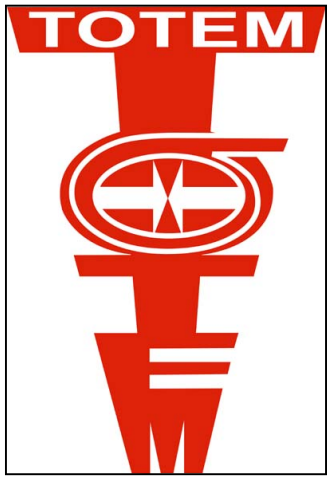


Physics at LHC

Prague, 6-12 July 2003

Elastic scattering at TOTEM: optics & detectors

V. Avati
University of Helsinki

on behalf of the

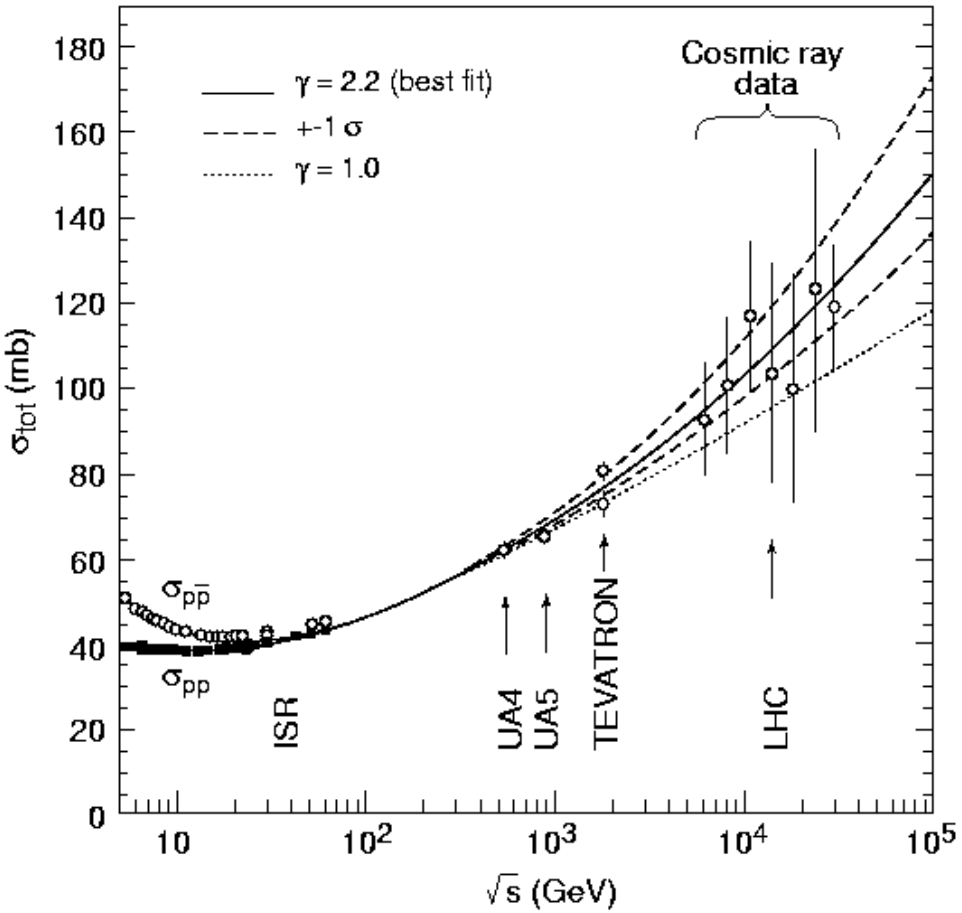
TOTEM Collaboration

http://www.cern.ch/Totem/

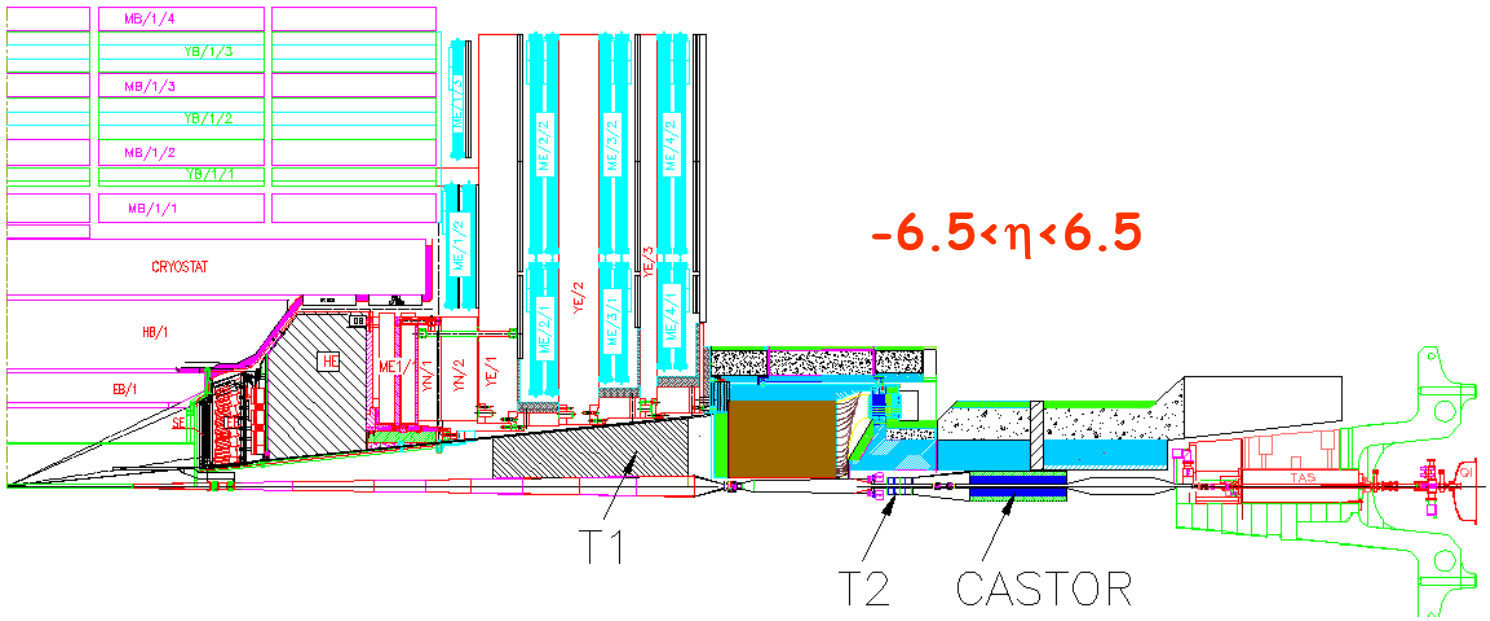
Collaboration

Università di Bari and Sezione INFN, Bari, Italy
Institut für Luft- und Kältetechnik, Dresden, Germany
CERN, Geneva, Switzerland
Università di Genova and Sezione INFN, Genova, Italy
Institut des Sciences Nucléaires, IN2P3,/CNRS, Grenoble, France
University of Helsinki and HIP, Helsinki, Finland
Warsaw University of Technology,Plock, Poland
Academy of Sciences, Praha, Republic Czech
Brunel University, Uxbridge, UK

The measurement of σ_{tot}



- Historical : CERN Tradition (PS-ISR-SPS)
- Dispersion relation fit $(\log s)^{\gamma}$, $\gamma = 2.2 \oplus 0.3$
- Current models predictions: 100-130mb
- Aim of TOTEM: ~1% accuracy
- Absolute calibration of Luminosity



(Optical Theorem)

$$L\sigma_{tot}^2 = \frac{16\pi}{1+\rho^2} \times \left.\frac{dN}{dt}\right|_{t=0}$$

$$L\sigma_{tot} = N_{elastic} + N_{inelastic}$$

$$\Rightarrow \quad \sigma_{tot} = \frac{16\pi}{1+\rho^2} \times \frac{\left.(dN/dt)\right|_{t=0}}{N_{el} + N_{inel}}$$

Special optics for the measurement of the forward proton(s)

LOW t measurement → angles ~ 10^{-2} mrad

At the IP : small beam divergence [$\sigma_\theta=(\varepsilon / \beta^*)^{1/2}$] → large β^*

→ large beam size [$\sigma_x=(\varepsilon\, \beta^*)^{1/2}$]

At the detector stations:

$y = L_y\, \theta_y^* + v_y\, y^*$ $\qquad L = (\beta\beta^*)^{1/2} \sin \mu(s)$

$x = L_x\, \theta_x^* + v_x\, x^* + \xi\, D_x$ $\qquad v = (\beta/\beta^*)^{1/2} \cos \mu(s)$

