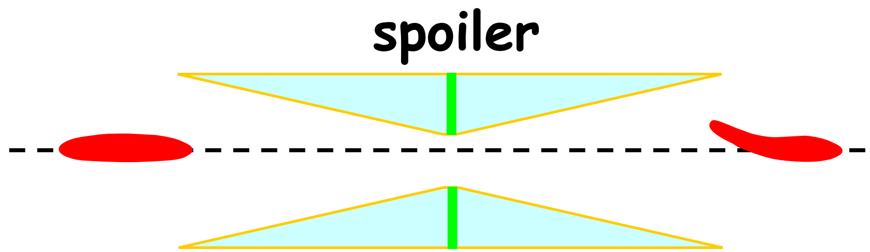
ILC Collimator Design



Nigel Watson (Birmingham)

LAL, 16-May-2006

- Aims
- Status
  - T-480 beam test
  - Damage studies
- Plans

People

- "Spoiler Wakefield and Mechanical Design" task
- Details on project web: http://hepunx.rl.ac.uk/swmd/

- Birmingham: N.Watson
- CCLRC: C.Beard,G.Ellwood,J.Greenhalgh,J.O'Dell,L.Fernandez
- CERN: F.Zimmermann,G.Rumolo,D.Schulte
- [DESY: I.Zagorodnov]
- Lancaster: D.Burton,N.Shales,J.Smith,A.Sopczak,R.Tucker
- Manchester: R.Barlow,A.Bungau,G.Kurevlev,R.Jones,A.Mercer
- TEMF, Darmstadt: M.Kärkkäinen,W.Müller,T.Weiland

- For ESA tests, working closely with
  - CCLRC on optics for wakefield and beam damage studies
  - SLAC for all aspects

Aims

Design / optimisation of spoiler jaws (geometry and materials) for wakefield and beam damage performance

- Development of improved EM modelling methods — Ongoing: analytic calcs. ECHO-2D/3D
- Benchmarking of wakefield calculations against experiments — Ongoing: Mafia, GdfidL
  - SLAC ESA beam test / data analysis — Completed 1st run
  - RF bench tests (training/code comparisons) — In preparation
- Tracking simulations with best models of wakefields — Ongoing
- Simulations of beam damage to spoilers — Ongoing
- Material studies using beam test — Planning

Project web: http://hepunx.rl.ac.uk/swmd/

Submitted 7 abstracts to EPAC, several EUROTeV reports/memos

Collimator Wakefields

- Improvements to theory (Stupakov et al)
  - Very difficult to calculate analytically - possible for simple, symmetric configurations
- Resistive wakes (tapered rectangular)
  - Kicks

$$\kappa = F_G \frac{\sqrt{2}}{\pi} \frac{r_e m_e c^2}{e^2} \frac{1}{r_1^2 \tan\alpha} \sqrt{\frac{1}{Z_0 \sigma \sigma_z}}$$

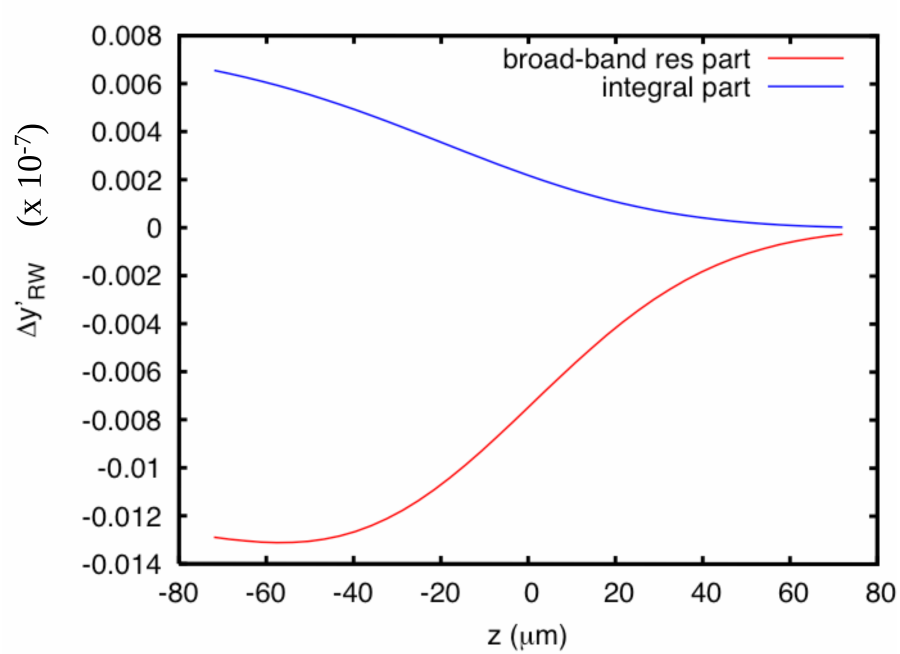
- Geometric wakes (tapered, rectangular) collimators
  - Inductive (shallow tapers)
  - Intermediate regime
  - Diffractive (steep tapers)

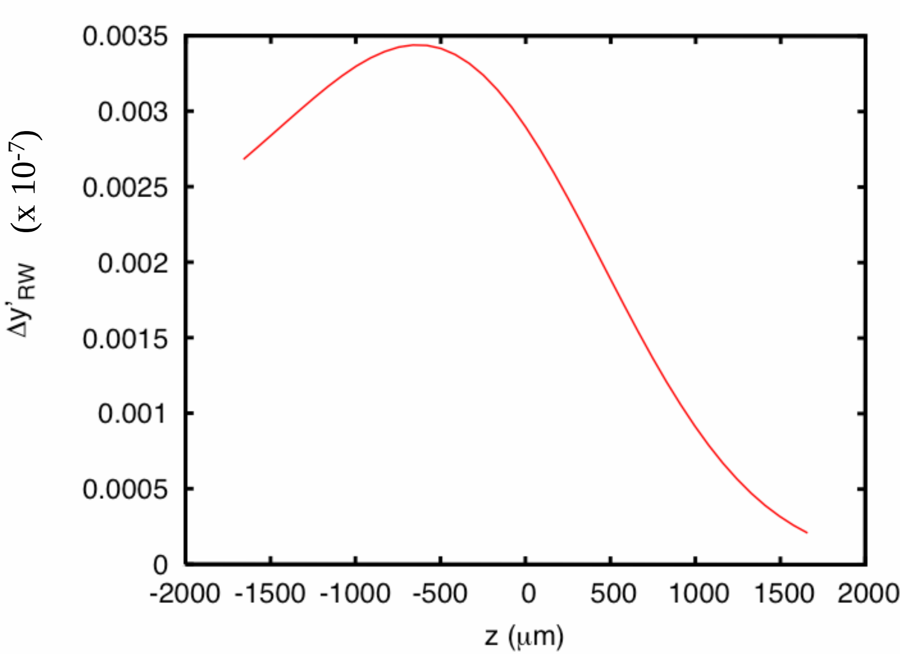
  } Behaviour on ½ gap, r, predicted ~ $1/r^2$ – $1/r^{3/2}$
- 3 runs with dedicated facility at SLAC, study geometric and resistive wakes, 2000-2004
- Analytic calculations used in TRC, assuming
  - σ is = Cu
  - No tail folding
  - Near-axis wakes (linear, dipole region)

- A C-module for wake fields has been constructed and implemented in PLACET in order to allow full tracking including the collimator wake fields
- According to the parameters of the problem, the module distinguishes between different regimes for the geometric part of the wake:
  - Inductive regime
  - Intermediate regime
  - Diffractive regime
  - Successfully started benchmarking of GdfidL

  and for the resistive wall part of the wake:
  - Short-range
  - Intermediate-range
  - Long-range

Examples of kick calculations in resistive wall wake field in the intermediate-range (left) and long-range (right) regimes.

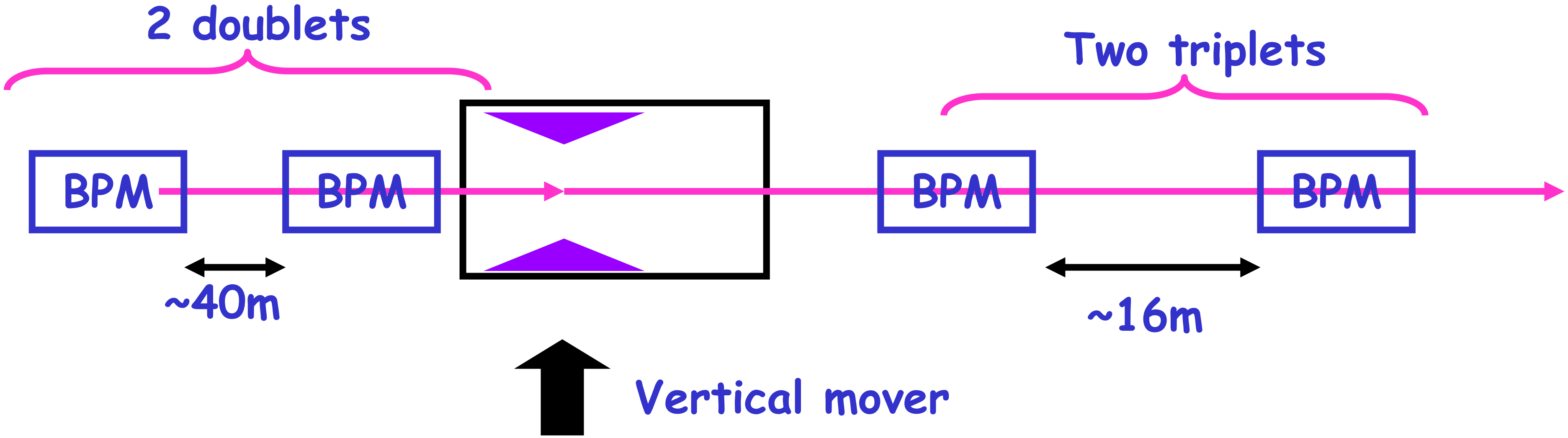




⇒ Details of the used approach and first results from actual particle tracking through the CLIC-BDS using PLACET will be presented in EPAC:

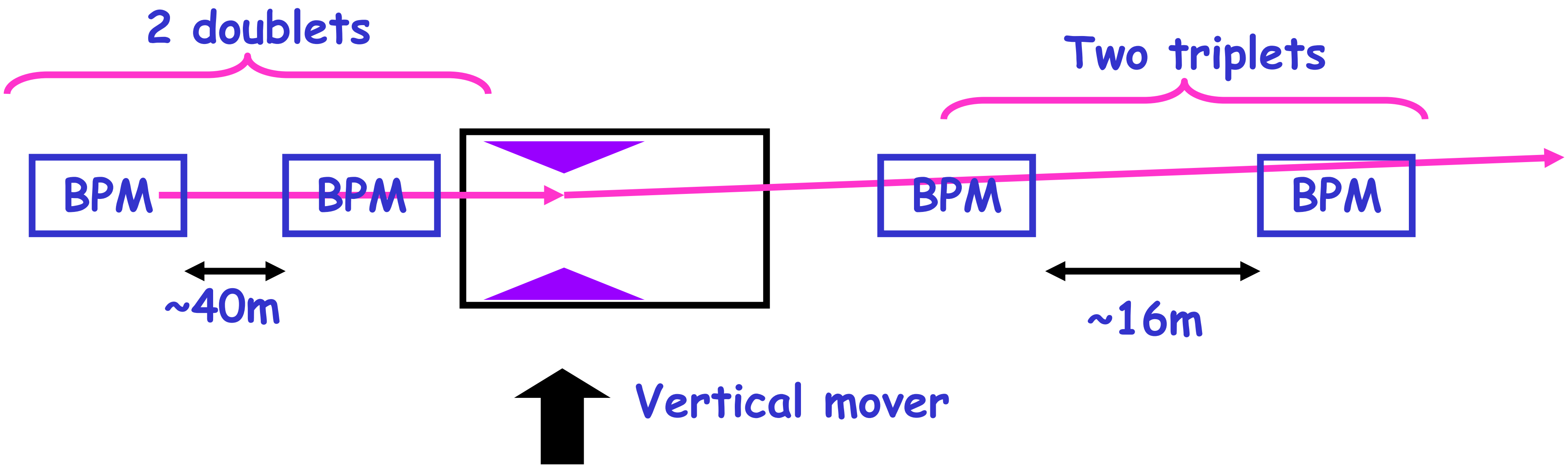
„*Effects of wake fields in the CLIC BDS*“, G.Rumolo, A. Latina and D. Schulte

