A Segmented Beam Dump for the Test Beam Line at CTF3

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November 24, 2011

Outline

- Motivation
  - Measure what, where and why?

- Segmented Beam Dump

- Results
  - Performance
  - Beam measurement examples

- Conclusion and outlook

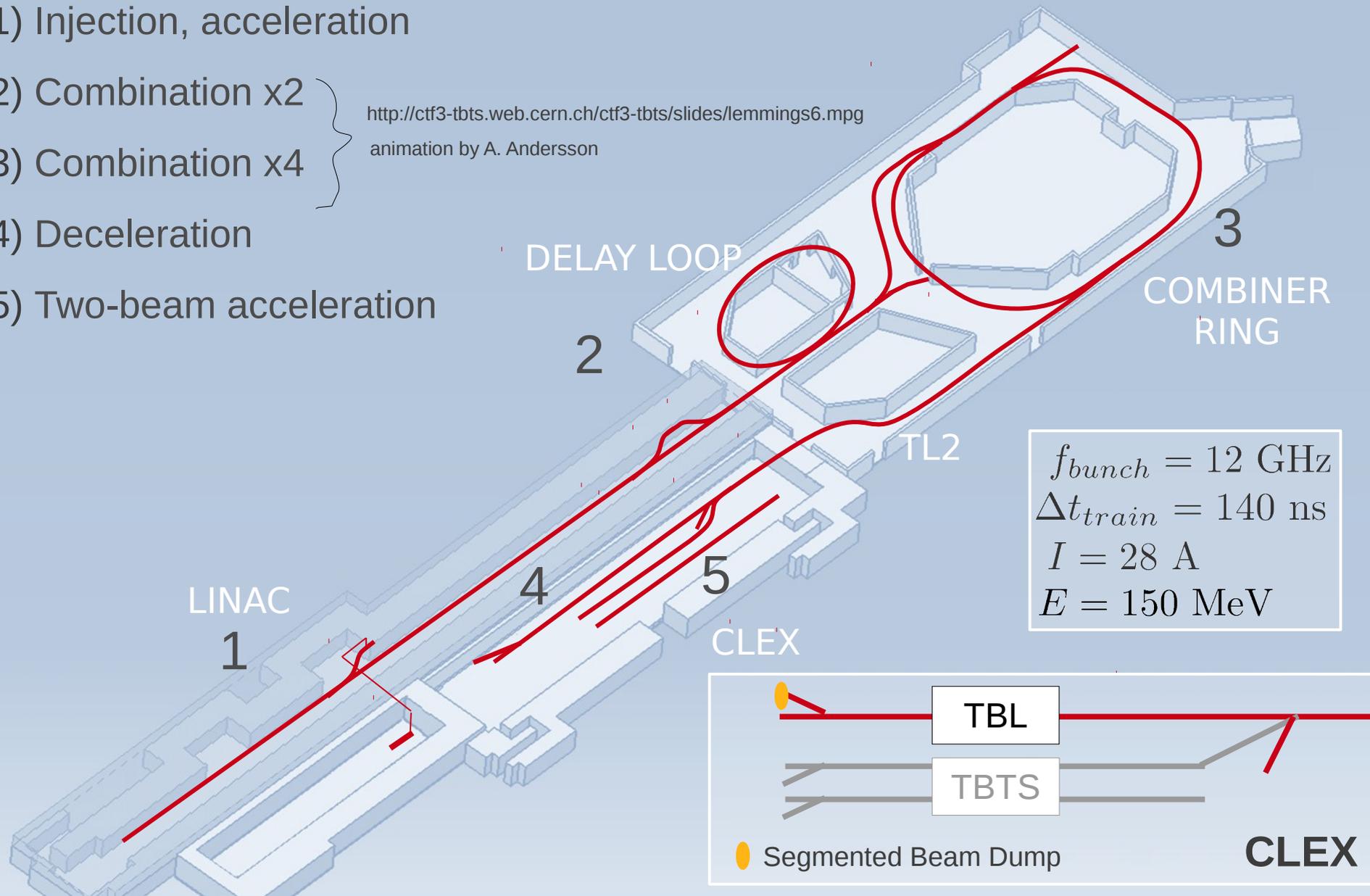# CTF3 – The CLIC Test Facility

1) Injection, acceleration

2) Combination x2

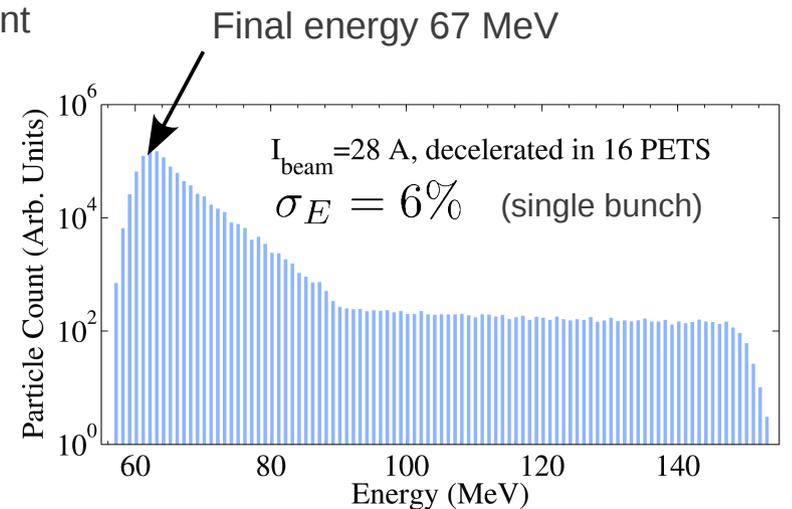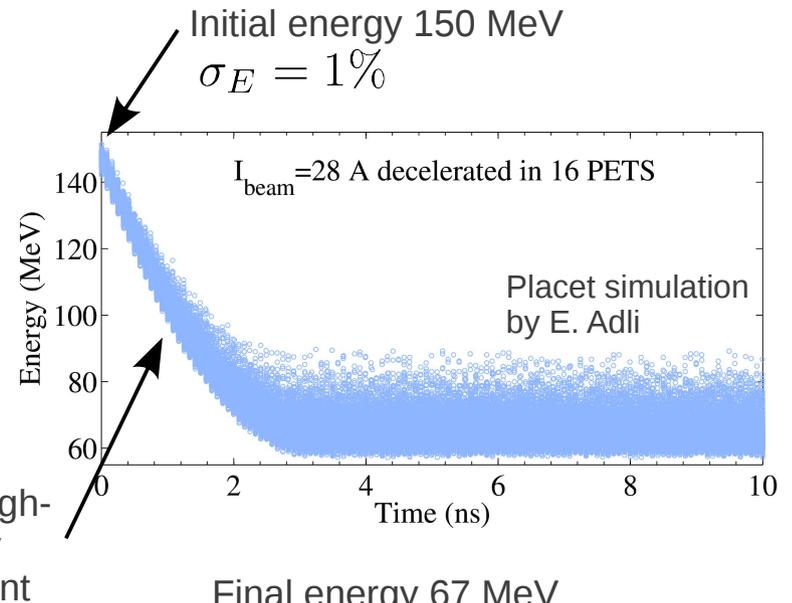3) Combination x4