Optimal conditions:

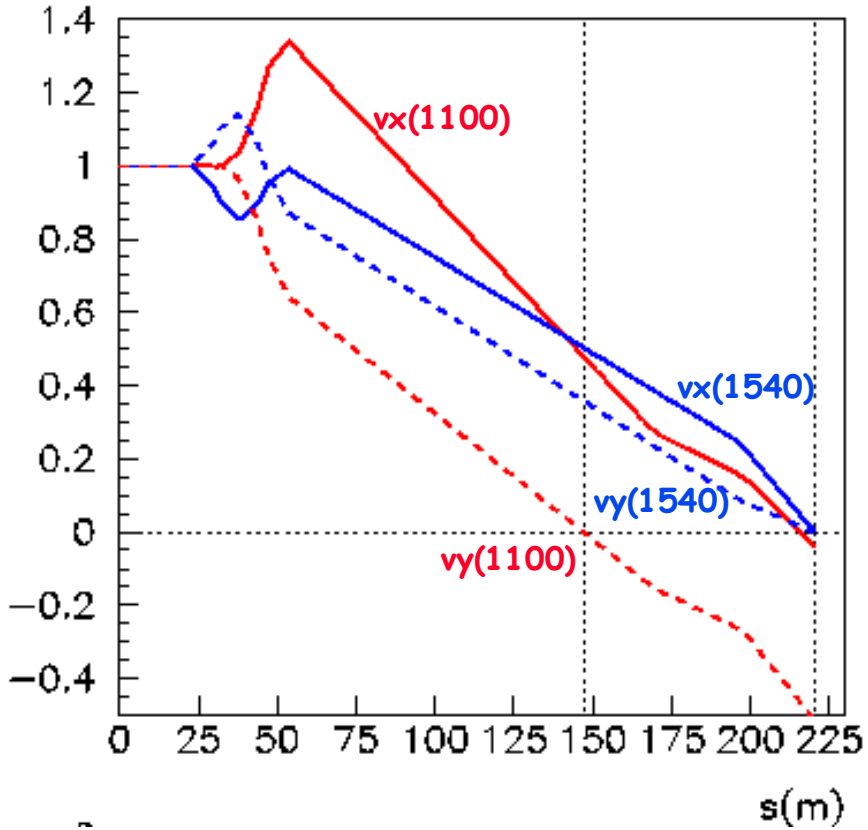
- parallel to point focussing planes (v=0) → unique position-angle relation
- largest L_{eff} → sizeable distance to the beam center (~1mm)
- lowest emittance (10^{-6} m· rad)

Luminosity : 10^{28} cm^{-2} sec^{-1},36 bunches (with β^*=1100 m)

An alternative optics (β^*=1540m) is under study: interesting feature and better performances

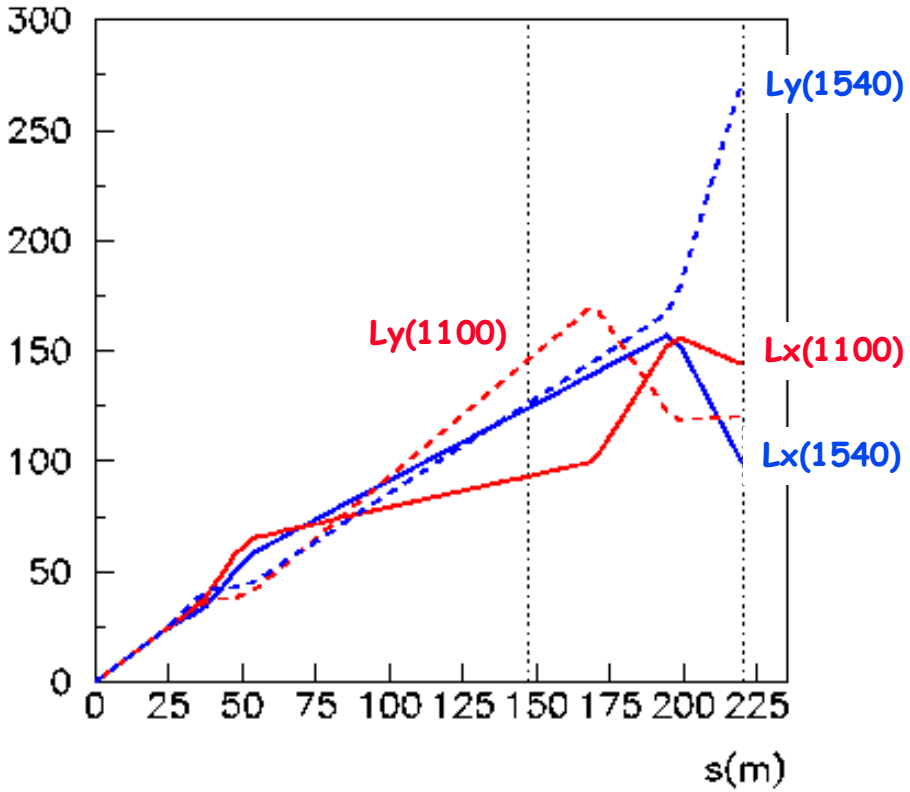
- parallel to point focussing planes in x and y simultaneously at ~220 m
- better "one arm resolution"