T-480 Experiment



- Wakefields measured in running machines: move beam towards fixed collimators
- Problem
  - Beam movement → oscillations
  - Hard to separate wakefield effect
- Solution
  - Beam fixed, move collimators around beam
  - Measure deflection from wakefields vs. beam-collimator separation
  - Many ideas for collimator design to test…

T-480 Experiment



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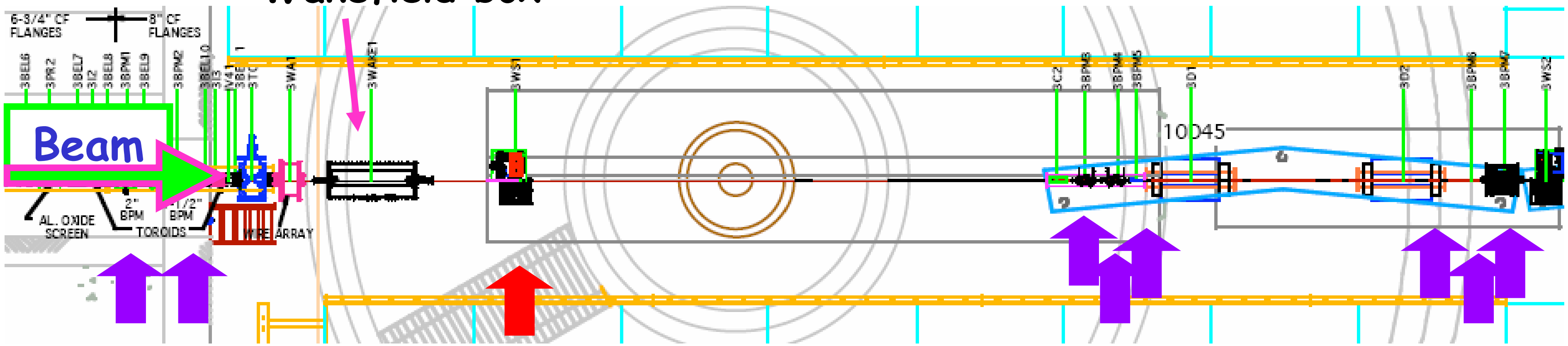
Collimator Wakefield Beam Test (T-480)

- Wakefield beam tests at ESA
  - SLAC Proposal T-480 (Watson, Tenenbaum et al), Apr-2005

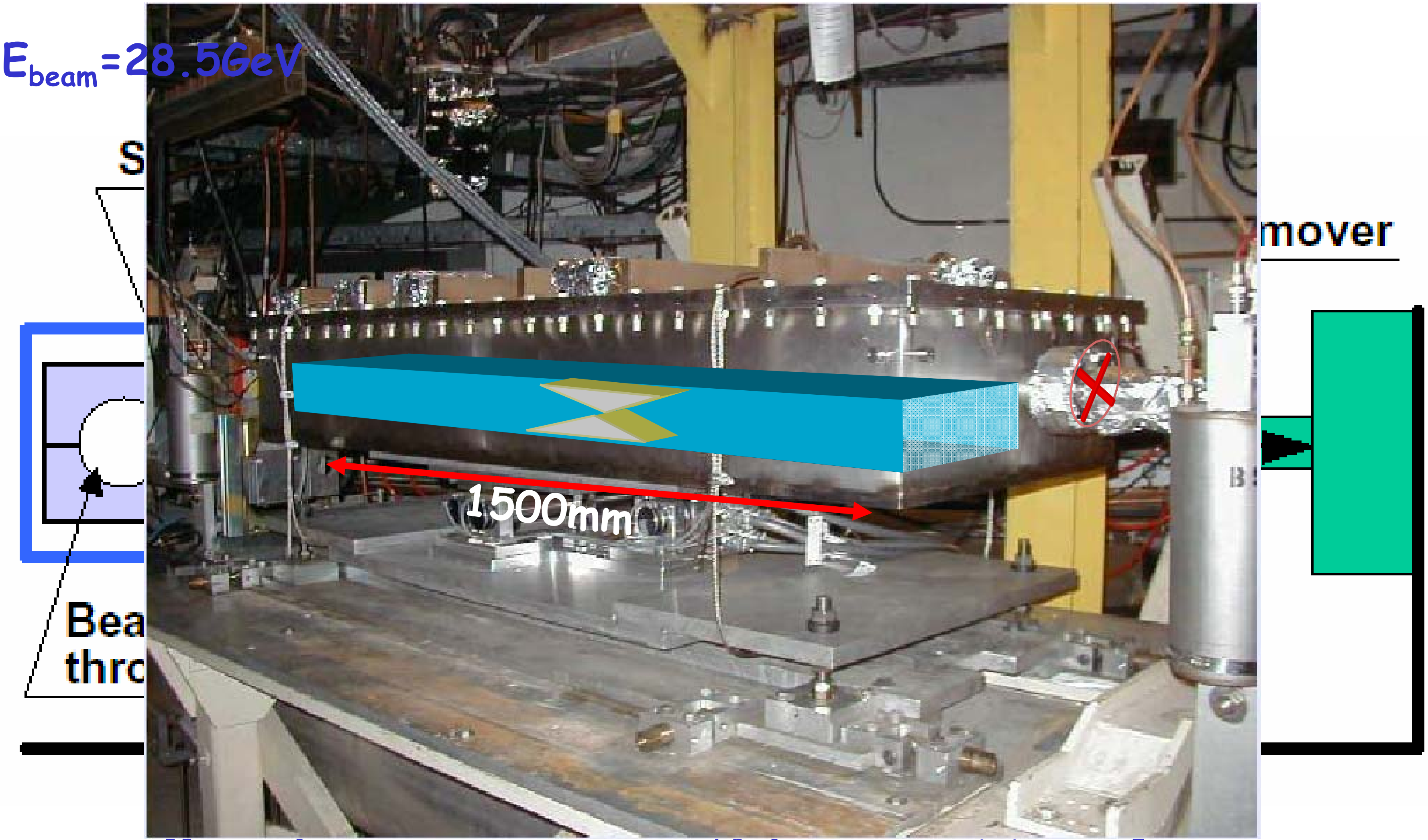
  Many people involved directly, see proposal
- Part of evolving programme of ILC tests at ESA
- Purpose
  - Commision/validate CollWake Expt. at ESA
  - Additional study of resistive wakes in Cu
  - First study of 2-step tapers
  - Development of explicit FDTD code (TEMF) for shallow tapers/short bunches
- Schedule
  - Commissioning, 4-9 Jan. 2006, 4 (old) collimators
  - Physics, 24-Apr – 8-May 2006, 8 new collimators (CCLRC)
- Data rate
  - "Real" DAQ, runs 10Hz (not via SCP) ➔ # pulses/scan point ~600
- Related activity
  - Implementation of validated/realistic 3D wakefunctions in Merlin
  - Collimator damage studies considered for ESA/TTF

ESA beamline layout (plan)



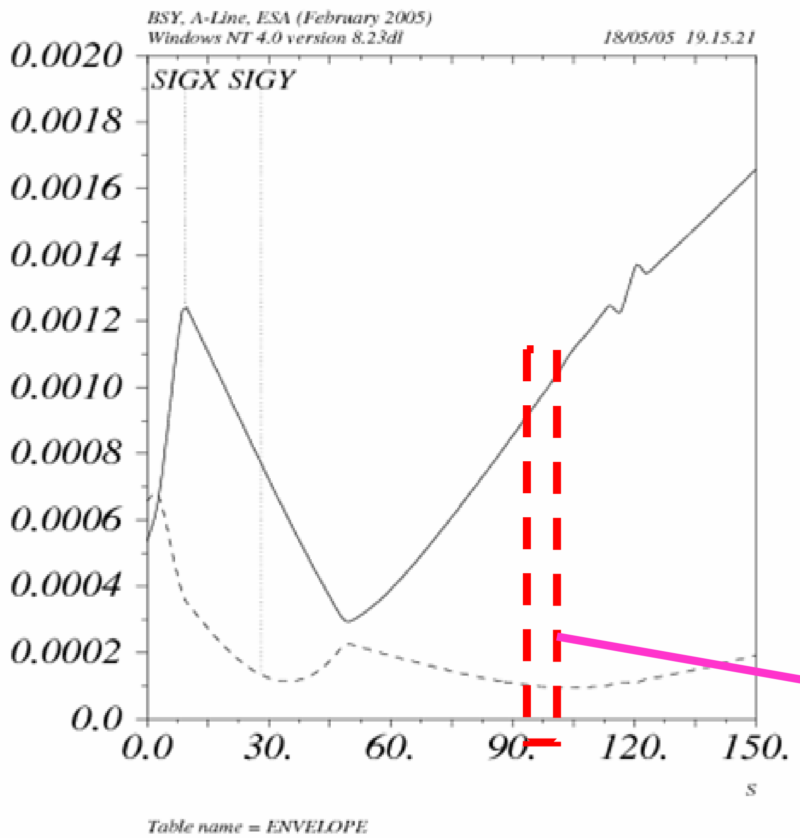
- Measure kick factor using incoming/outgoing beam trajectory, scanning collimator gap through beam
- Stage 1, 5 rf cavity BPMs, 1 stripline BPM, 2 wire scanners
  - Downstream BPMs themselves R&D project …
- Wakefield box, proposal for 2 sets of four pairs of spoiler jaws
- Each set mounted in separate "sandwich" to swap into WF box
  - (Relatively) rapid change over, in situ – ½ shift for access
  - Commissioning run, Jan 4-9, 2006
  - Physics run, 24-Apr – 8-May, 2006

Wakefield box

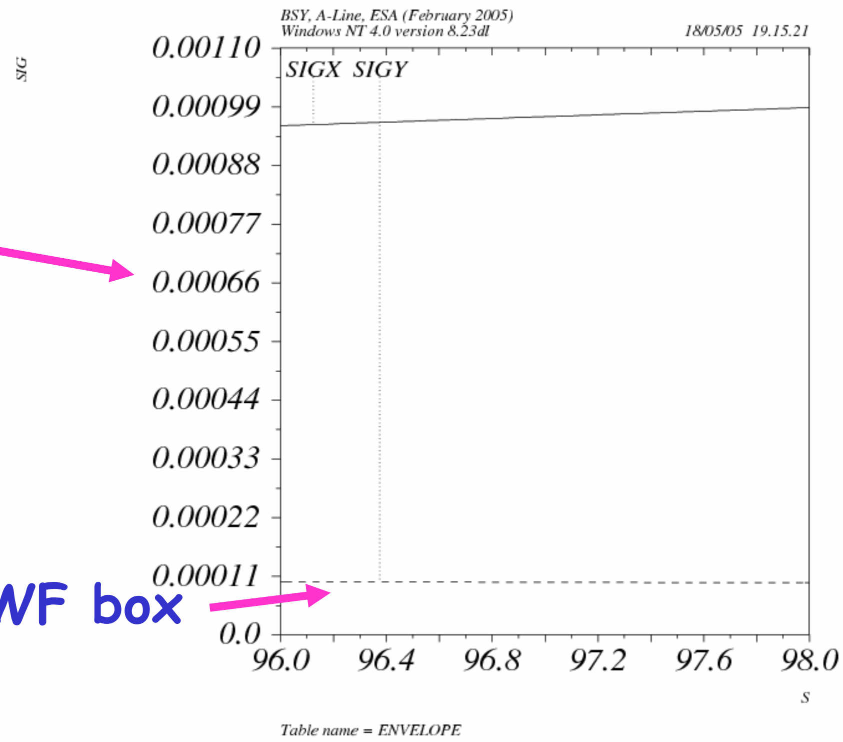


Magnet mover, y range = ±1.4mm, precision = 1μm

Optical design



- Optical design of A-line for T-480 (F.Jackson/D.Angal-Kalinin)