4) Deceleration

5) Two-beam acceleration

http://ctf3-tbts.web.cern.ch/ctf3-tbts/slides/lemmings6.mpg

animation by A. Andersson

DELAY LOOP

2

COMBINER
RING

3

TL2

$f_{bunch} = 12$ GHz
$\Delta t_{train} = 140$ ns
$I = 28$ A
$E = 150$ MeV

LINAC

1

4

5

CLEX

TBL

TBTS

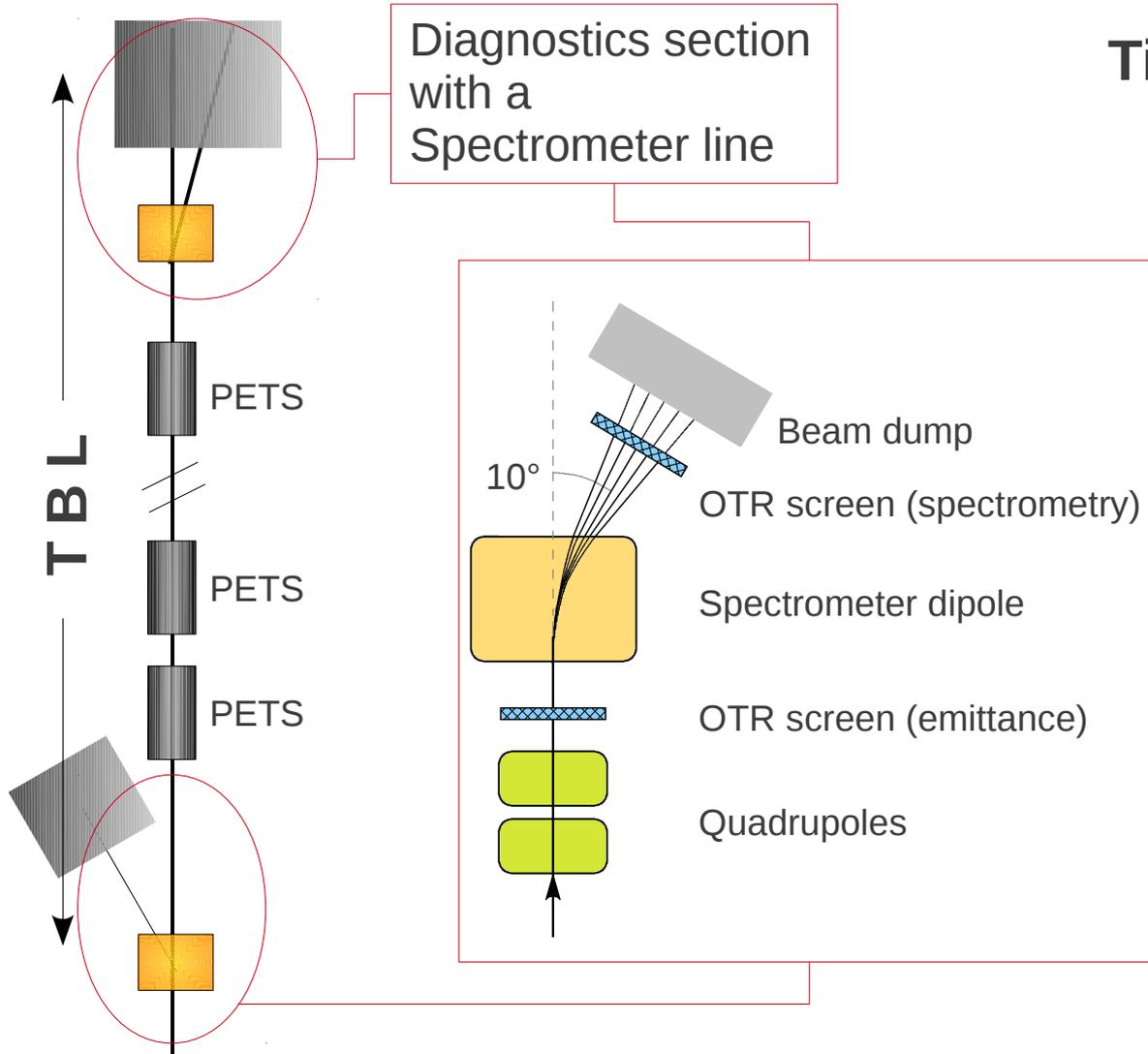Segmented Beam Dump

CLEX

TBL - The Test Beam Line

- **Small-scale Drive Beam decelerator:**

  – Goal study beam transport under deceleration

- **Space for 16 PETS, 9 PETS installed so far**

- **5.2 MeV deceleration for nominal beam (28 A, 12 GHz)**

Initial energy 150 MeV
$$\sigma_E = 1\%$$

I_{beam}=28 A decelerated in 16 PETS

Placet simulation by E. Adli

3 ns high-energy transient

Final energy 67 MeV

I_{beam}=28 A, decelerated in 16 PETS

$$\sigma_E = 6\%$$ (single bunch)

