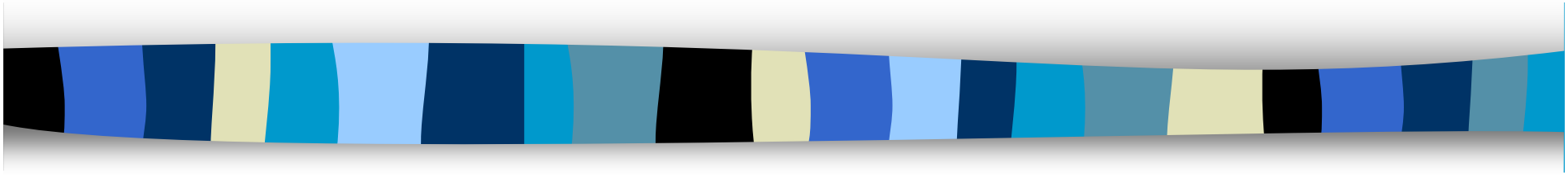
The Gas Ionization Beam Size Monitor



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- Measuring transverse dimensions is usually done by scanning some high density matter accross the beam
- Below 1 μm, the energy density burns everything: has to imagine other ways
- Several candidates :
  - Laser interference pattern (T. Shintake - KEK)
  - Liquid wire (F. Villa - SLAC)
  - Ion beam (J. Bosser - CERN)
  - Image of SR light (BEUV on LEP & LHC)
  - Gas ionization
    - rest gas (LHC monitor)
    - injected gas (this talk)

FFTB (1990-1995)

Space charge field

- Round beam $E_m \propto \frac{1}{\sigma}$
- Flat beam

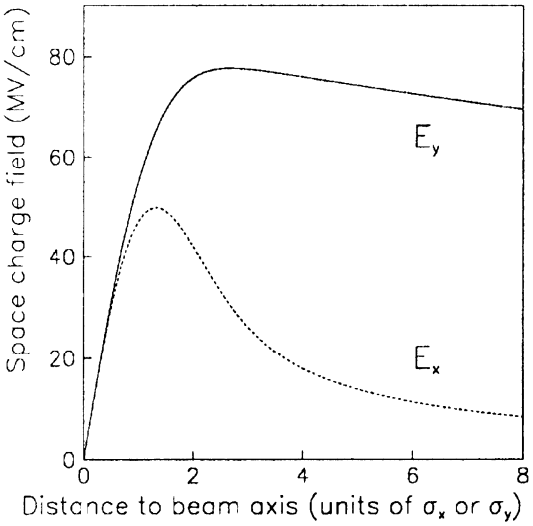
$$R = \frac{\sigma_x}{\sigma_y}$$

$$E_{x,m} = f(z,t)\frac{1.082}{\sigma_x\sqrt{2}}\left(1-\frac{0.726}{R}\right)$$

$$E_{y,m} = f(z,t)\frac{1.772}{\sigma_x\sqrt{2}}\left(1-\frac{\sqrt{\pi}}{R}\left[\sqrt{\ln(R)}+\frac{1}{\sqrt{\ln(R)}}\left(\frac{2}{\pi}+\frac{1}{2}\right)\right]\right)$$

- Max field in FFTB
  - Round beam: 0.29 V/Å
  - Flat beam: 0.50 and 0.78 V/Å

Nominal FFTB:
2 x 0.06 x 600 μm^3
and N_e = 7.0 10^9

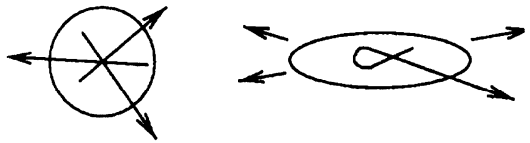


BSM principle (1/2)

- Ionization of injected gas by individual incident particules
  - Ions are created at rest
  - Cross-section: several Mb
  - They experience the beam space charge field
  - Receive a transverse kick (several keV)

BSM principle (2/2)

- Heavy ion : receive a kick depending on its transverse creation position
  - Minimum TOF is related to σ_x through maximum field
- Light ion : oscillate in the beam potential well
  - Round beam : azimutal distribution is isotropic
  - Flat beam : azimutal distribution is not isotropic