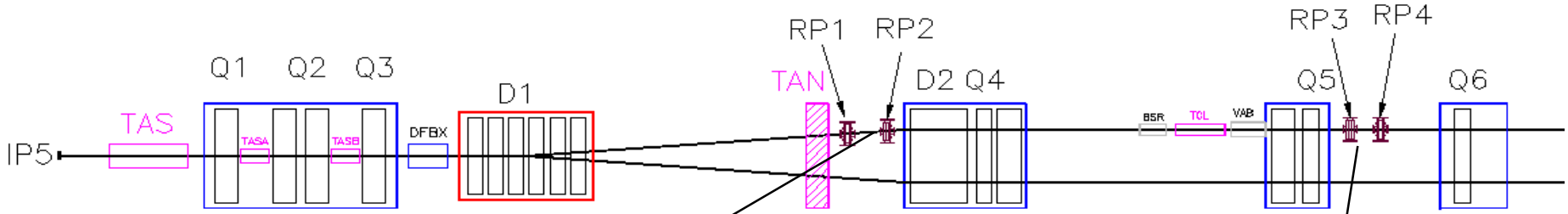
High β optics: lattice functions



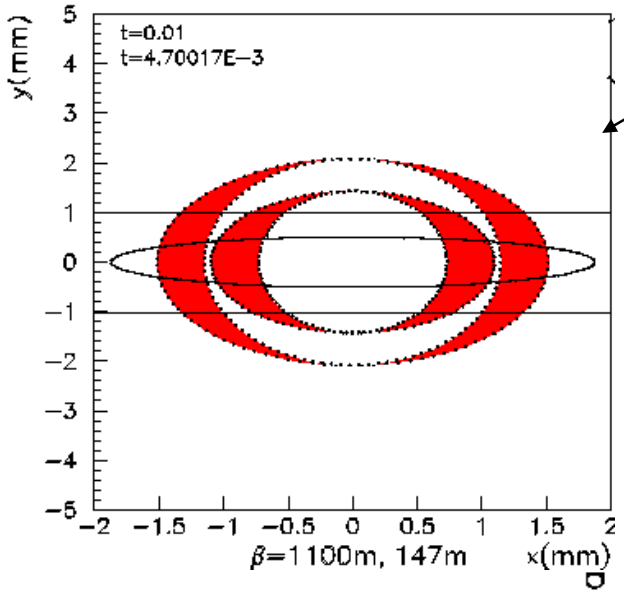
$v = (\beta/\beta^*)^{1/2} \cos \mu(s)$

$L = (\beta\beta^*)^{1/2} \sin \mu(s)$

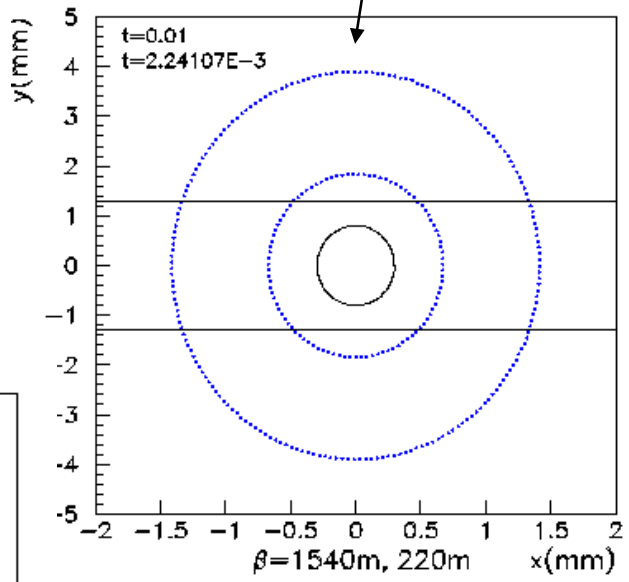




Elastic Scattering

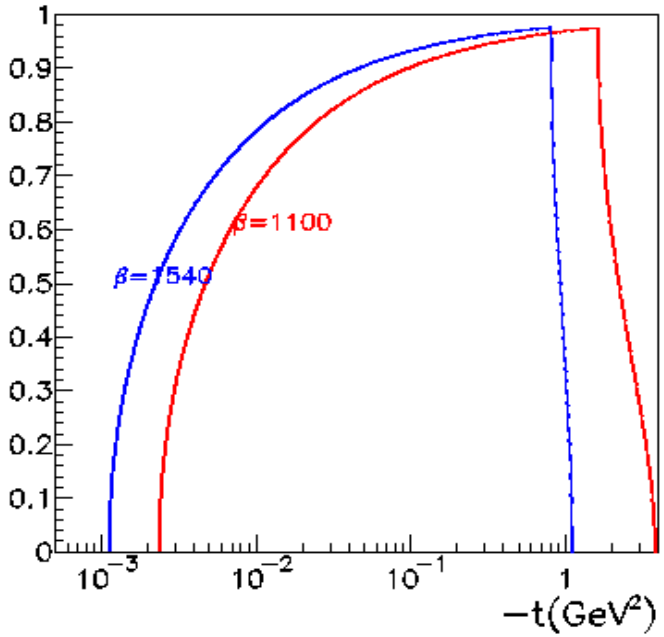


β* = 1100 m

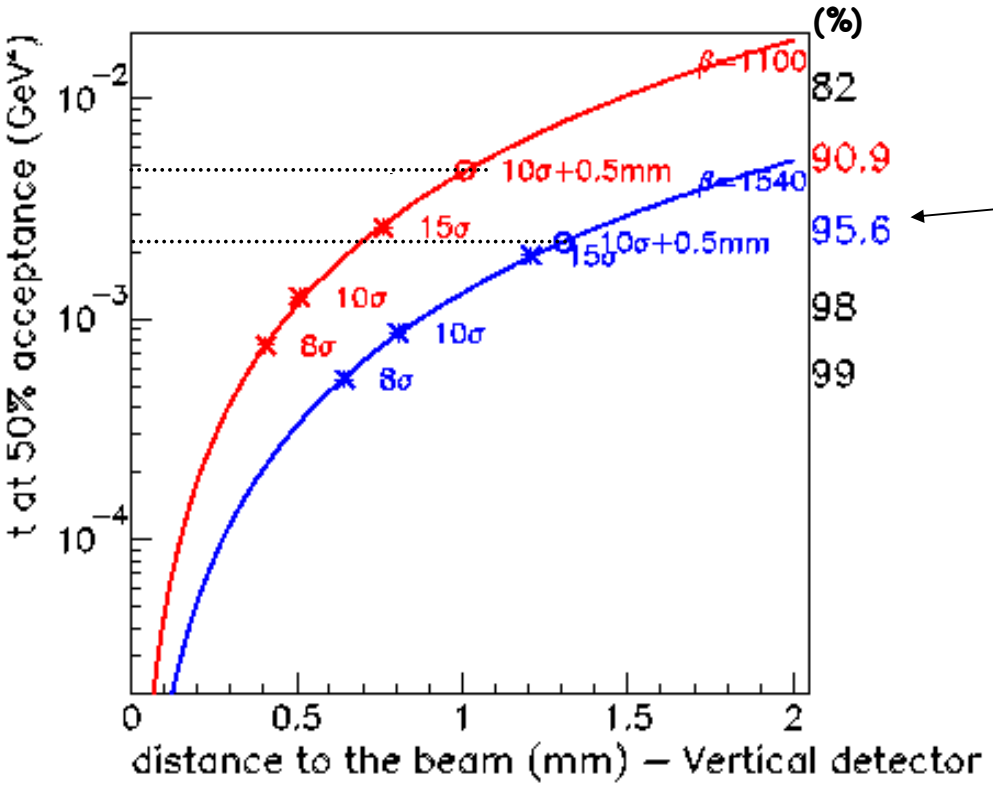


β* = 1540 m

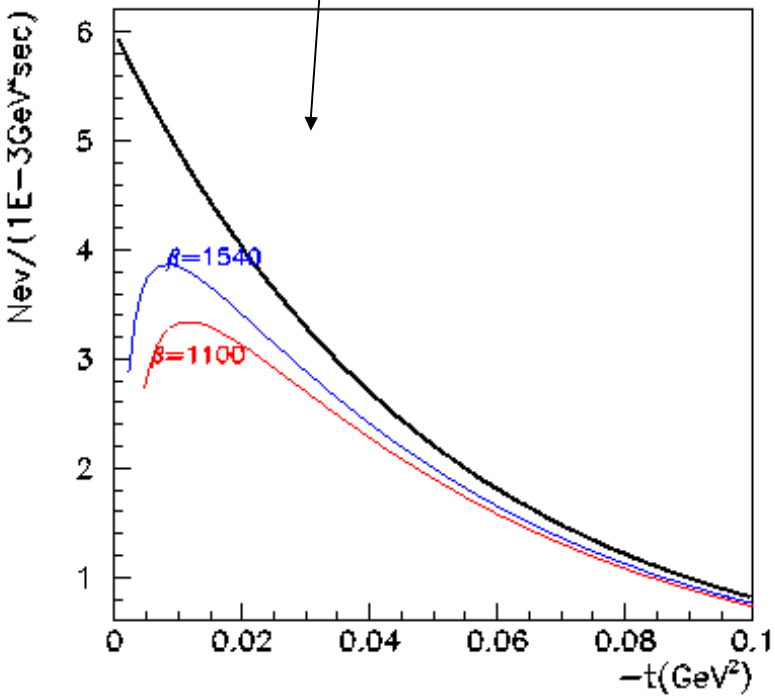
acceptance



t-acceptance (50%) vs detector position



Number of events



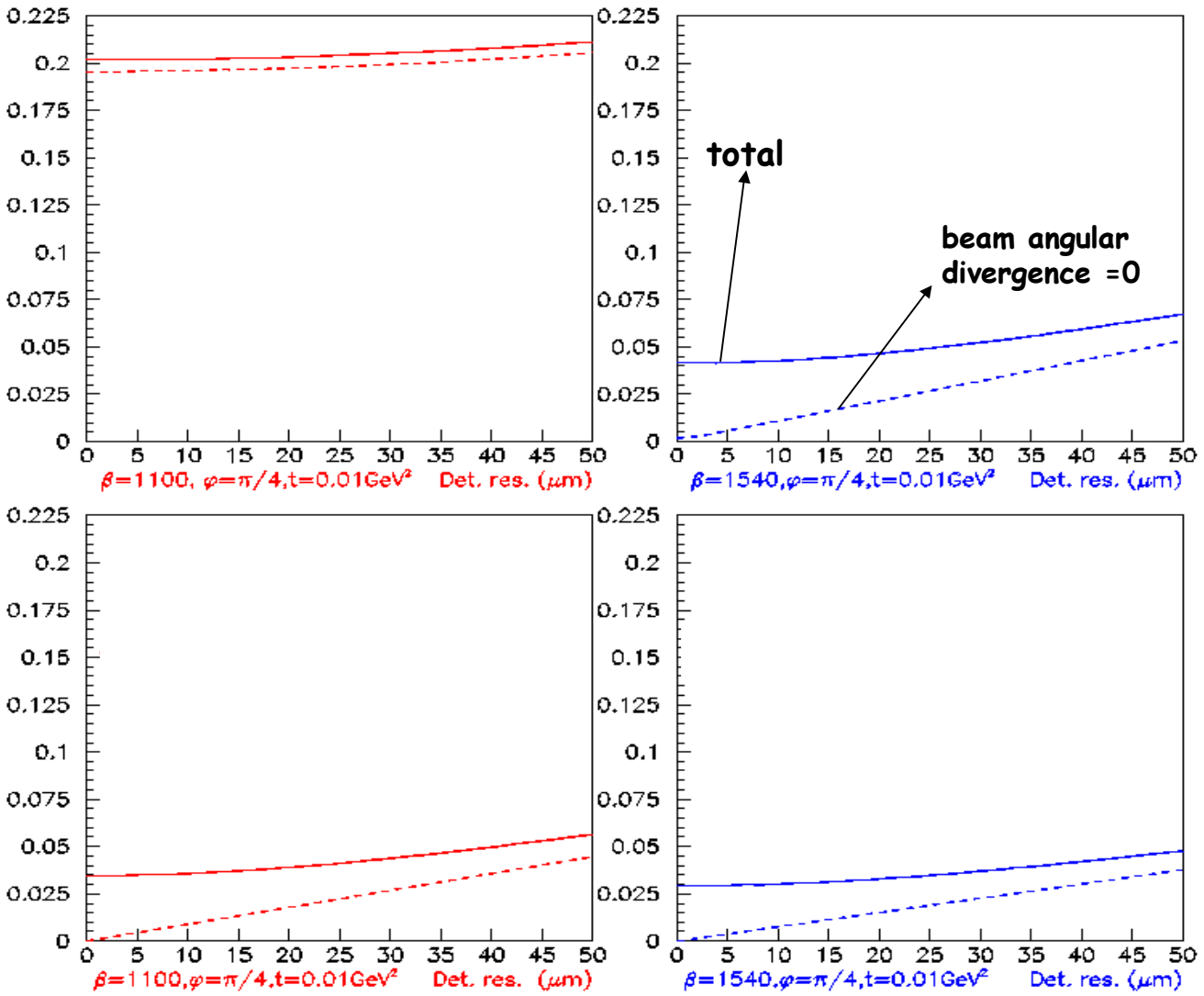
Errors on the extrapolation to t=0