PETS
 - Power Extraction and Transfer Structure
High-impedance structure
Strong wakefield built up coherently with the beam passage

Spectrometry in TBL

Diagnostics section with a Spectrometer line

10°

Beam dump

OTR screen (spectrometry)

Spectrometer dipole
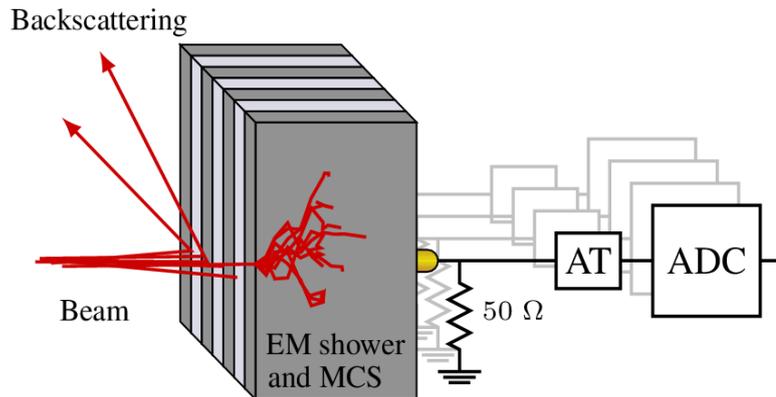
OTR screen (emittance)

Quadrupoles

PETS

PETS

PETS

TBL

Time-resolved spectrometry:

- OTR screen imaged by gated camera
  - Multi-shot
  - 20 ns time resolution
- OTR on streak camera
  - Long optical lines
  - "Expert" operation
- … Segmented beam dump?
  - + Single-shot
  - + Simple, robust
  - + Good S/N

Segmented Beam Dump


Backscattering

Beam

EM shower and MCS

AT ADC

50 Ω

- Detection principle same as Faraday cup: stop particle and measure absorbed charge as current.
- Horizontal segmentation --> spectrometric profile.
- Fast sampling --> time-resolved profile

FLUKA simulation

— Tungsten
— Stainless Steel
— Carbon
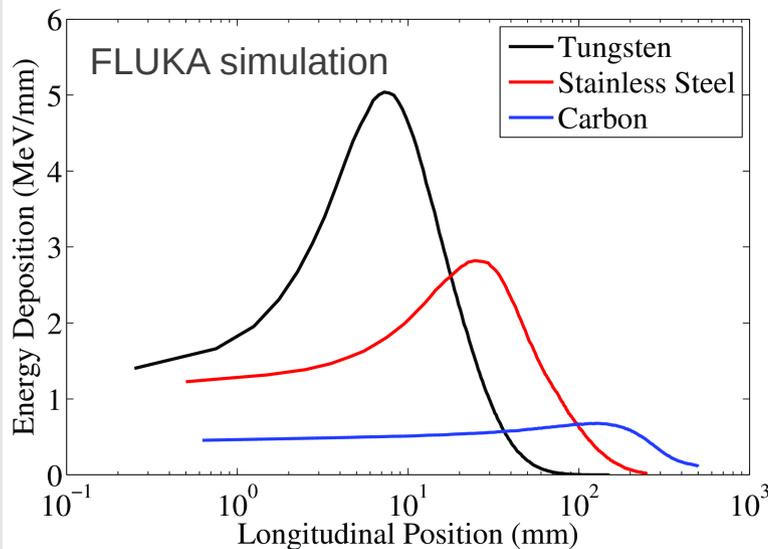
- Design based on FLUKA simulations of electromagnetic showers --> optimize for TBL:
  - Material and dimensions; resolution
  - Thermal robustness
  - Long term survival

Energy deposition

Multi-slit collimator as thermal buffer
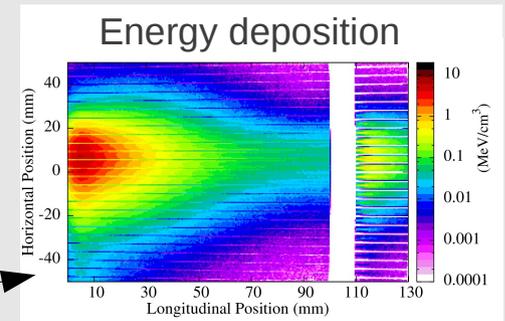
Segmented Beam Dump