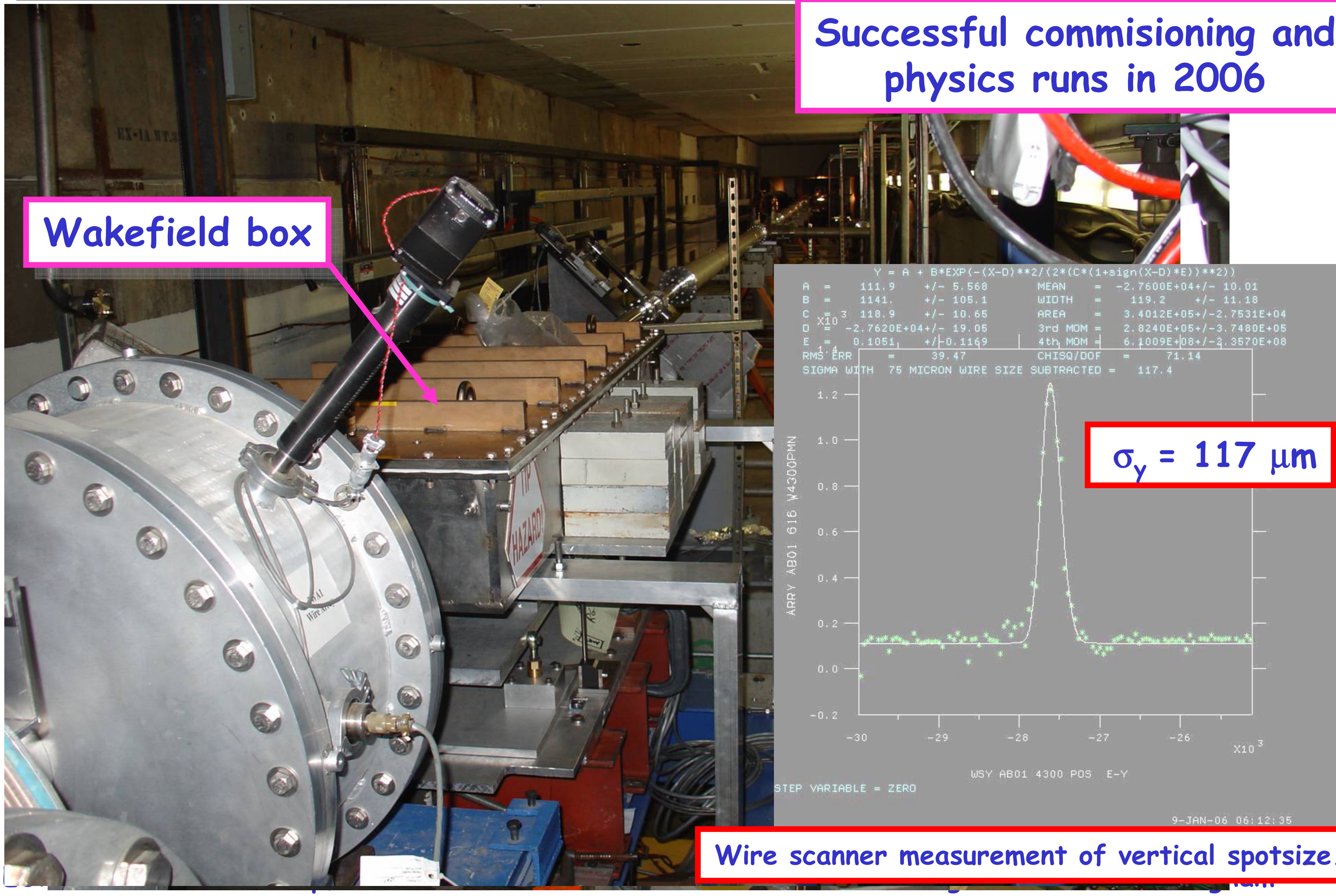
σ_y~100μm and flat in vicinity of WF box

Wakefield Box Relocation

ESA Test Beam for T-480

Successful commisioning and physics runs in 2006

Wakefield box

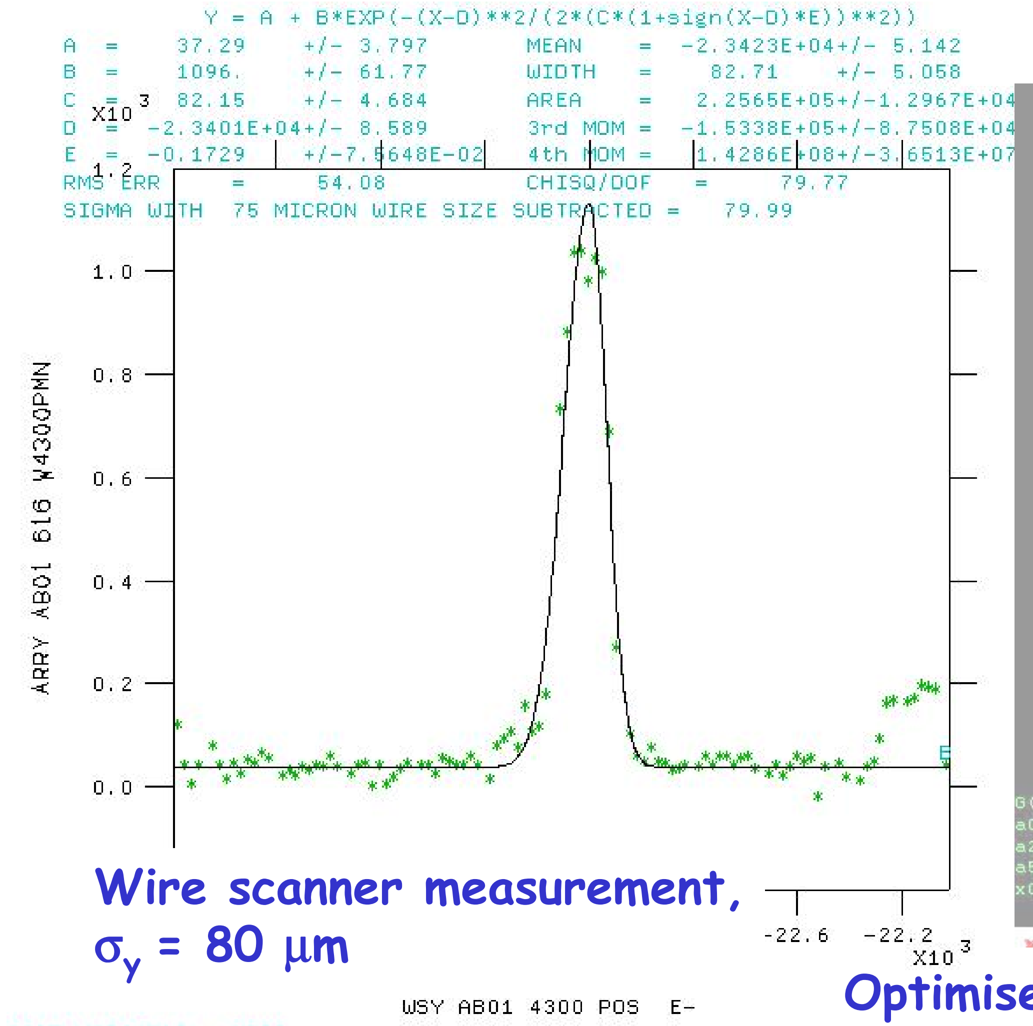


σ_y = 117 μm

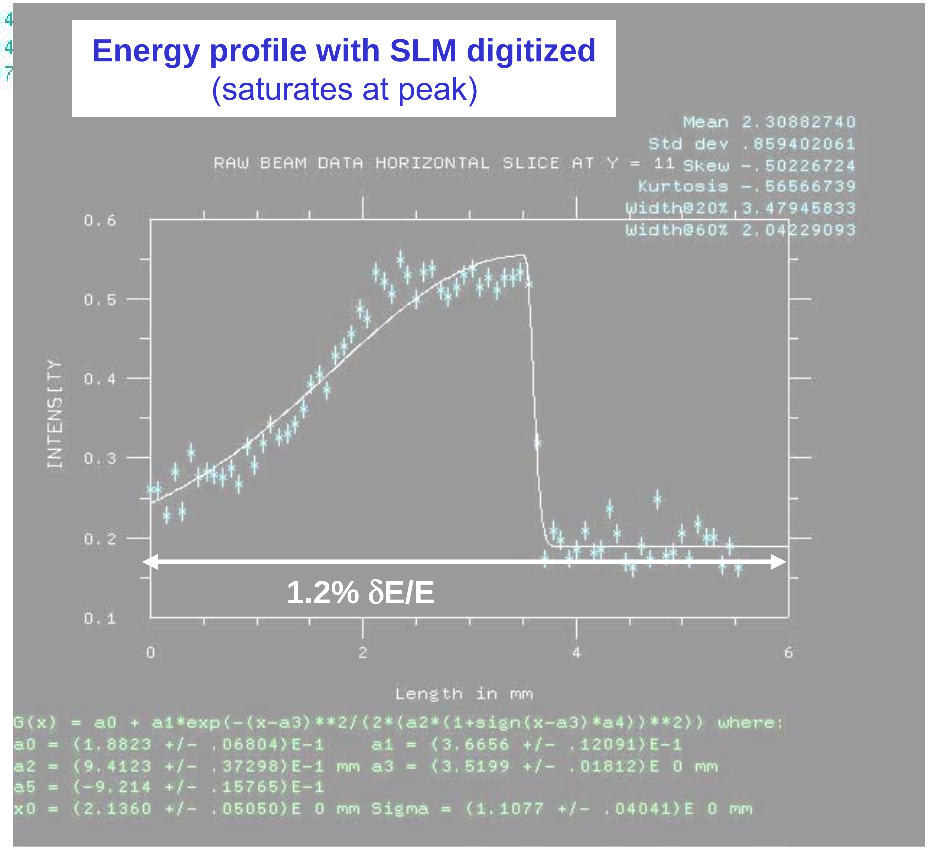
Wire scanner measurement of vertical spotsize.

Physics run, Apr-May 2006

Successful!