1. **Beam angular divergence** $\sigma_\theta=(\varepsilon / \beta^*)^{1/2}$
2. **Optical functions**
3. **Beam position**
4. **Crossing angle**

5. **Detector resolution: statistical and systematical (detector offset)**
6. **RP station alignement**

7. **Background (beam halo, double pomeron exchange…)**

t-resolution (one and two arms) versus detector resolution



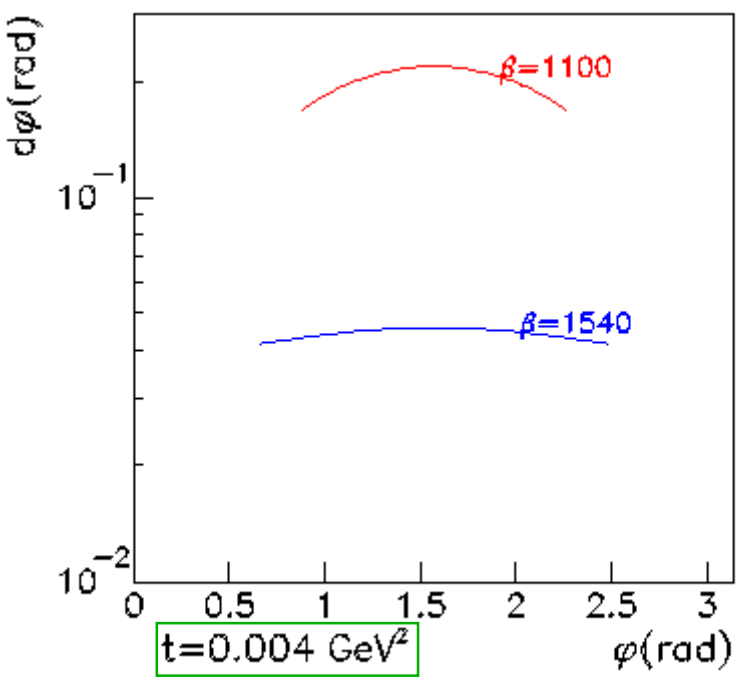
σ(t)/t (1 arm)

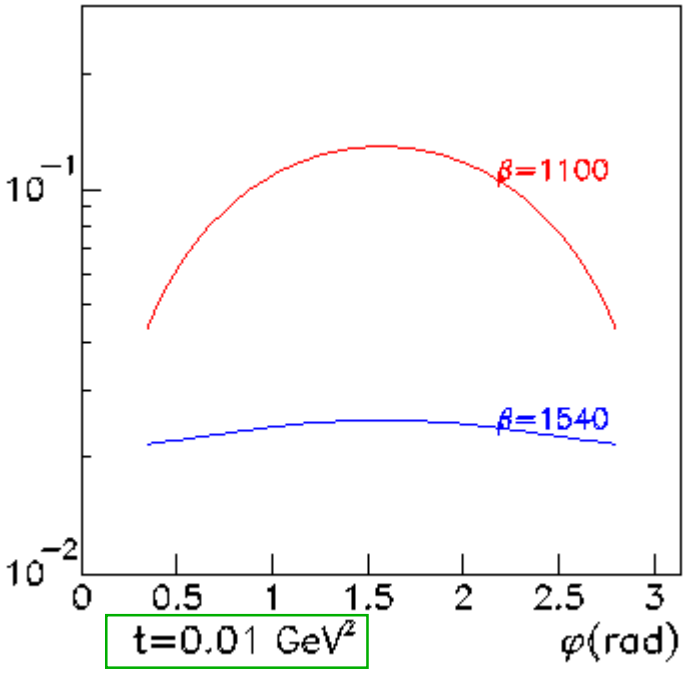
v dependence!

σ(t)/t (2 arms)

coplanarity

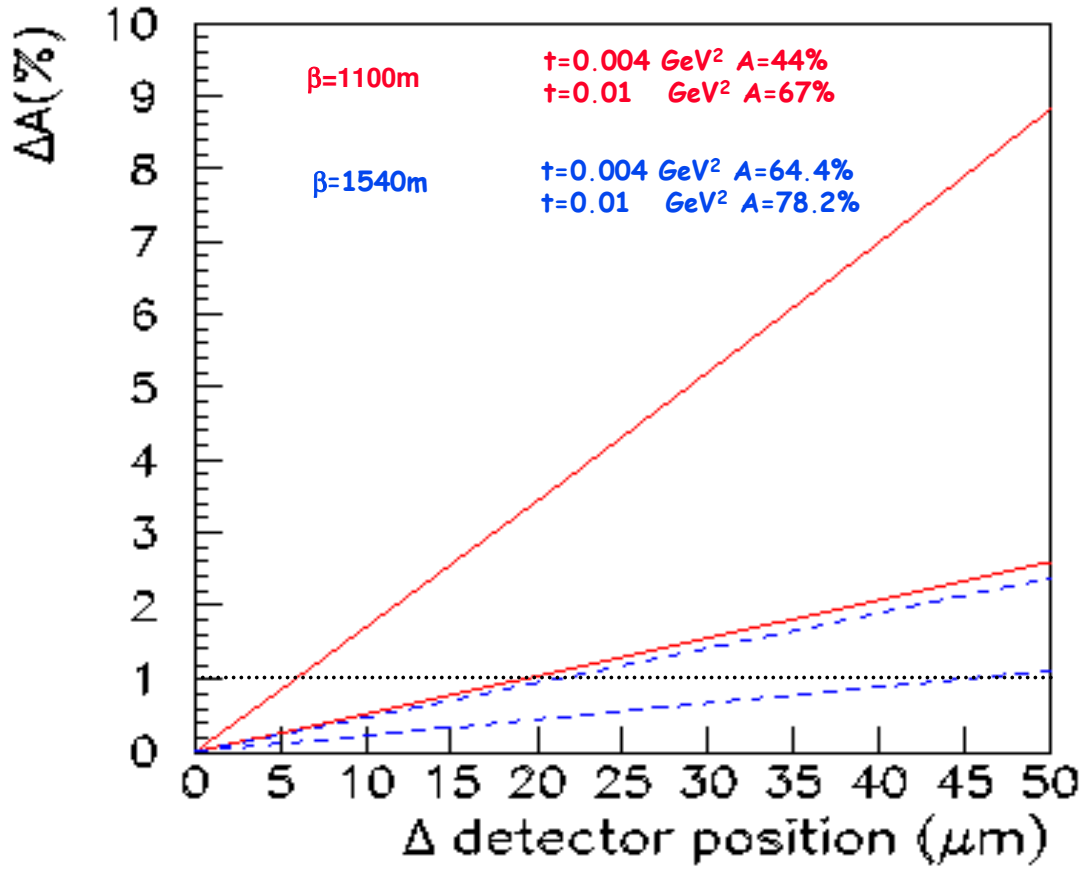
Coplanarity test, background rejection: ϕ resolution