- 32 tungsten segments:
  - 3 mm wide
  - 20 mm deep
  - 1 mm spacing
- Alumina insulators
- Semi-rigid cables attached to readout PCB
- 20dB signal attenuation
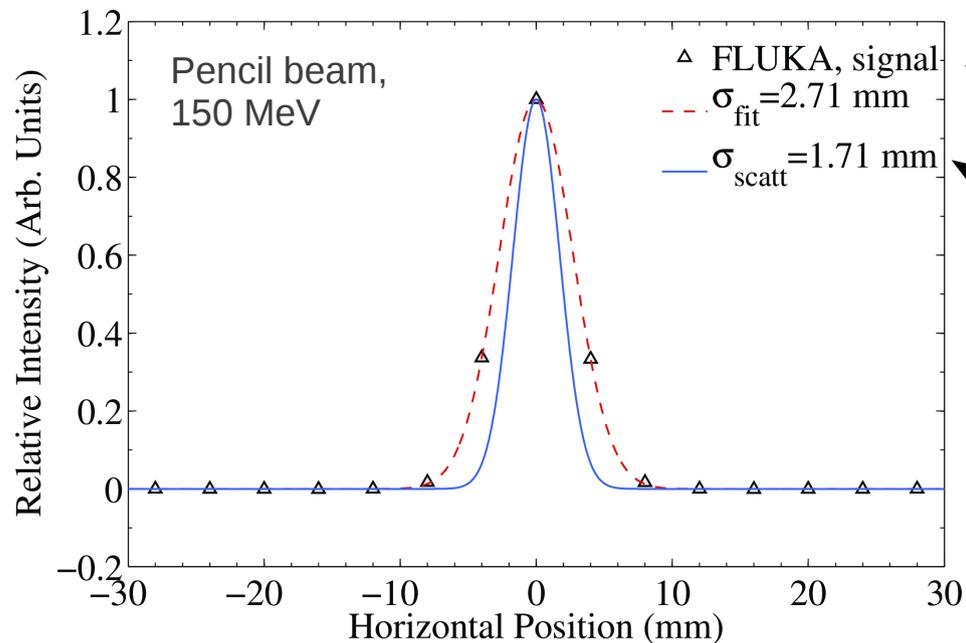- SIS 3320 ADCs (250 MS/s)
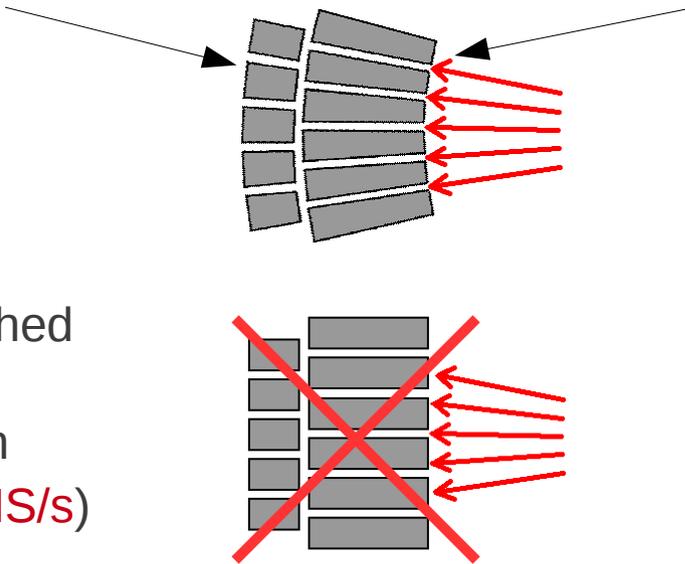
- Water-cooled collimator
  - 32 slits 400 μm wide
  - 100 mm long
  - Material: Inermet (high tungsten content)
- New concentric geometry to match angles of incoming particles.