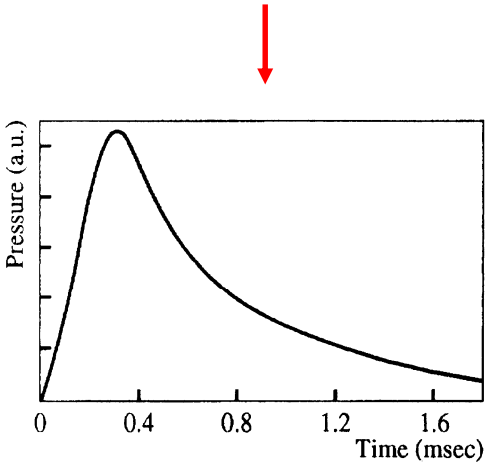


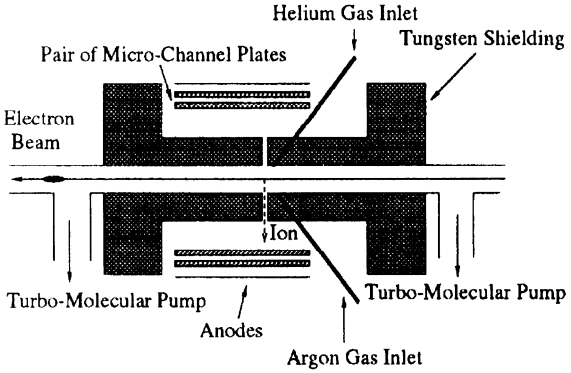
Round beam Flat beam

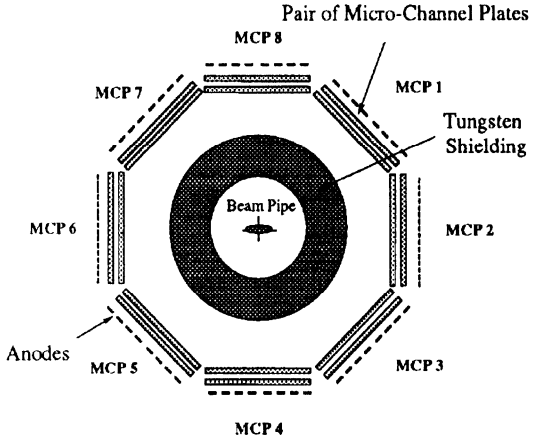
Setup

- Gas injection (Ar + He)
- Ion detector

Pressure recorded with fast jauge



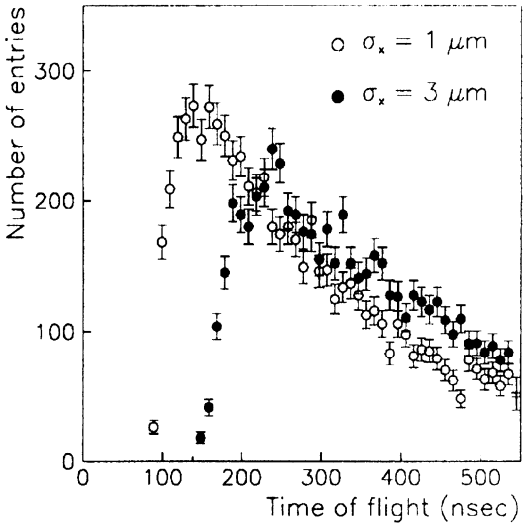




From LAL Orsay museum …

Horizontal measurement: He gas !

