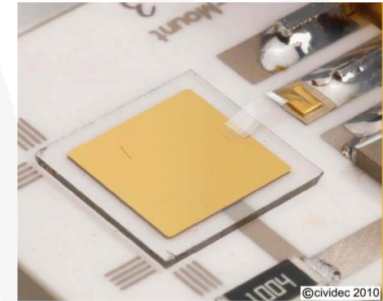
- Stainless steel cylinder
- Parallel electrodes distance 0.5 cm
- Diameter 8.9 cm
- Voltage 1.5 kV
- Low pass filter at the HV input

IC: Total losses at aperture restrictions

- Al electrodes
- Length 60 cm
- Ion collection time **85 us**
- N₂ gas filling at 1.1 bar
- Sensitive volume 1.5 l
- Sensitivity 54 uC/Gy
- Dynamic range 9 orders of magnitude

Secondary Emission monitor

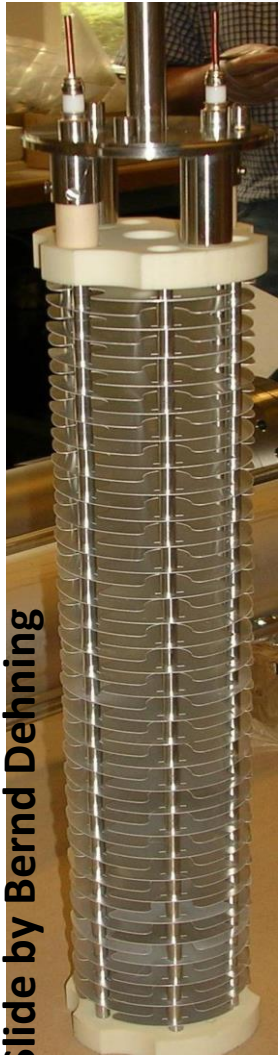
Diamond
pCVD
+
sCVD



CVD: Fast losses at injection

- Poly or Single Crystal chemical Vapor Deposition diamonds
- Signal amplitude comparable to 1.5 litre ionisation chamber
- Radiation tolerant amplifier near to detector
- Response time below **1 ns**

Sensitive to charges particles: Electrons, muons, pions... Cost ~5-8kCHF



Energy and polarization measurements

Energy:

Magnetic spectrometers measure the particle momentum by precisely determining the angle of deflection in a dipole magnet. $\theta \propto \frac{1}{E} \int B ds$

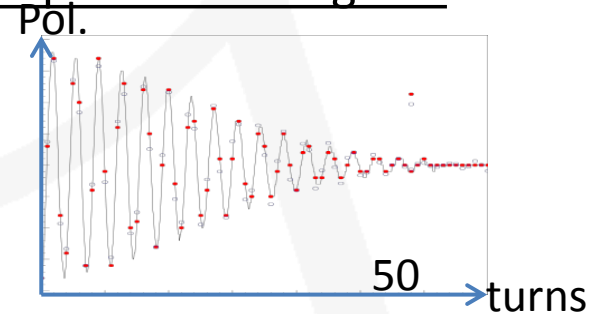
Use Scintillating screens / SEM-grids in arcs combined with collimator (well known position), well known magnet fields (spectrometer magnet) and beam optics:

$$\sigma = \sqrt{\epsilon\beta + \left(\frac{\Delta p}{p} * D\right)^2}$$

Polarization measurement:

The precession of the spin associated with each muon in a magnetic field is governed by the Thomas-BMT equation. At every turn this precession is given by the spin tune which is a function of the muon energy.

No experience in the CERN BE/BI group.



MUON POLARIMETER IN A NEUTRINO FACTORY DECAY RING

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WEPE053, Proceedings of IPAC'10, Kyoto, Japan

BI proposals

| | Instrument | Unit cost | Quantity | Comments |
|----------------------|----------------------------------|-----------|----------|---------------|
| Intensity | BCT | 75kCHF | 1 | |
| Beam position | Button BPM | 15kCHF | ? | 10cm diameter |
| Beam profile | Scintillating screen / SEM-grids | 50kCHF | ~15 | Destructive |
| Tune | BBQ | 10kCHF | 1 | |
| Beam loss | Ionization chamber + Diamonds | 5-8kCHF | | Ring tuning |
| Energy | Polarimeter | ? | 1 | |
| Energy spread | Scintillating screen / SEM | 50kCHF | ? | In arcs |

Summery

- More precise specifications are needed to refine instrument choices.
- Structured beam is a plus for BI, and knowledge about bunch lengths, injection scheme and intensities is needed.
- Turn clock timing signal, for synchronized measurements ?
- **Big is expensive: Ceramics, screens, in-out...**