3 mm

20 mm

Contact pins

Segment assembly

Collimator
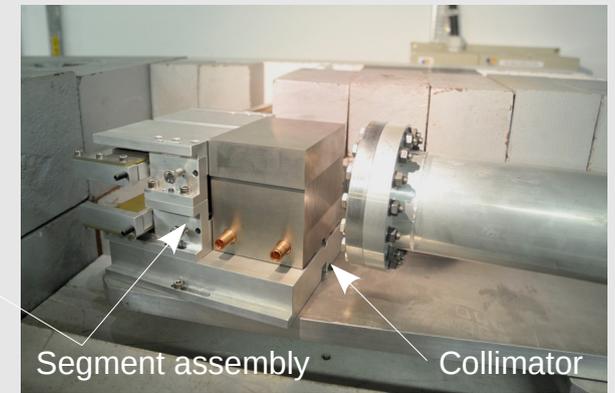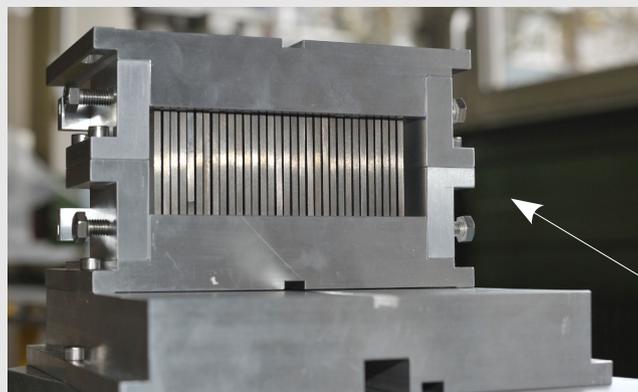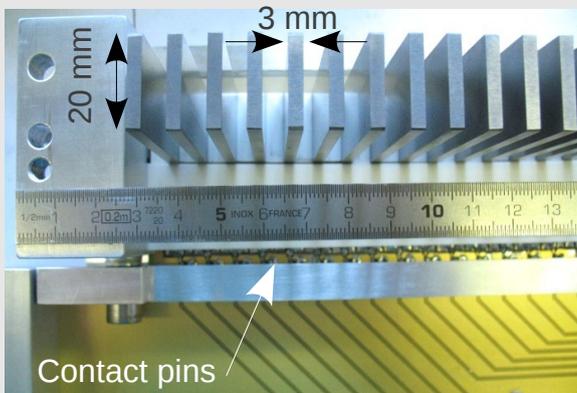
Performance: Resolution

Final design used in FLUKA simulations to test performance:

Segment crosstalk from scattered particles
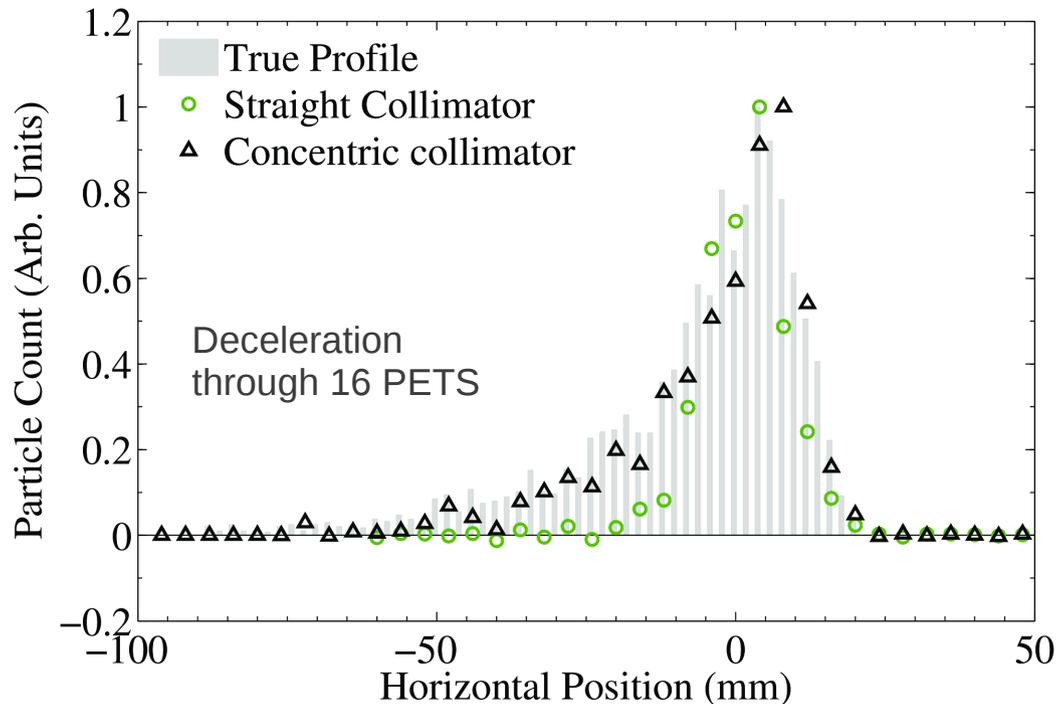
Profile broadening from scattering in OTR screen, vacuum window, etc