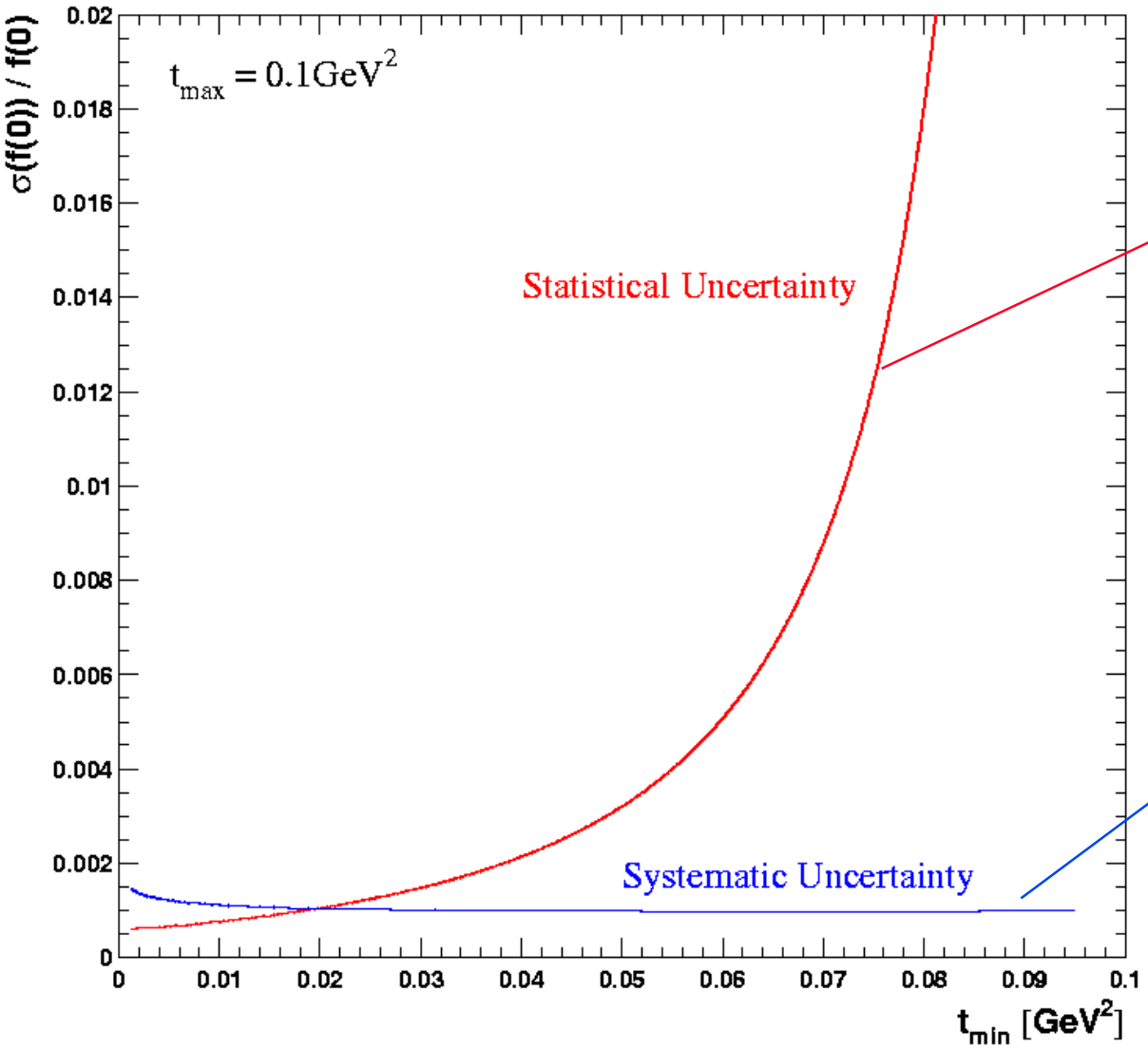


Detector resolution = 20 μm

Acceptance dependence from detector offset



Elastic Cross section (t=0): stat. and syst. errors



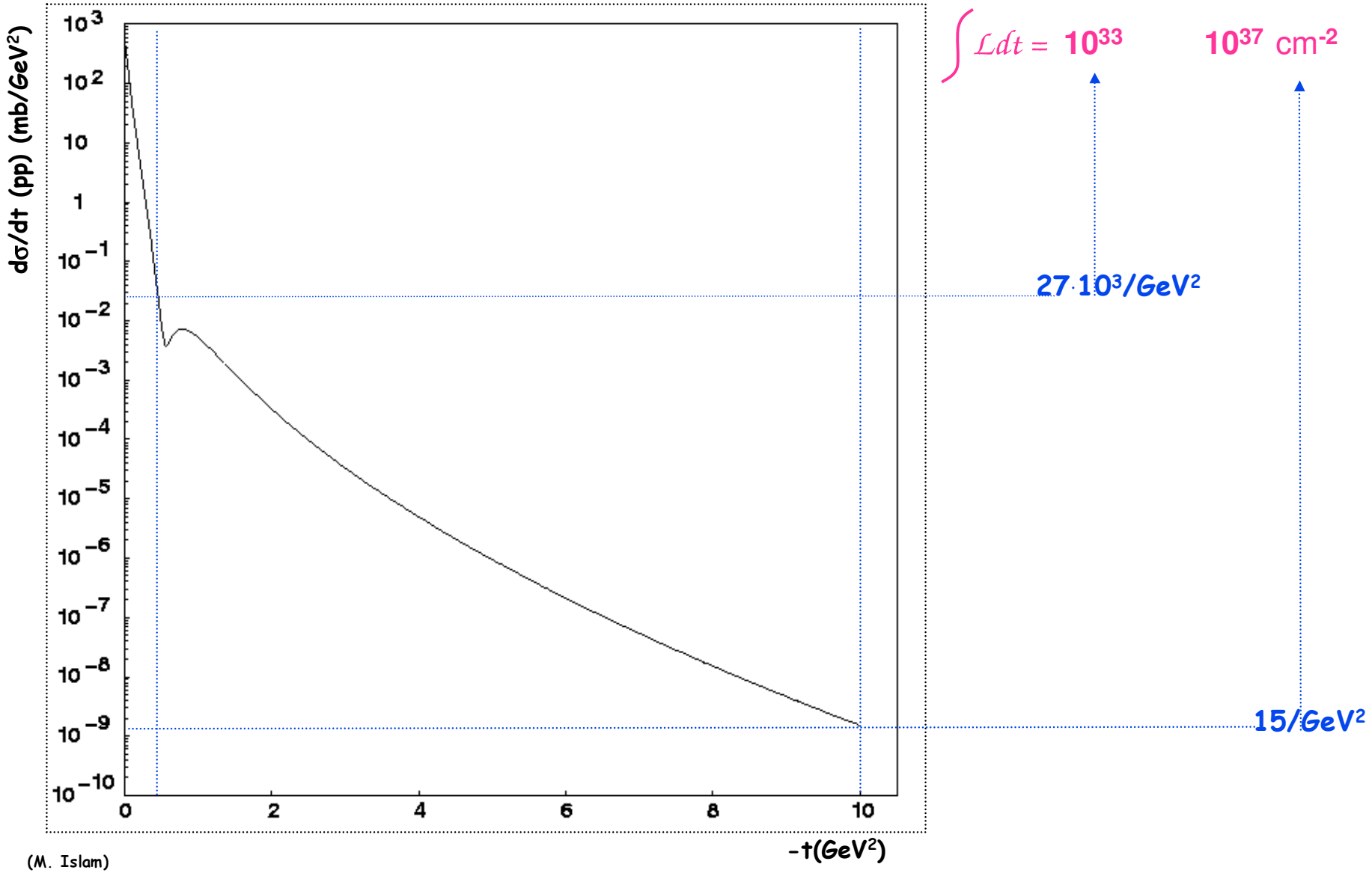
$\mathcal{L}=10^{28}$ cm^{-2} s^{-1}

run time = $4 \cdot 10^4$ sec

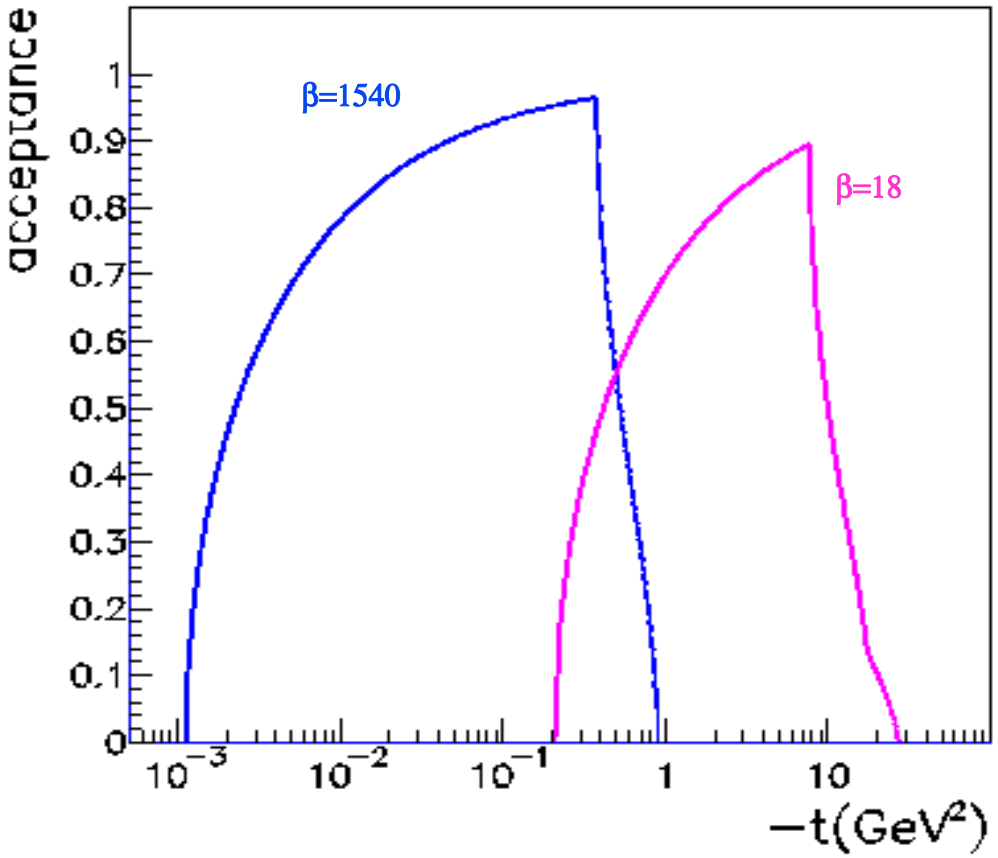
10μm detector position uncertainty

Large t scattering

1 eff.day (10^5sec) at high β and 18 m

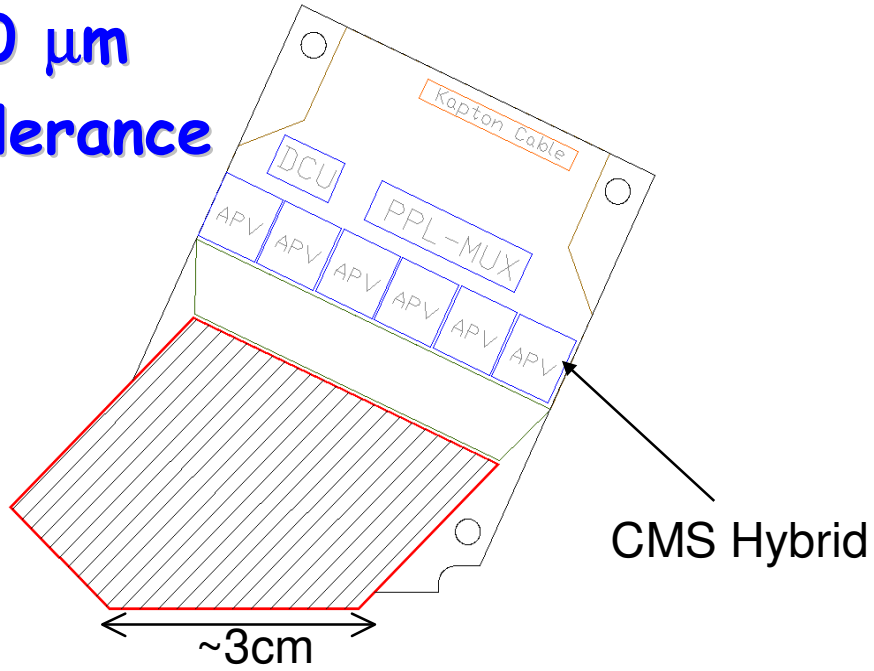


Acceptance


acceptance
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
β=1540
β=18
10^{-3}
10^{-2}
10^{-1}
1
10
−t(GeV²)

Detector requirements

- High and stable efficiency near the edge facing the beam, edge sharpness < 10 μm
  - Try to do better than present technology guard rings ~0.5 mm
- Detector size is ~ 3 x 4 cm^2