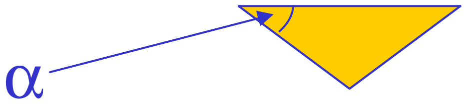


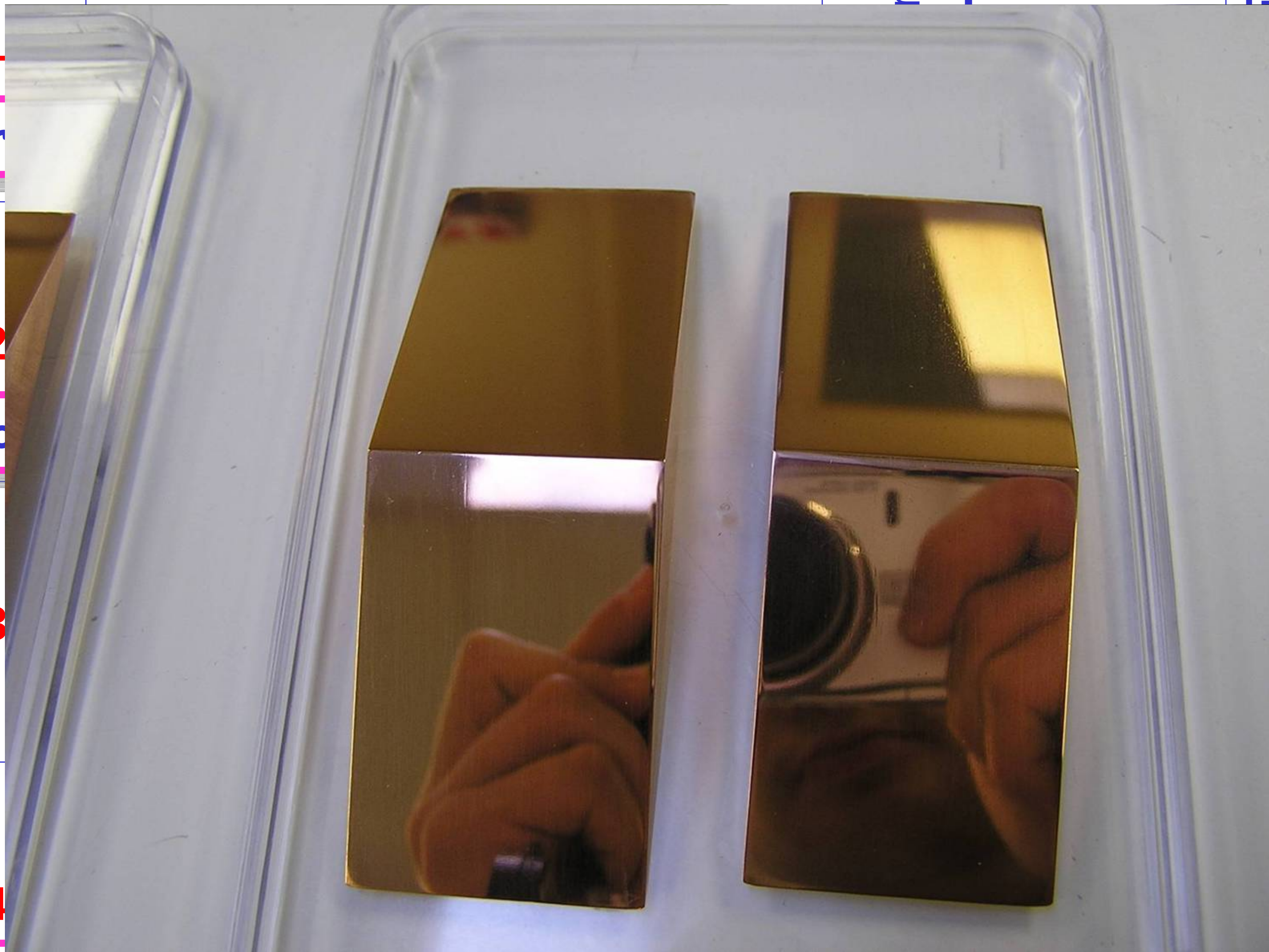
Wire scanner measurement, σ_y = 80 μm

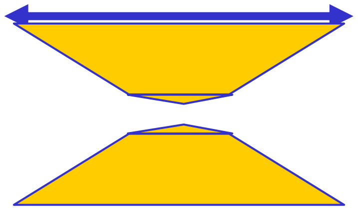
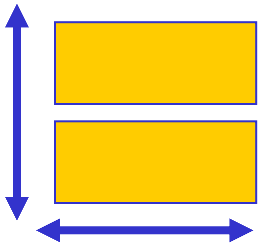
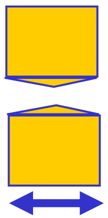
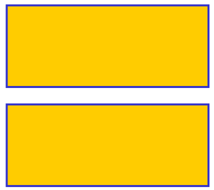
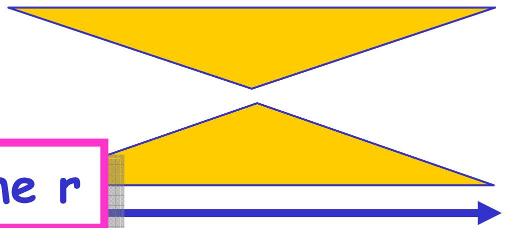
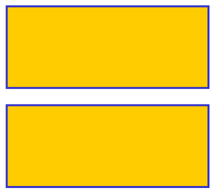
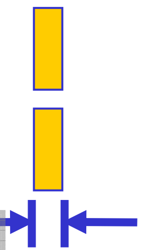
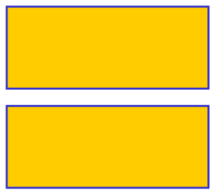


4-MAY-06 23:02:20

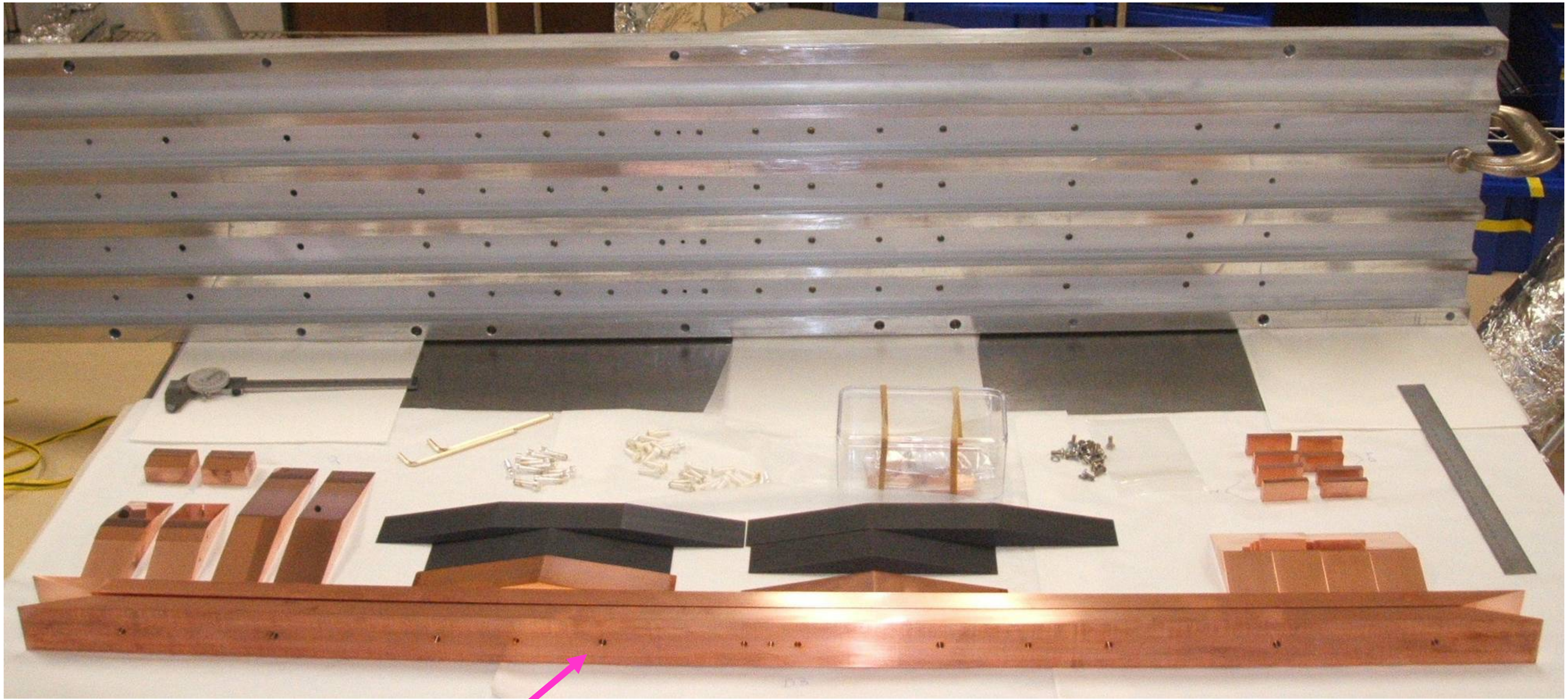
Optimised Linac injection phase, compressor voltage for short bunches removes low energy tail (for high energy tail)

Collim. #, **slot**	Side view **(“DESY sandwich”)**	Beam view	Revised 4-May-2006
1, **1** As per	 α	 mm	α=324mrad r=2.0mm
2, **2** Extenc			=324mrad =1.4mm
3, **3**			=324mrad =1.4mm
4, **4** cf. same r, tapered			=π/2rad =4.0mm



Collim.#, slot	Side view ("SLAC sandwich")	Beam view	Revised 4-May-2006
8, 1 cf. collim. 7, and same step in/out earlier data	 133mm	 38 mm h=38 mm	r_1 =4.0mm r_2 =1.4mm α_1=289mrad α_2=166mrad
7, 2 cf. collims. 4 and 6	 31mm		$\alpha_1=\pi/2$ rad α_2=166mrad r_1=4.0mm r_2=1.4mm
6, 3 cf. collim. 2, same r	 211mm		α=166mrad r=1.4mm
5, 4 cf. collim. 4 smaller r	 7 mm		$\alpha=\pi/2$rad r=1.4mm

All jaws



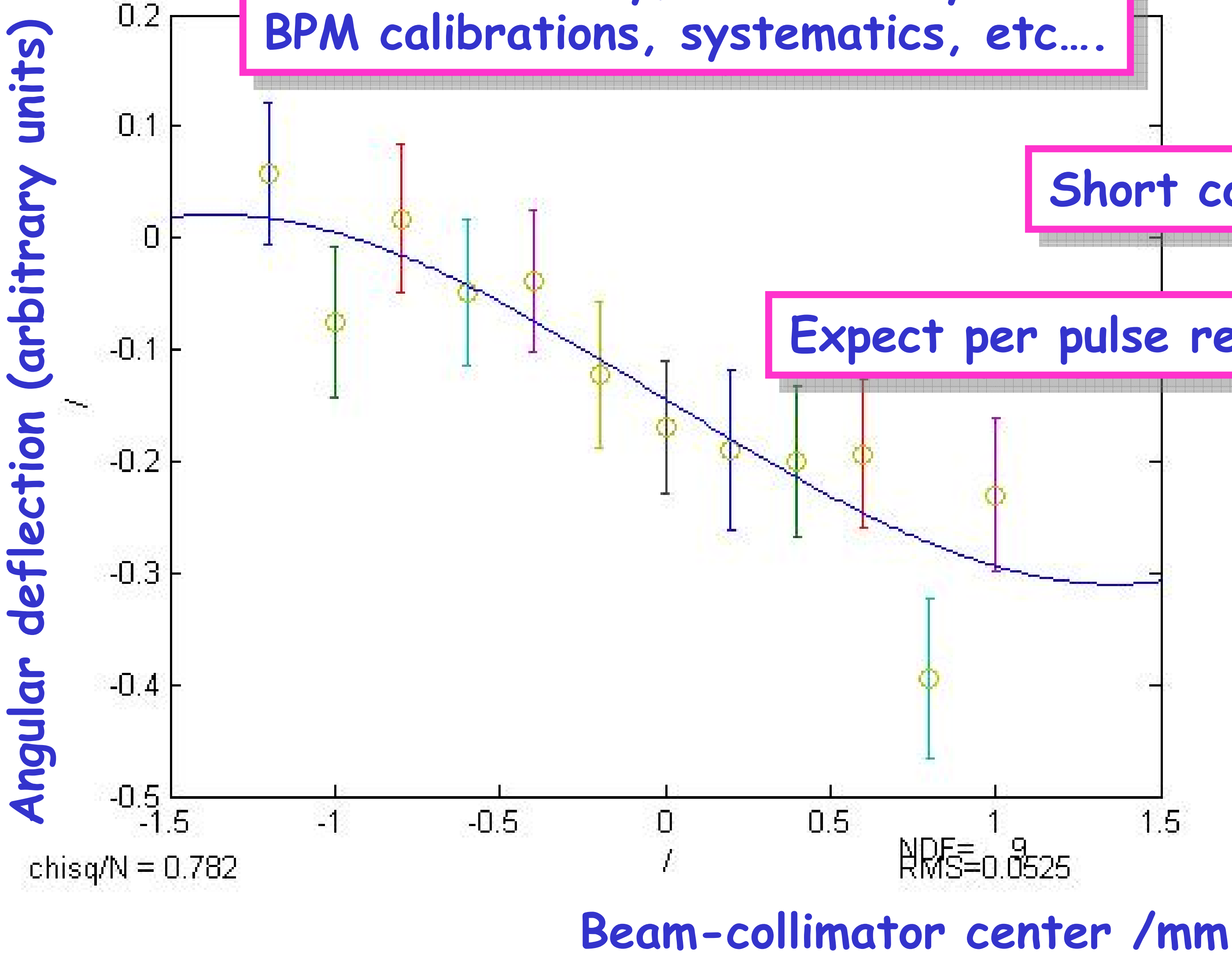
1000mm OFE Cu, ½ gap 1.4mm

First glimpse of data

Preliminary, one run only
BPM calibrations, systematics, etc….