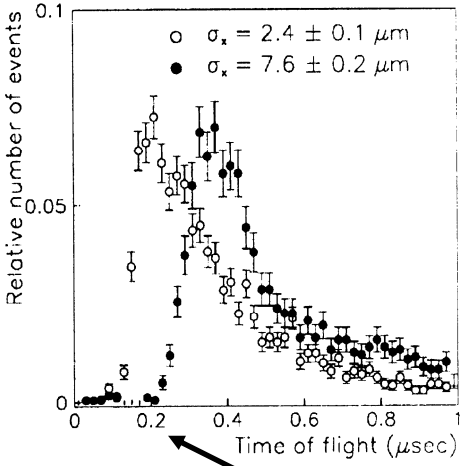
Simulation



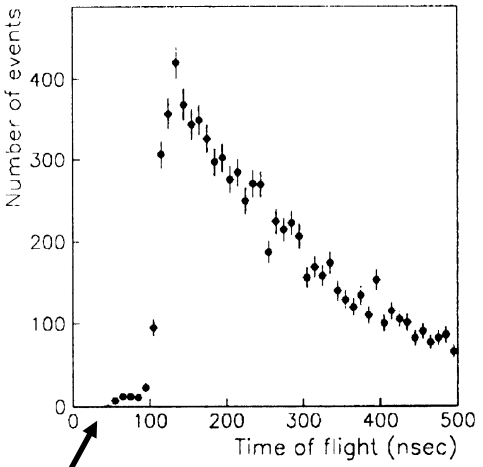
σ_y= 0.2 μm

Data

σ_x= 1.53 ± 0.01 μm
σ_y= 64 ± 10 nm



78 gas pulses each



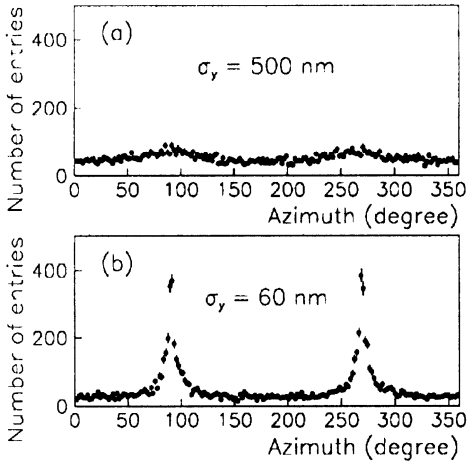
400 gas pulses

Low background: easy determination of the minimum TOF

Estimator: **minimum time of flight**

Azimutal measurements: He gas

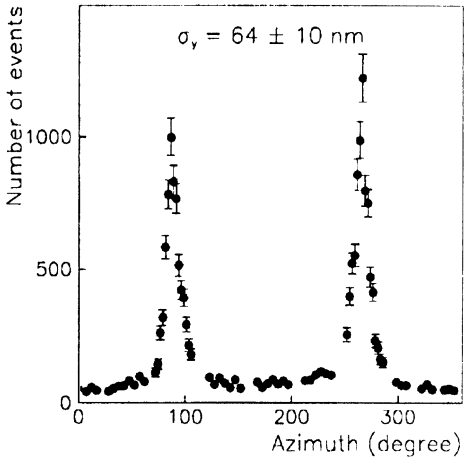
Simulation



10000 He^+

σ_x= 2 μm

Data



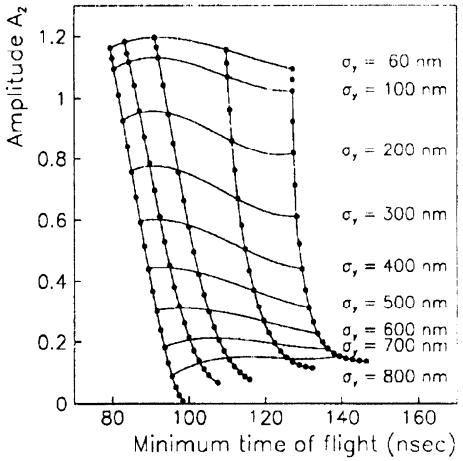
σ_x= 1.53 ± 0.01 μm
σ_y= 64 ± 10 nm

400 gas pulses

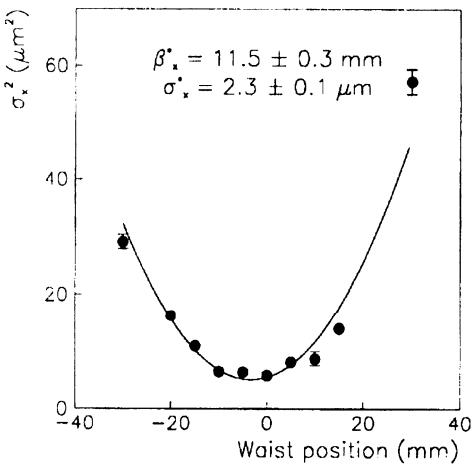
Estimator: **amplitude of the 2nd order Fourier coefficient**

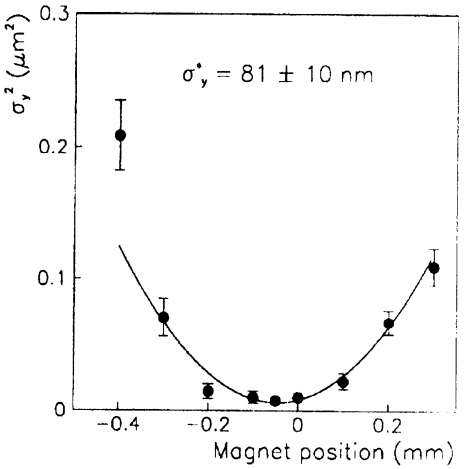
How to extract beam sizes ?