- Spatial resolution ~ 20 μm
- Moderate radiation tolerance (~10^{14} n /cm^2 equiv)



Cold Silicon

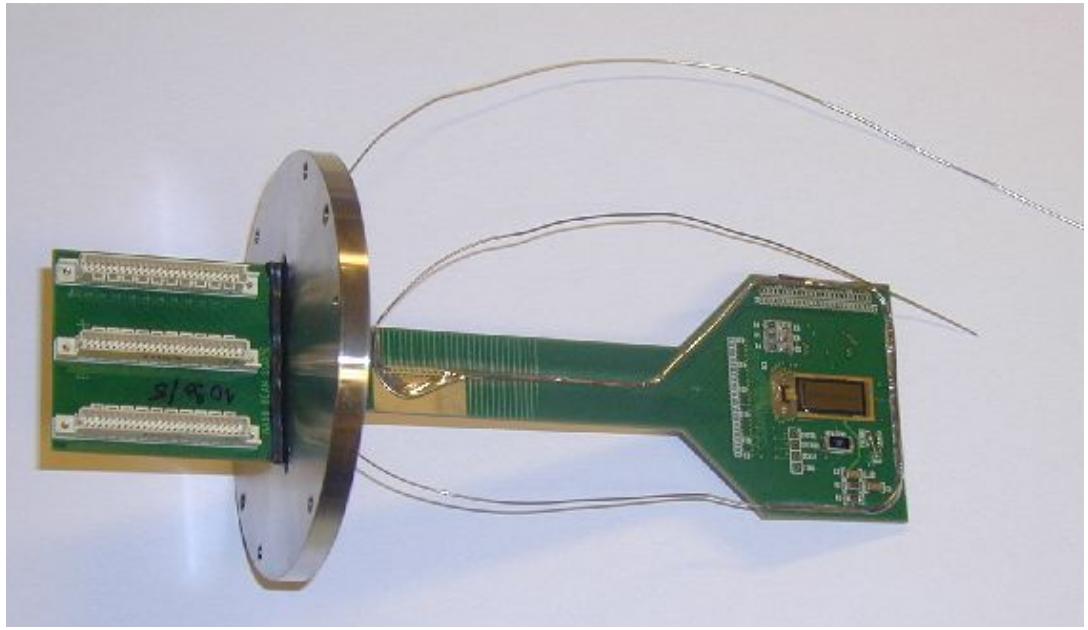
- **RD39/NA60 have investigated/used silicon at cryogenic temperatures (~ 100-130 K)**
- **Studies hint at possibility of operating silicon microstrip without guard rings at LN temp.**

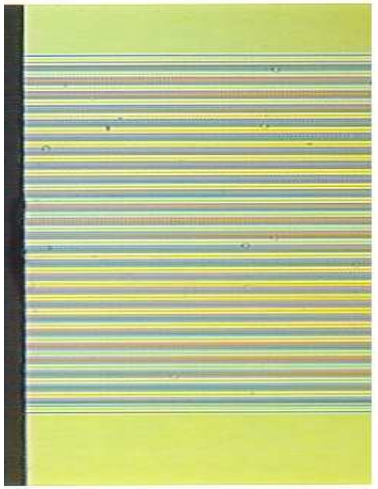
K.Borer et al., "*Charge collection efficiency of irradiated silicon detector operated at cryogenic temperatures*" NIM A 440 (2000) 5.

L.Casagrande et al., "*A new ultra radiation hard cryogenic silicon tracker for heavy ions beams*" NIM A (2002) 325-329.

S.Grohman et al., "*Detector development for TOTEM Roman Pots*", IX Blois Workshop on El. and Diff. Scatt., Pruhonice, Czech Republic, (2001), 363.