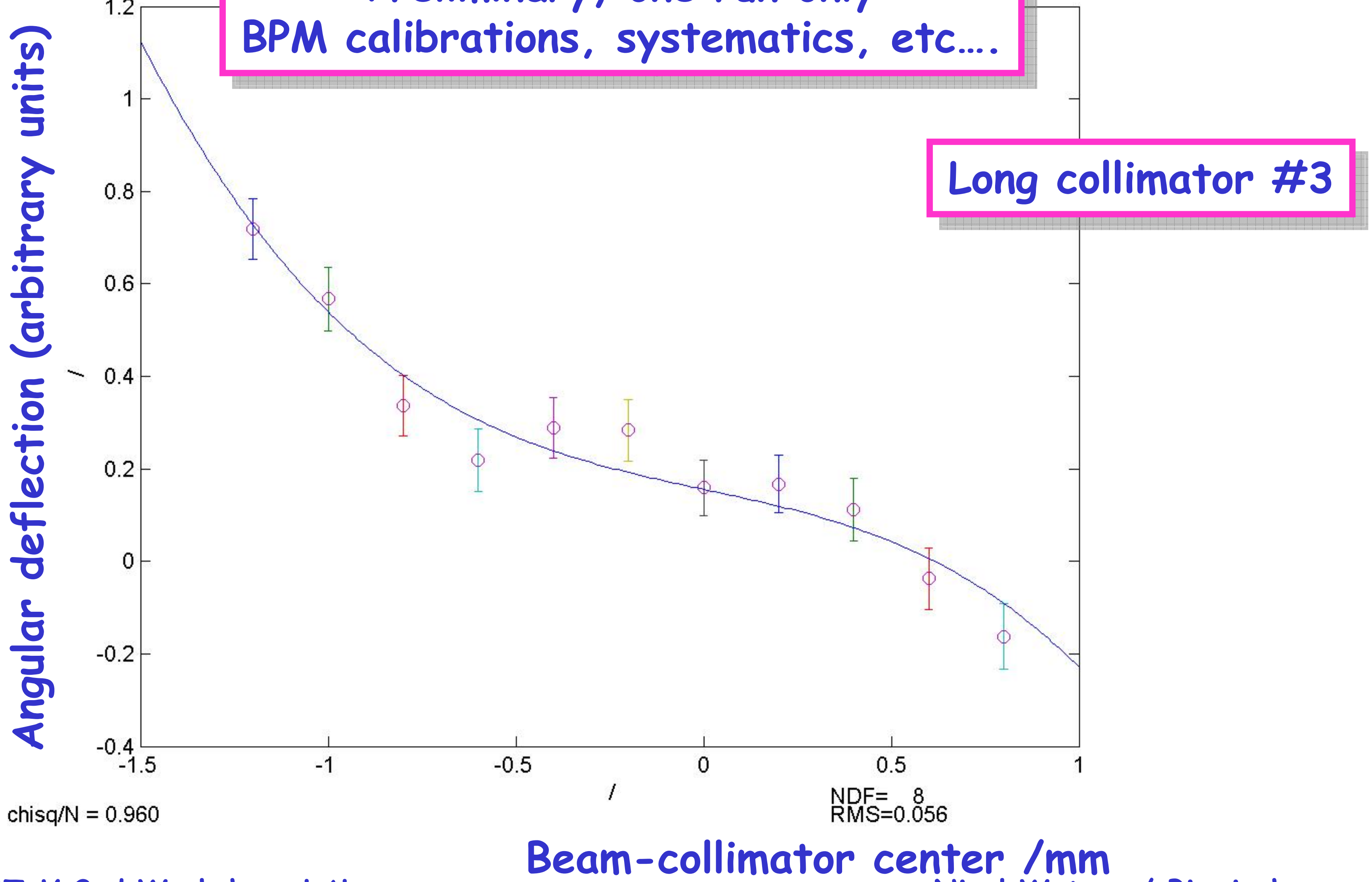
Short collimator #2

Expect per pulse resolution ~μrad

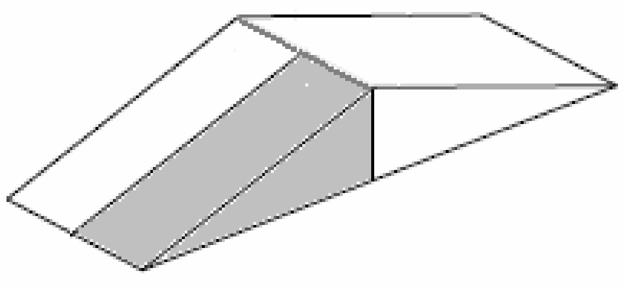


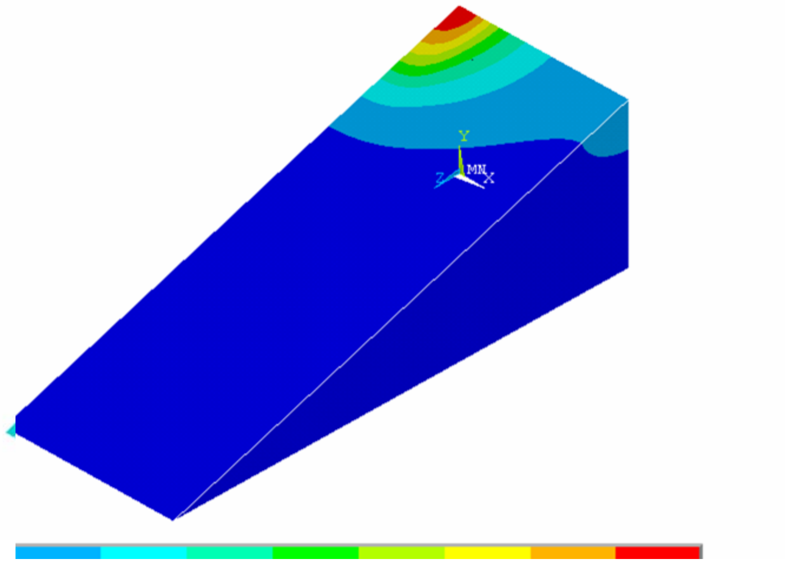
First glimpse of data

Preliminary, one run only
BPM calibrations, systematics, etc….



Damage Studies





[G.Ellwood]

- Considered steady state heating, and bunch impacts
- Energy deposition profile from Fluka/Geant4
- Study transient effects, fracture, etc.
  - Using CCLRC expertise from NF target studies as necessary
- Beam tests to be designed following simulations
  - Could use ESA, TTF?
  - Quantify damage
    - ⇒ detection also?
  - Consider using new collimators in these tests – assess impact on measured wakefields

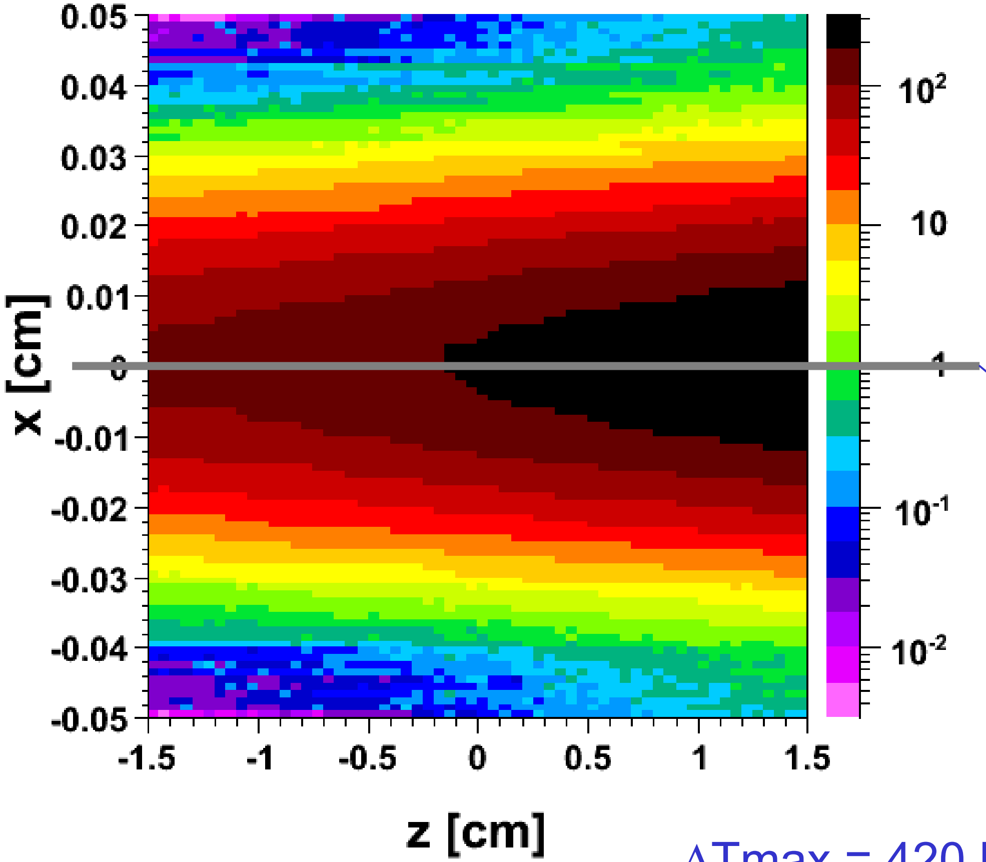
Details in EUROTeV Reports 2006-015, -021