- Apply corrections for bunch length and bunch charge
- Combine minimum TOF with amplitude of 2nd order Fourier coefficient



Waists scans

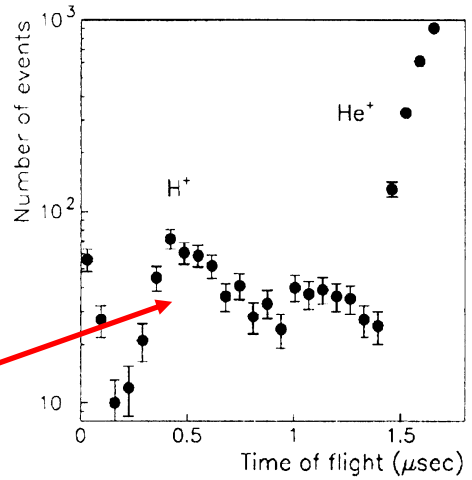




Just use it as a regular BSM

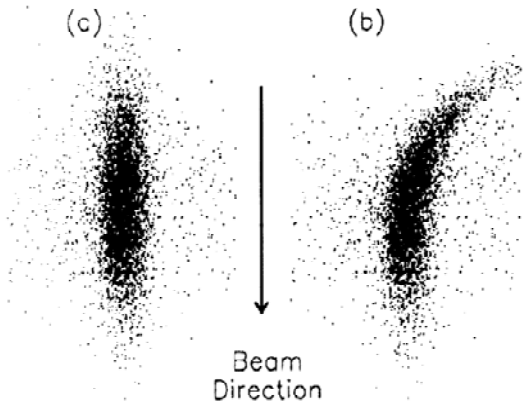
Why not using Ar gas for σ_x ?

- Reduced sensitivity for He, but enough for FFTB
- No double charged ions
- We discovered in situ there was no background



Low background:
H^+ ions (and not He^{2+})

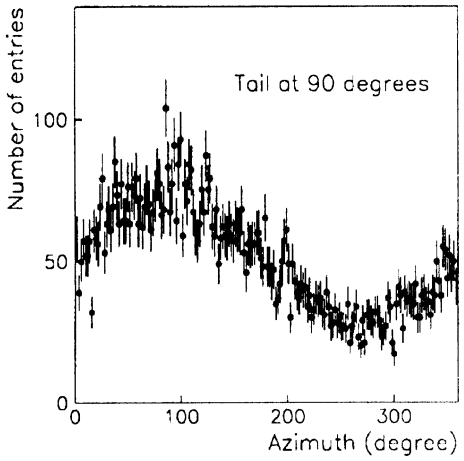
Sensitivity to banana shape: simulations



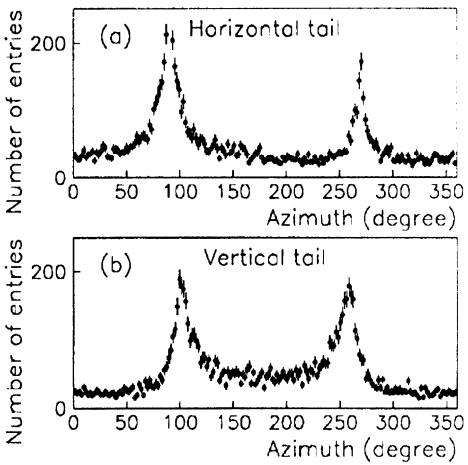
Ions created by the head are kicked towards the tail

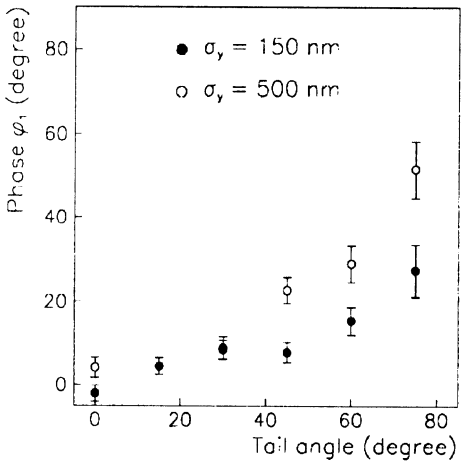
Estimator: **amplitude of the 1st order Fourier coefficient**