- **In 2002 we have performed a first measurement on cold edgeless silicon detector**



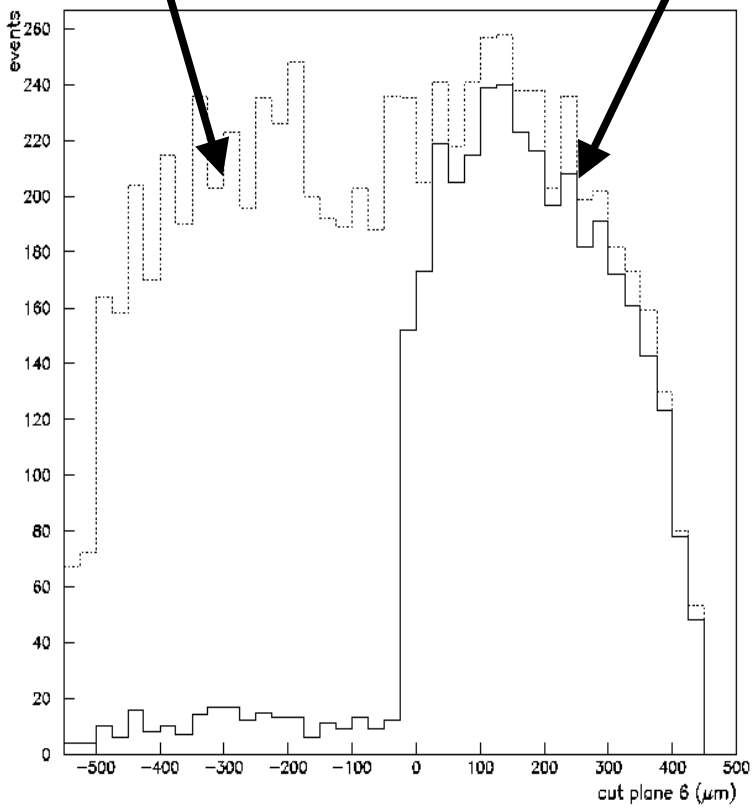


Z. Li et al, "*Electrical and TCT characterization of edgeless Si detector diced with different methods*", IEEE NSS Proc., San Diego, Nov. 2001

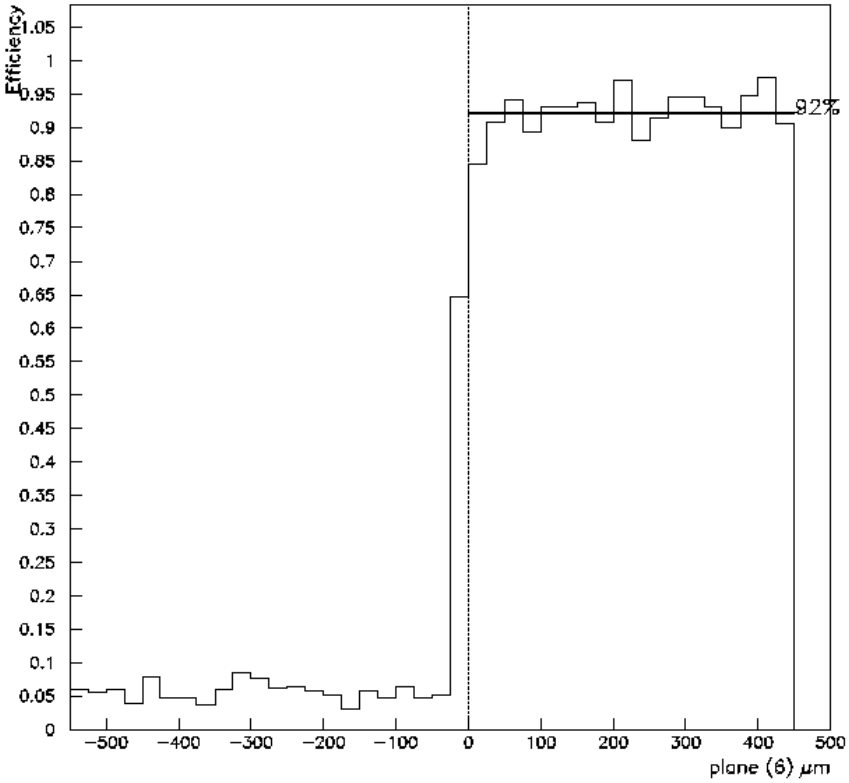
Reconstruction of the cut edge

Hits in the telescope (all good tracks)

Hits in the cut detector

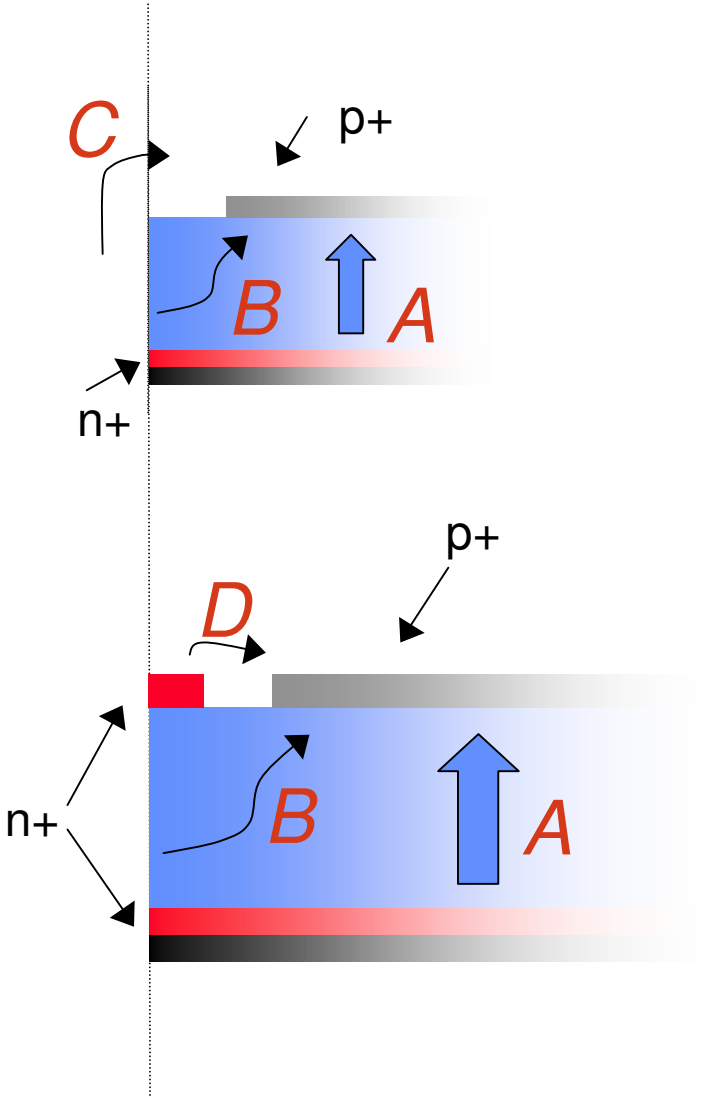


Efficiency



Edge at: 0+20micron

Development with planar technology



n+ ring (20 μm) at ~30μm from p+
set at the same pot as backplane

hope:
n+ ring stops the **c** current

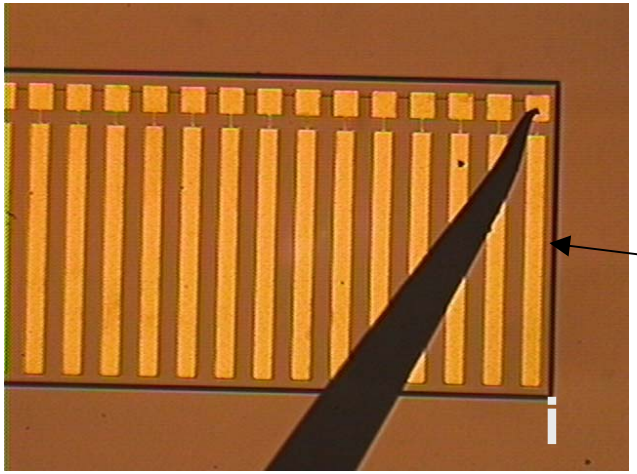
B under control with temperature

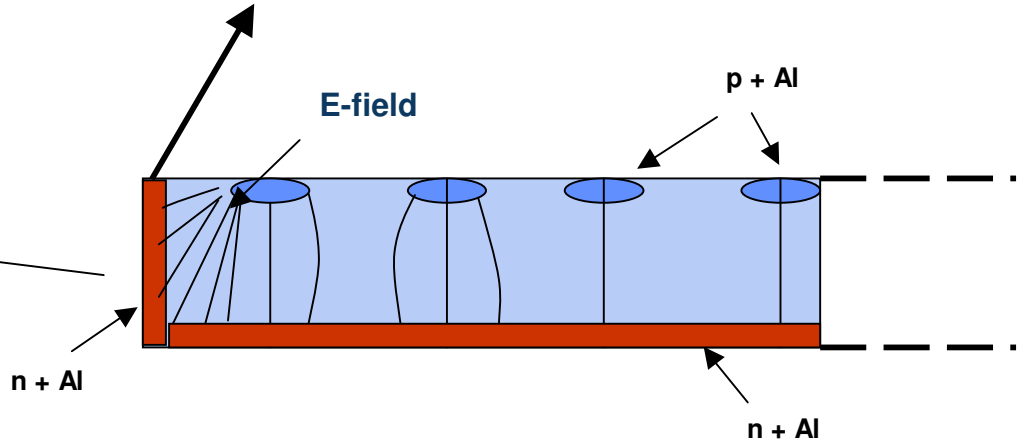
test of various configuration this summer