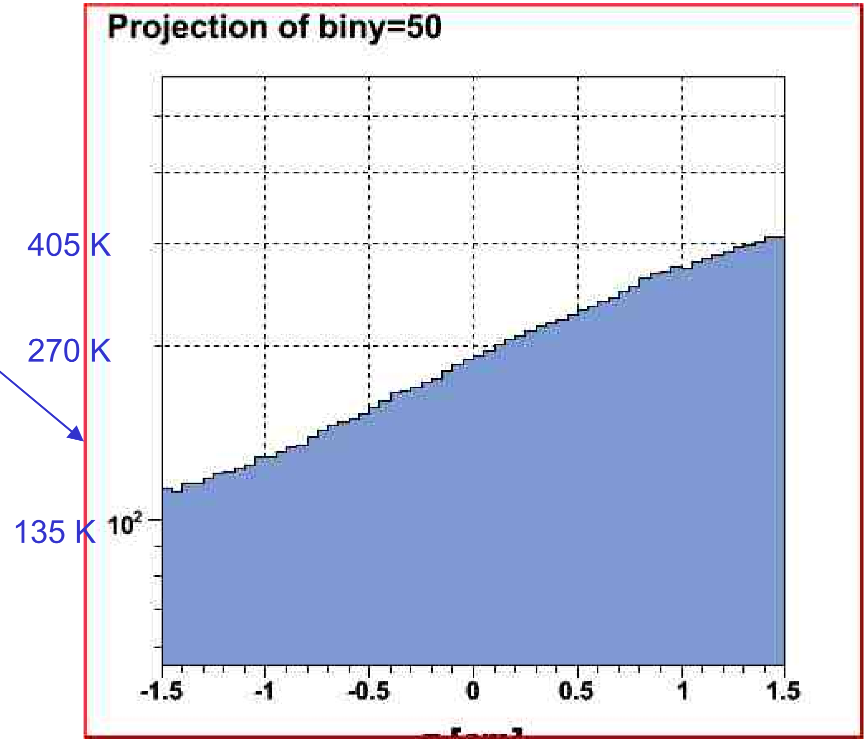
Preliminary

2 mm deep from top

Full Ti alloy spoiler

250 GeV e- [GeV/cm^3]





ΔTmax = 420 K per a bunch of 2E10 e- at 250 GeV

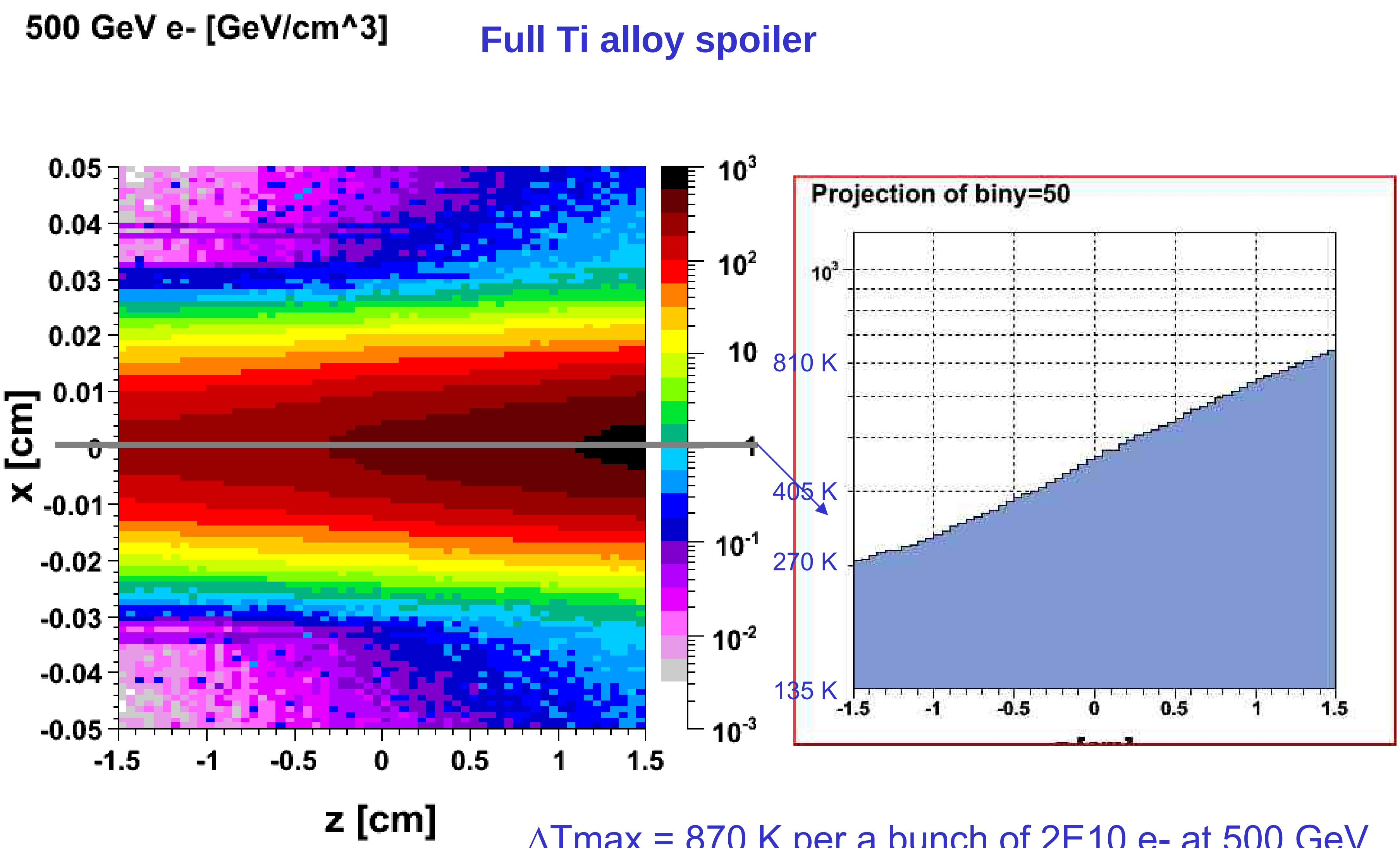
σ_x = 111 μm, σ_y= 9 μm

[L.Fernandez, ASTeC]

Preliminary

2 mm deep from top

Full Ti alloy spoiler

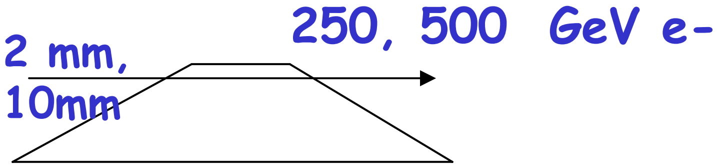


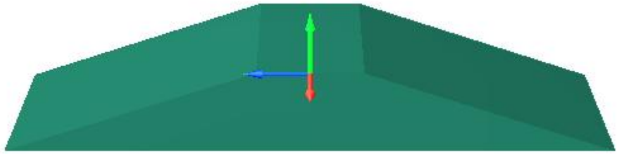
ΔTmax = 870 K per a bunch of 2E10 e- at 500 GeV

σ_x = 79.5 μm, σ_y= 6.36 μm

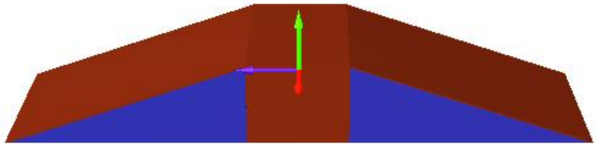
[L.Fernandez, ASTeC]

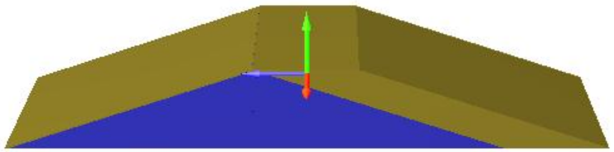
Spoilers considered include…



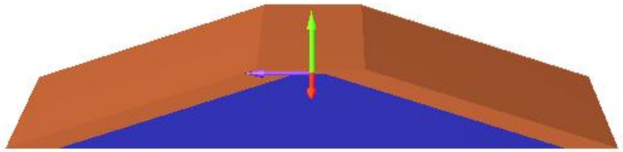


Ti/C





0.6 Xo of Ti alloy leading taper (gold), graphite (blue), 1 mm thick layer of Ti alloy

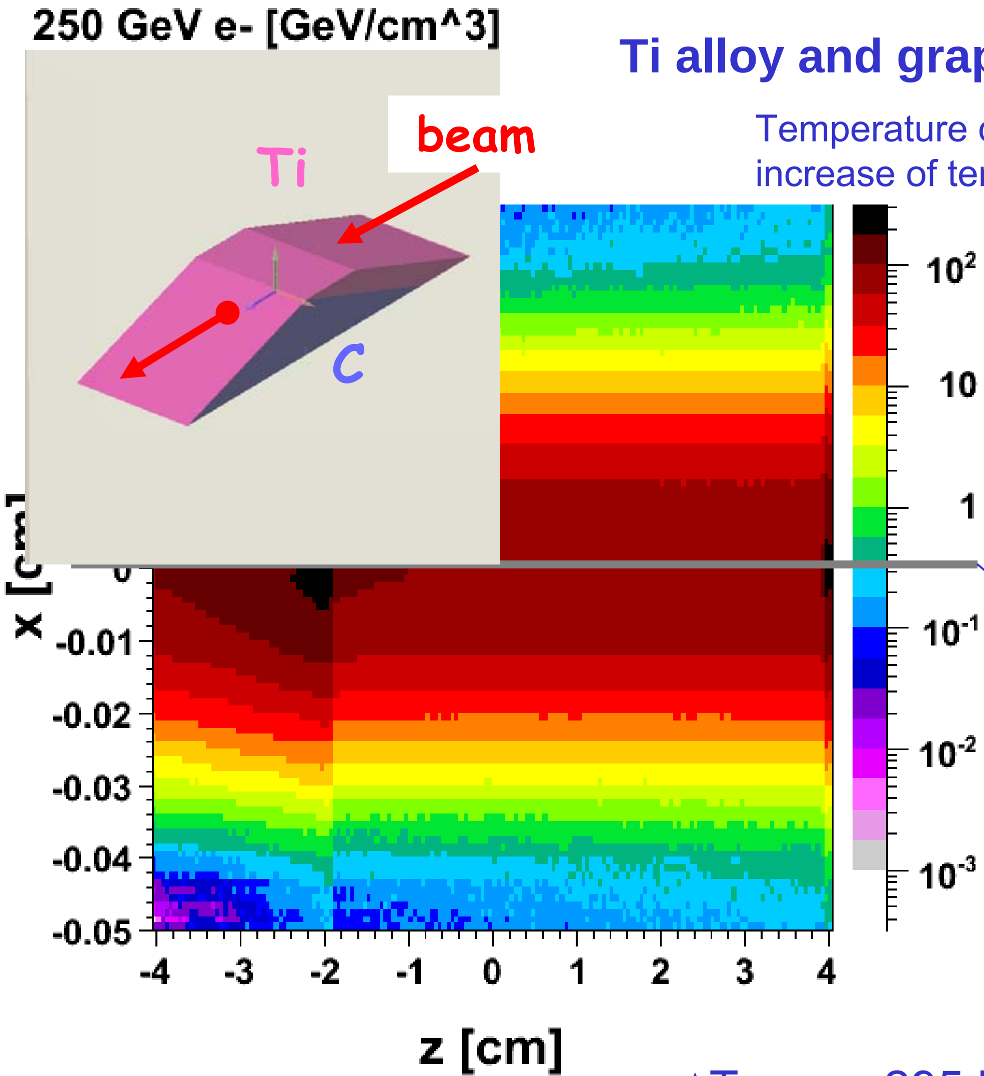


0.3 Xo of Ti alloy each side, central graphite part (blue).

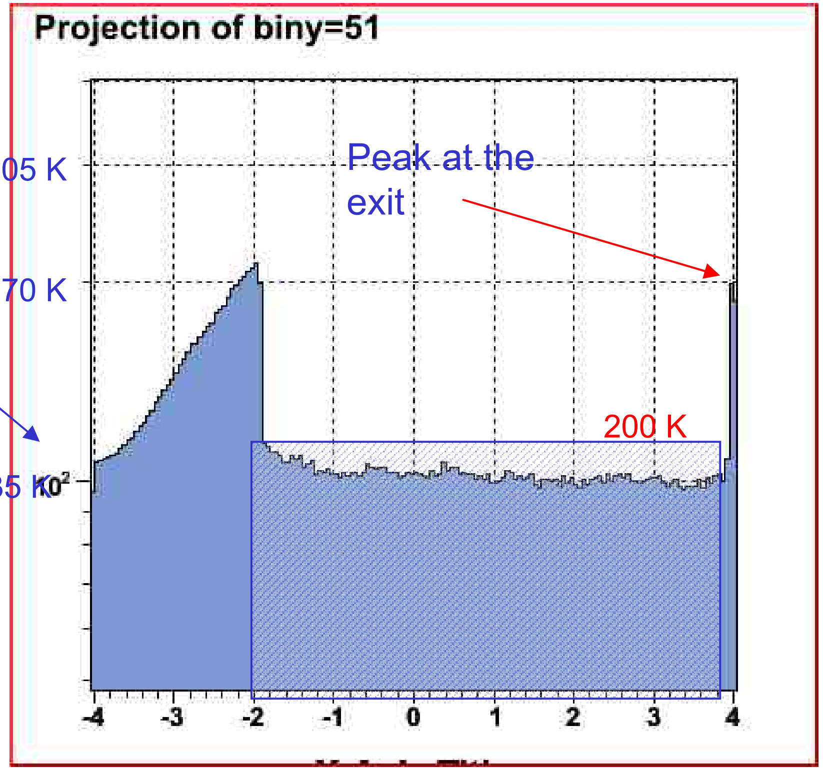
Preliminary

10 mm deep from top

Ti alloy and graphite spoiler



Temperature data in the left only valid the Ti-alloy material. Top increase of temp. in the graphite ~200 K. Dash box: graphite region.