$\sigma_x = \sigma_y = 2\ \mu m$

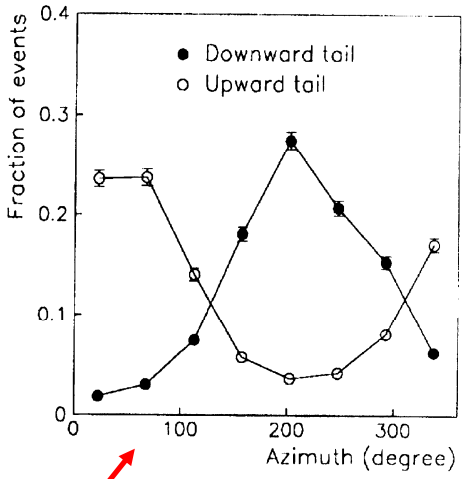


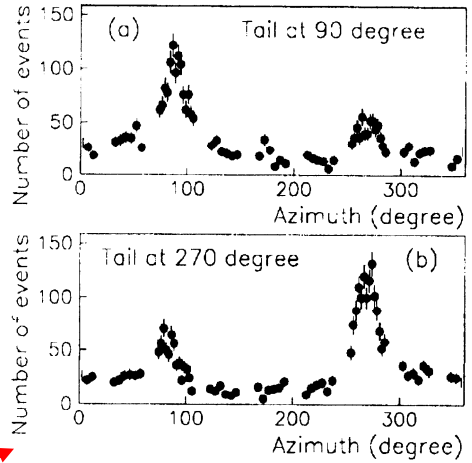
$\sigma_x = 2\ \mu m$ - $\sigma_y = 100\ nm$





Sensitivity to banana shape: data



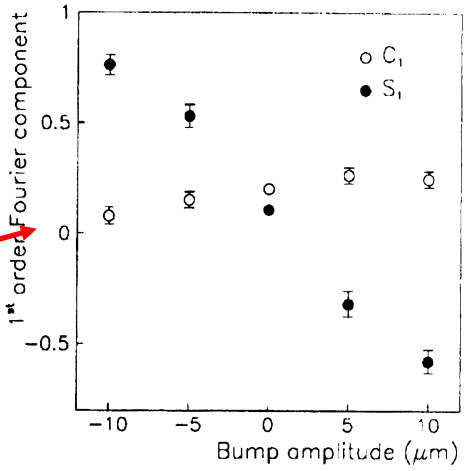


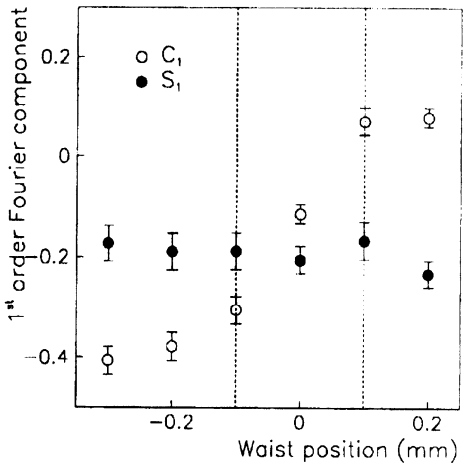
Round beam

Flat beam

C1 varies rapidly in $\pm\beta^*_y$ around the vertical waist due to fast variation of vertical betatron phase

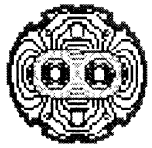
S1 changes signe with the bump amplitude in the linac





Extra problems relevant to NLC (1/2)

- Multibunch



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Proposal of a Gas Ionization BSM for the LHC

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Keywords: Gas-ionization, LHC

Summary

A new type of Beam Size Monitor (BSM) for the LHC is proposed here. This monitor is a residual-gas ionization detector and its working principle is based on the measurement of the acceleration given to ions by the space charge field of the beam. Such a BSM is able to measure the transverse beam size over the whole LHC energy range.

Extra problems relevant to NLC (2/2)

- Positron beam (from old remembrance)
  - TOF method is unchanged (even sharper)
  - Azimutal distribution is less sensitive by factor 2
- Tunnelling ionization
  - If the E field is higher than ≈ 1-2 V/Å, ionization by the field itself

Conclusion (1/2)

- **This device is more a probe of the beam space charge field than a BSM**
- Advantages
  - Extract information in the transverse plane (not sensitive to background in the forward direction)
  - Very low energy dependance
  - Sensitive to 3D shape of the bunch
  - No background because of the finite ions speed

Conclusion (2/2)

- Disadvantages
  - Not always easy to interpret
  - Need bunch charge and bunch lenght
- My personal impression is that this is not suited for a ring or the IP of an NLC, but very well suited for single pass devices (Linac or transfert line)