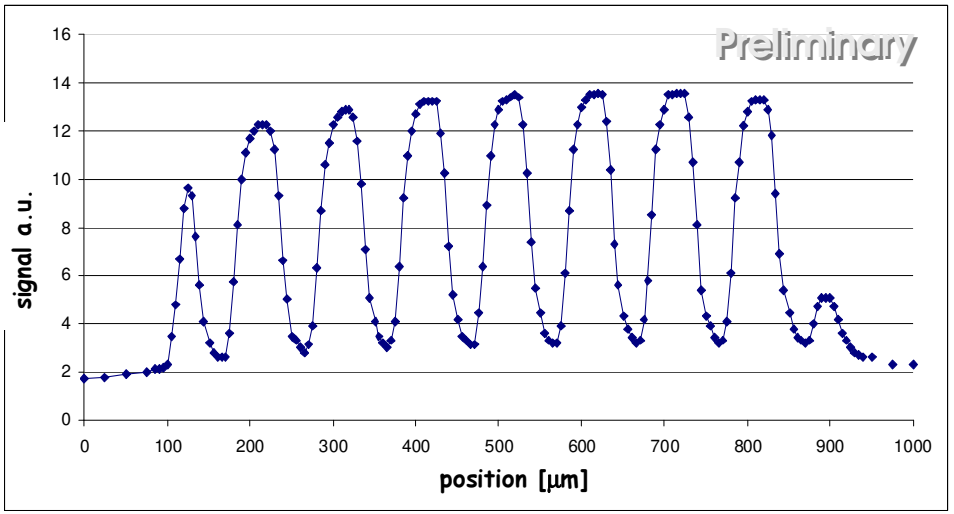
goal:increase of operation temperature

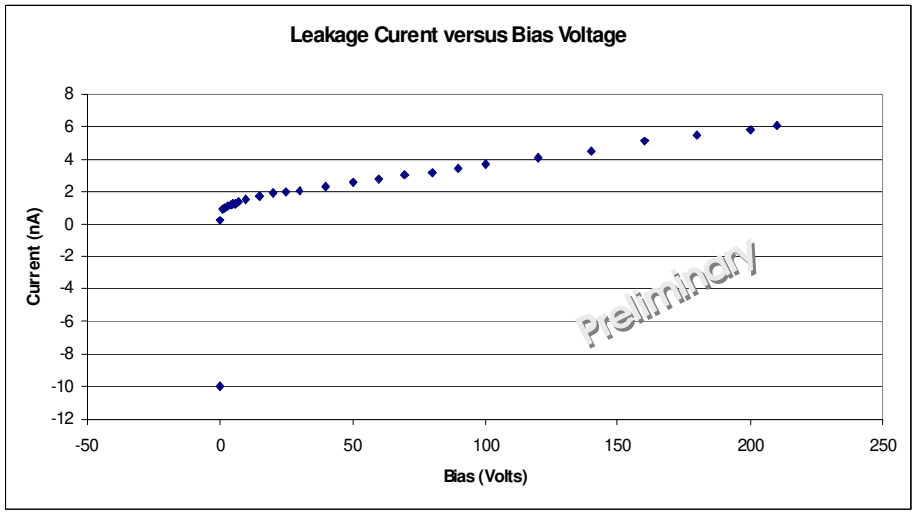
PLANAR-3D DETECTORS

TRADITIONAL PLANAR DETECTOR
+ DEEP ETCHED EDGE FILLED
WITH POLYSILICON









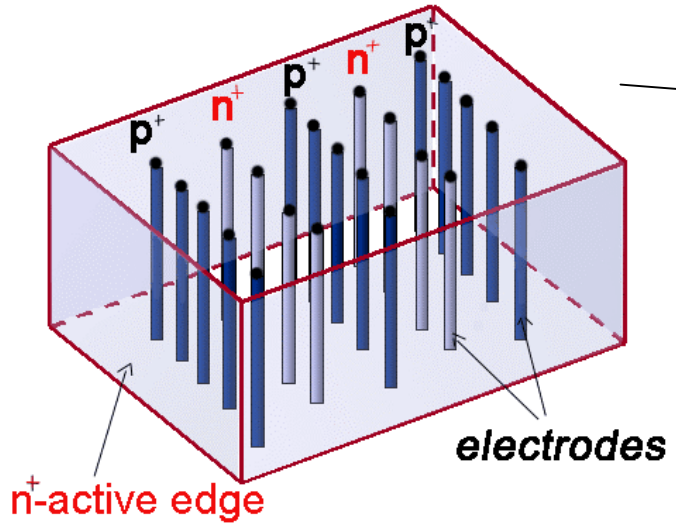
Edge sensitivity ~20 μm

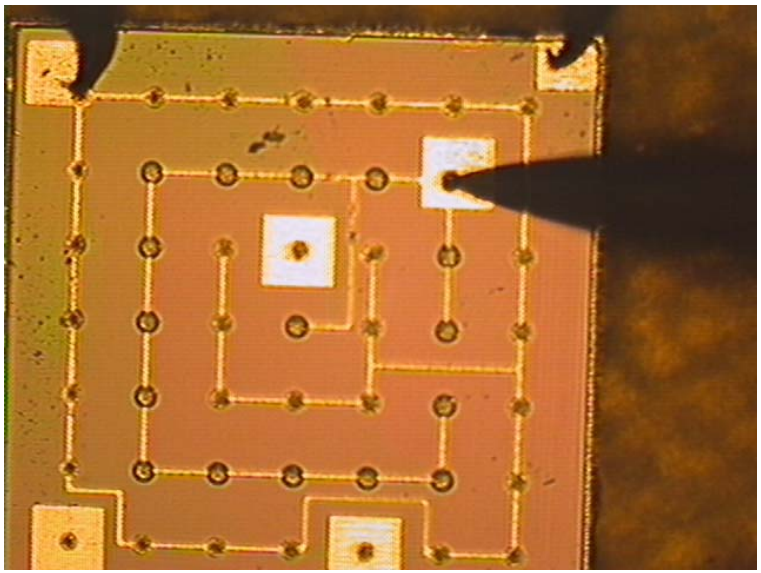
Leakage current =6nA at 200V

Brunel, Hawaii, Stanford

3D DETECTORS AND ACTIVE EDGES

Brunel, Hawaii, Stanford



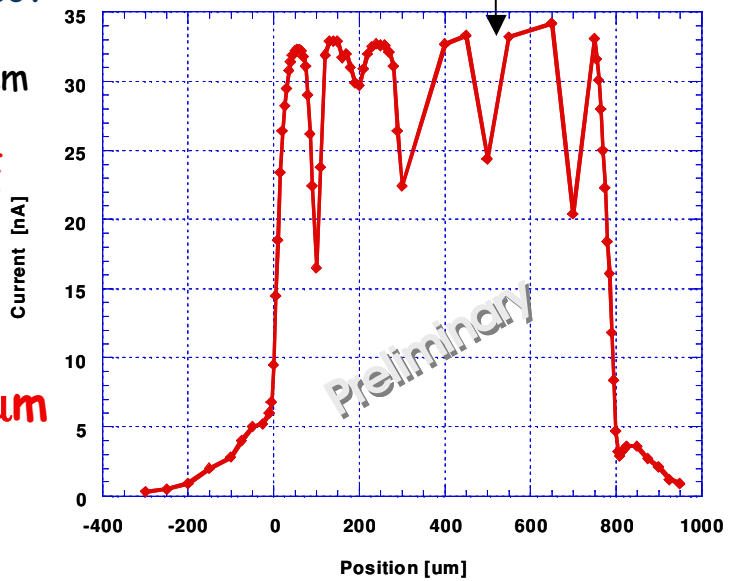


❖EDGE SENSITIVITY	<10 μm
❖COLLECTION PATHS	~50 μm
❖SPATIAL RESOLUTION	10-15 μm
❖DEPLETION VOLTAGES	< 10 V
❖DEPLETION VOLTAGES at 10^{15}n/cm^2	~105 V
❖SPEED AT RT	3.5 ns
❖AREA COVERAGE	3X3 cm^2
❖SIGNAL AMPLITUDE before Irradiation	24 000 e
❖SIGNAL AMPLITUDE at 10^{15}n/cm^2	15 000 e$^-$

❖**15 μm InfraRed beam spot**
❖FWHM = 772 μm
❖Edge Al strip width = 16 μm

INSENSITIVE EDGE (INCLUDING **16 μm Al** STRIP):

(813 - 772) / 2 = **21 μm**



❖*CERN Courier, Vol 43, Number 1, Jan 2003*

To measure the total cross section with ~ 1% precision

- total inelastic rate within 1 %
- extrapolation to t=0 within 0.3-0.4 %

Near Future plans:

- Optics optimization
- Further studies on the systematic
- Tests of different forward detectors