ΔTmax = 295 K per a bunch of 2E10 e- at 250 GeV

σ_x = 111 μm, σ_y= 9 μm

[L.Fernandez, ASTeC]

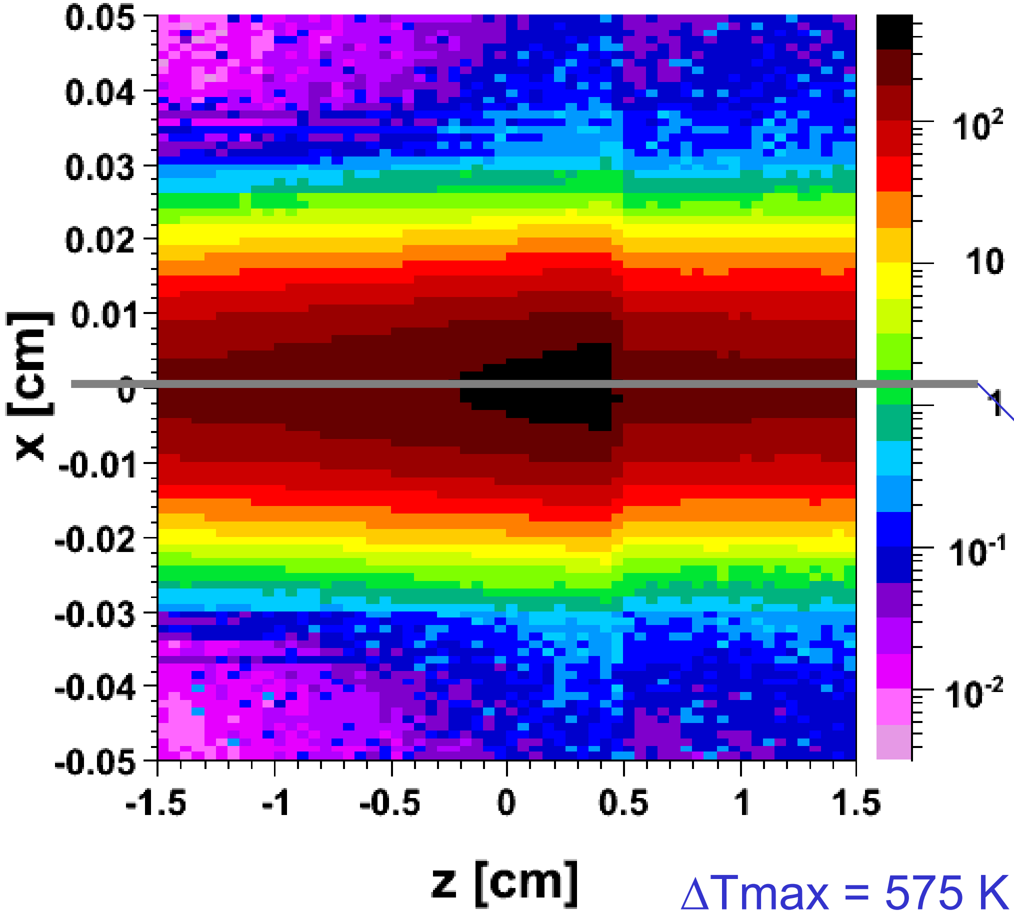
Preliminary

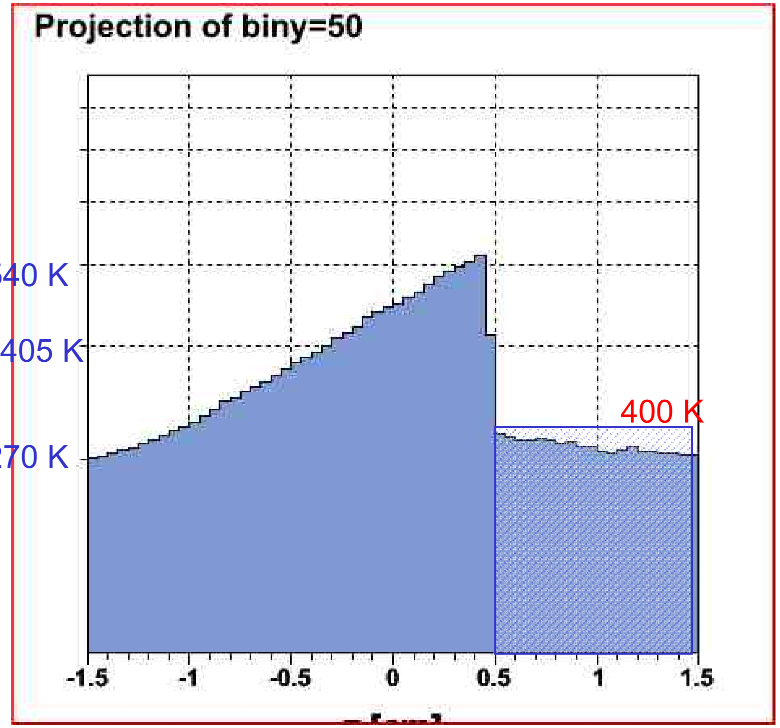
2 mm deep from top

Ti alloy and graphite spoiler

500 GeV e- [GeV/cm^3]

Temperature data in the left only valid the Ti-alloy material. Top increase of temp. in the graphite ~400 K. Dash box: graphite region.





ΔTmax = 575 K per a bunch of 2E10 e- at 500 GeV

σ_x = 79.5 μm, σ_y= 6.36 μm

[L.Fernandez, ASTeC]

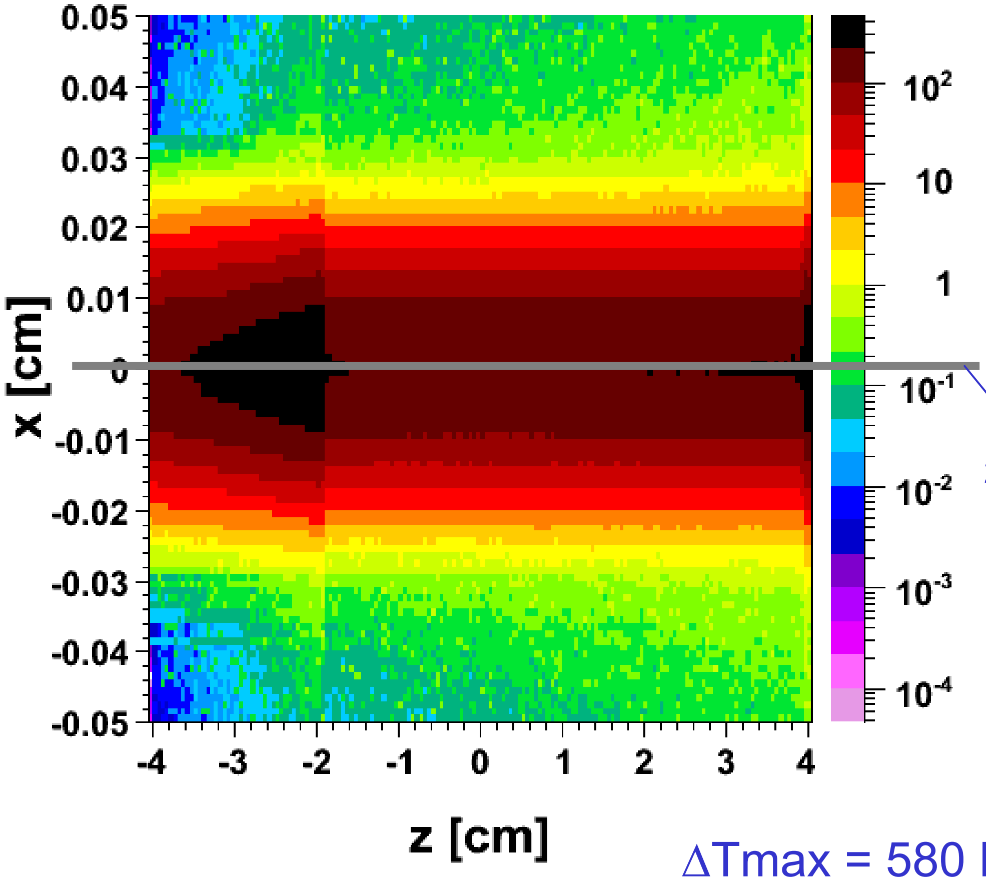
Preliminary

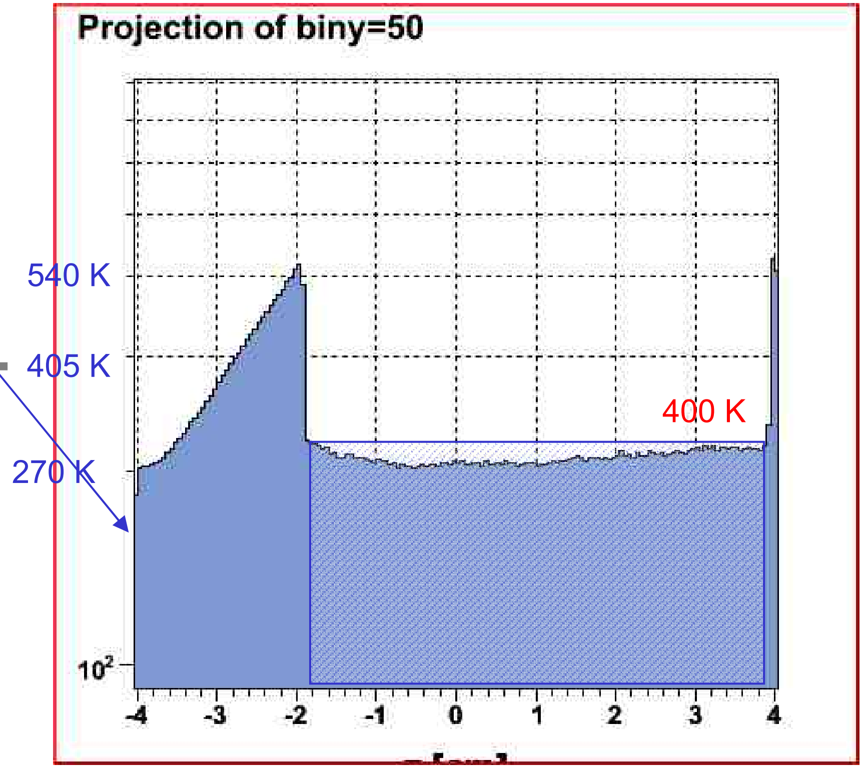
10 mm deep from top

Ti alloy and graphite spoiler

500 GeV e- [GeV/cm^3]

Temperature data in the left only valid the Ti-alloy material. Top increase of temp. in the graphite ~400 K. Dash box: graphite region.





ΔTmax = 580 K per a bunch of 2E10 e- at 500 GeV

σ_x = 79.5 μm, σ_y= 6.36 μm

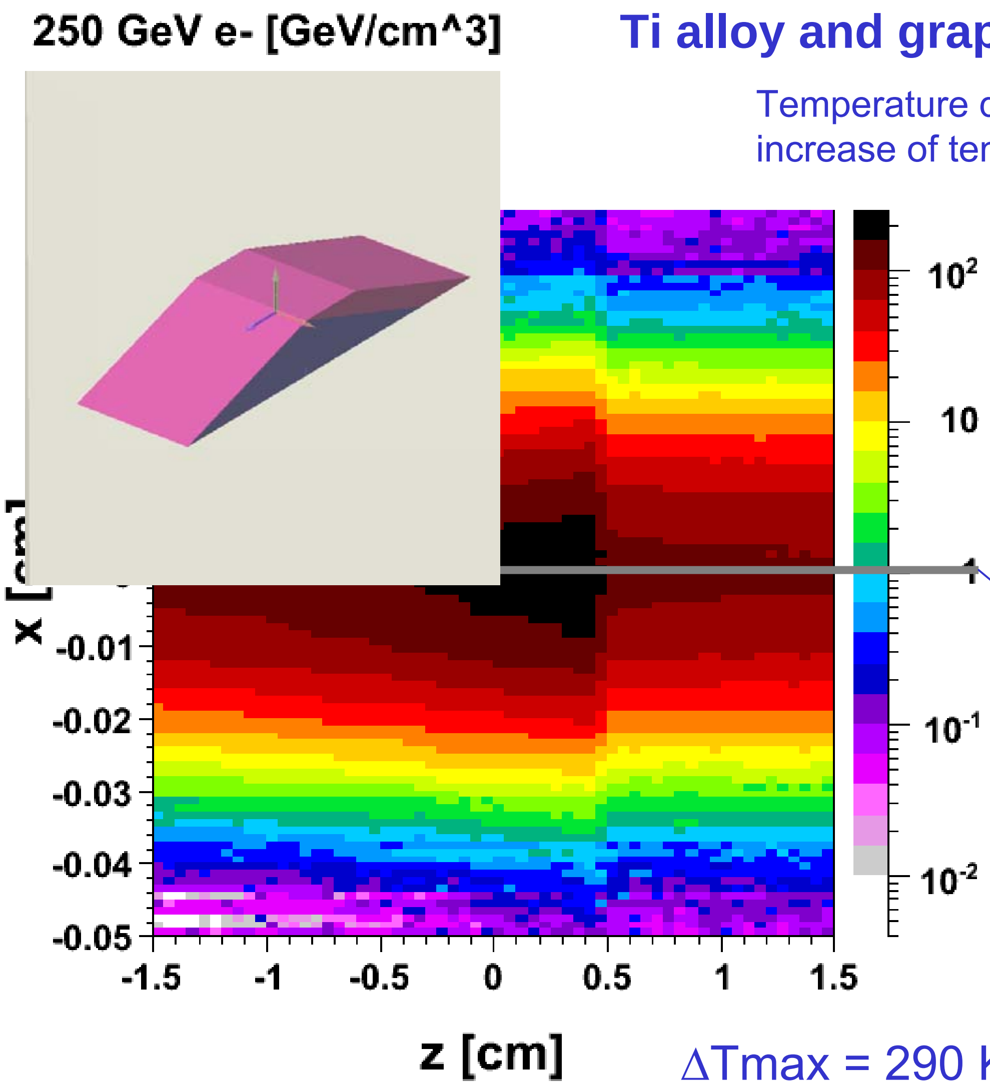
[L.Fernandez, ASTeC]

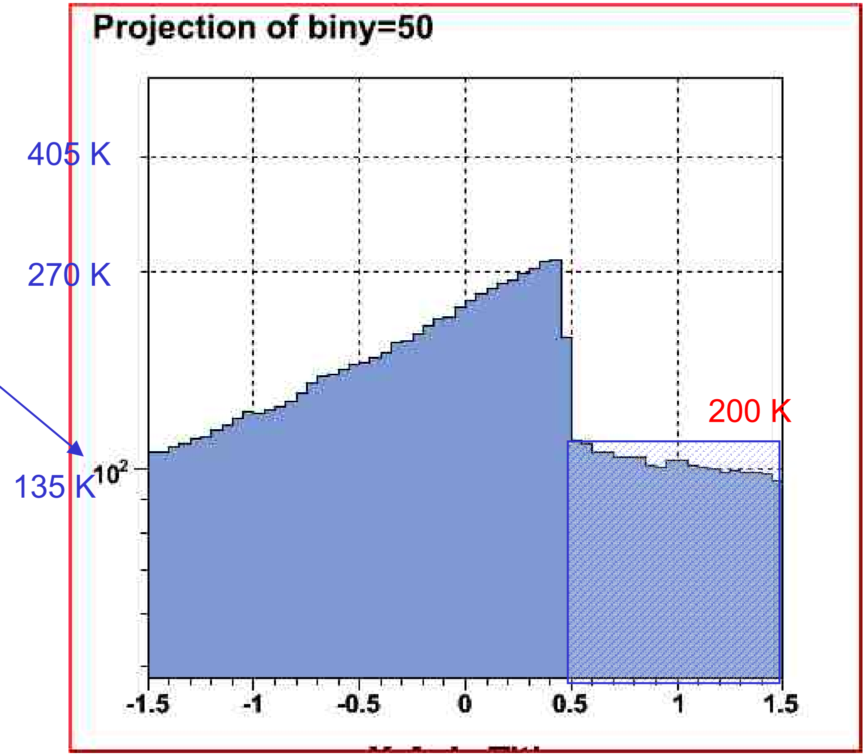
Preliminary

2 mm deep from top

Ti alloy and graphite spoiler

Temperature data in the left only valid the Ti-alloy material. Top increase of temp. in the graphite ~200 K. Dash box: graphite region.





ΔTmax = 290 K per a bunch of 2E10 e- at 250 GeV

σ_x = 111 μm, σ_y= 9 μm

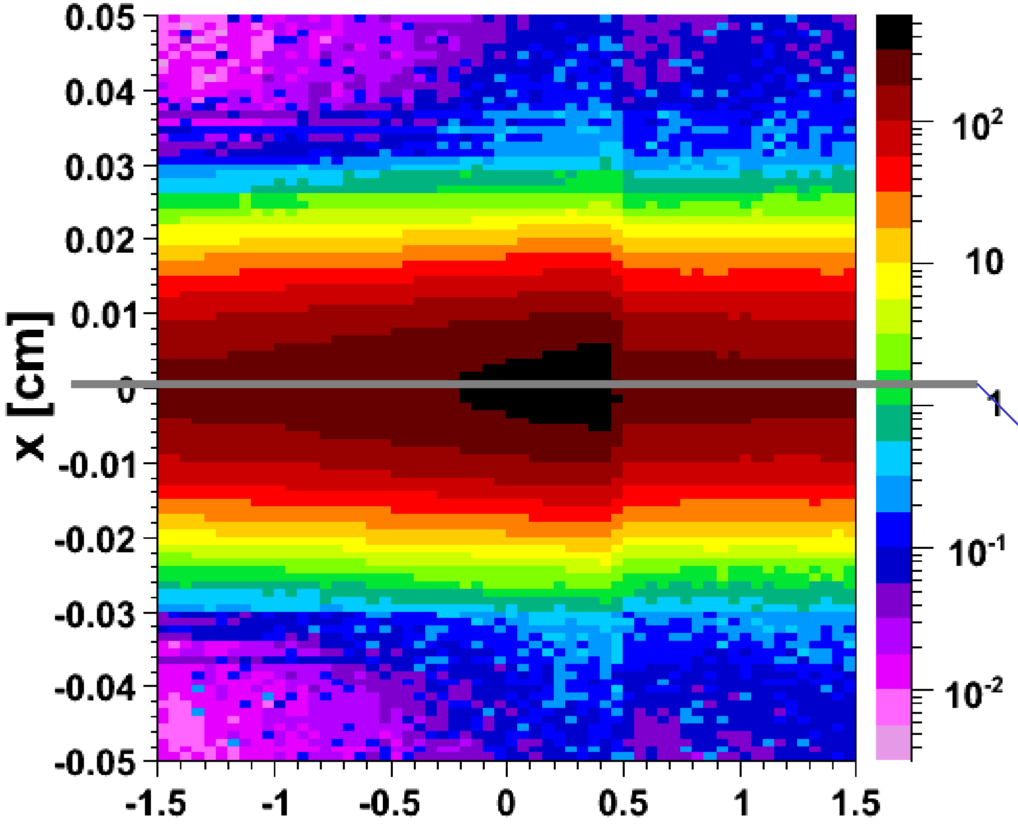
[L.Fernandez, ASTeC]

2 mm deep from top

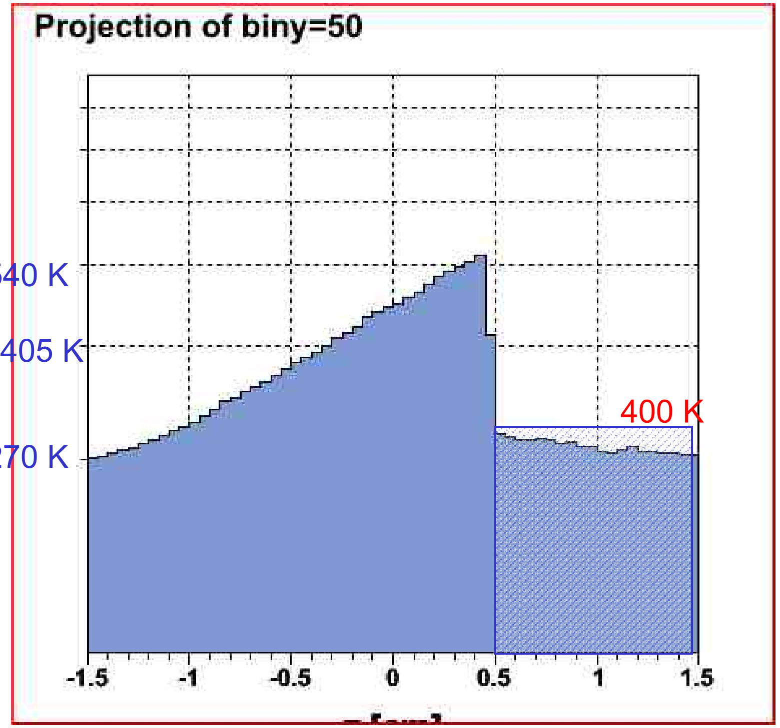
Ti alloy and graphite spoiler

500 GeV e- [GeV/cm^3]

Temperature data in the left only valid the Ti-alloy material. Top increase of temp. in the graphite ~400 K. Dash box: graphite region.



z [cm]

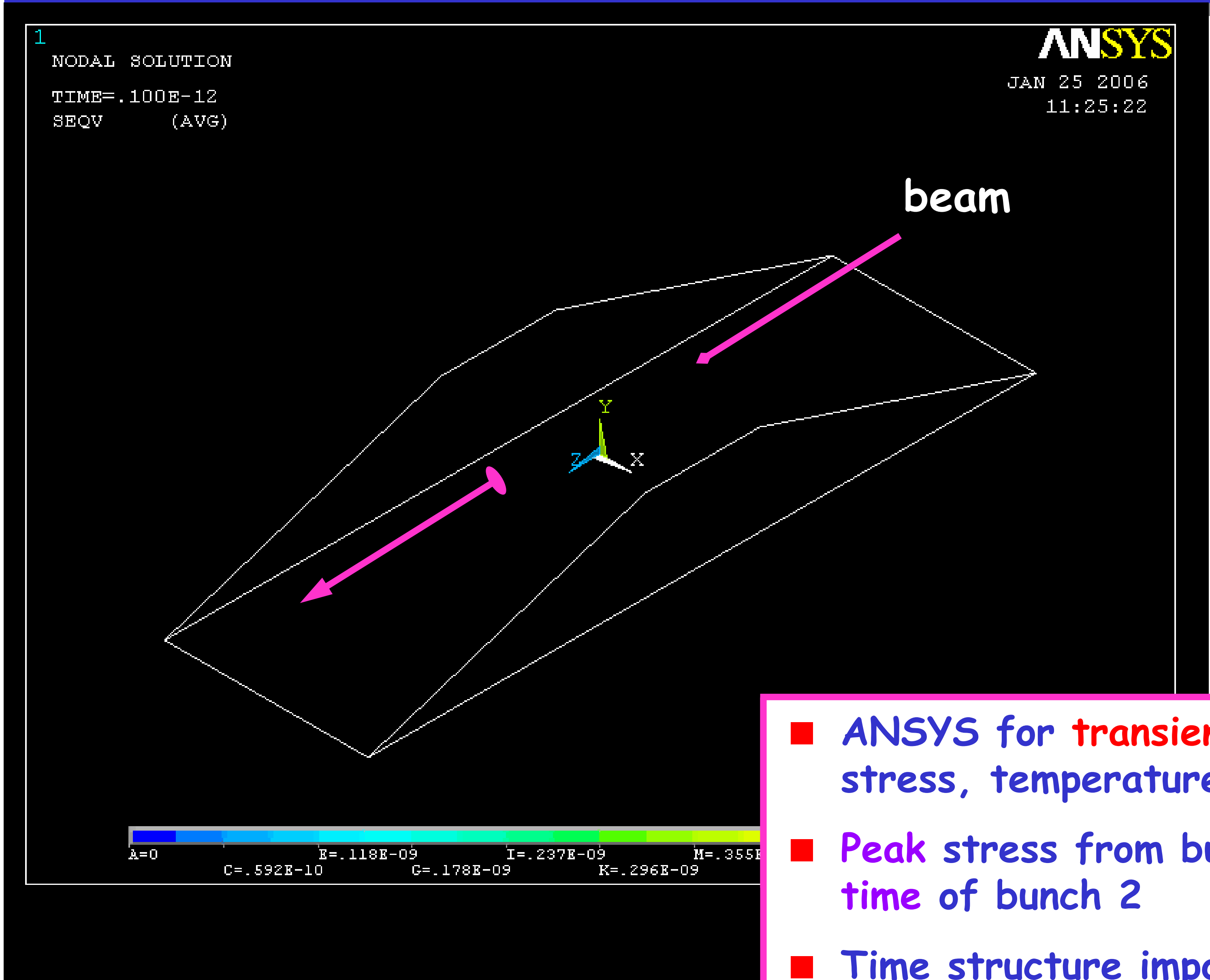


ΔTmax = 575 K per a bunch of 2E10 e- at 500 GeV

σ_x = 79.5 μm, σ_y= 6.36 μm

[L.Fernandez, ASTeC]

2 ILC bunches



[Ellwood/RAL]

- ANSYS for transient mechanical stress, temperature rise
- Peak stress from bunch 1 ~ arrival time of bunch 2
- Time structure important for tests