Minimum beam size at position of dump:

$$\sigma_{res} \geq \sqrt{\sigma_{scatt}^2 + \sigma_{part}^2} = 3.2 \text{ mm} \Rightarrow \frac{\sigma_E}{E} \approx 1\%$$

Performance: Accuracy

Placet beam distribution used in FLUKA:

Deceleration through 16 PETS

Accuracy within 5% on energy spread
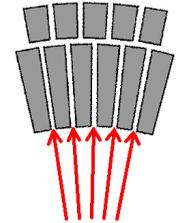
True beam width (rms):

$$\Delta x_{Placet} = 18.9 \text{ mm}$$

Reproduced beam width (rms):

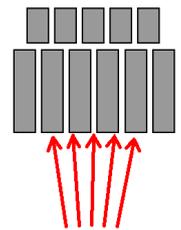Concentric geometry

$$\Delta x = 19.7 \text{ mm}$$

-> 4% overestimation

Straight geometry
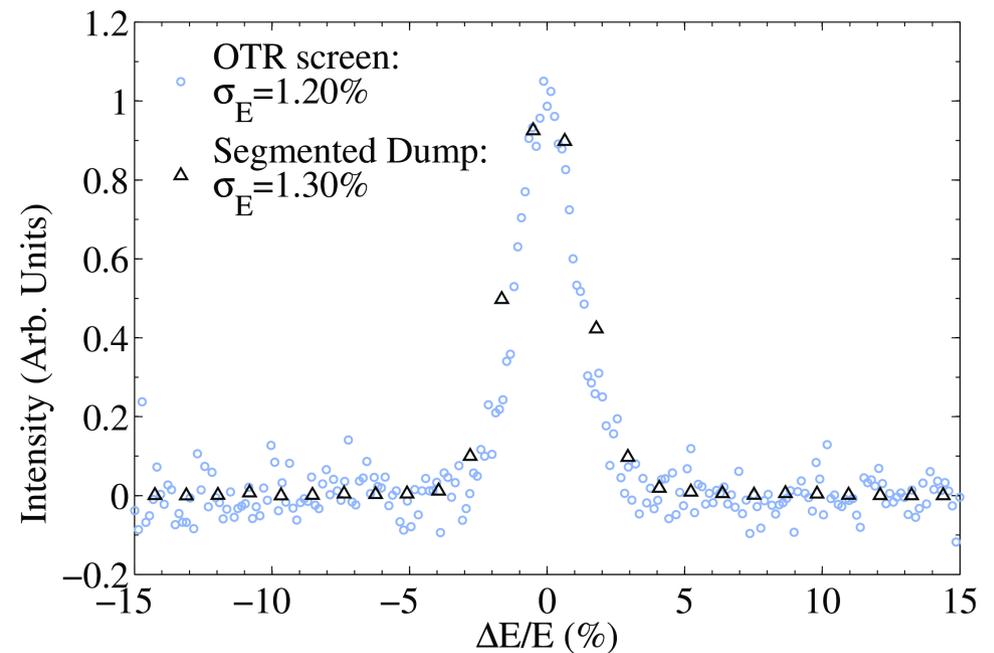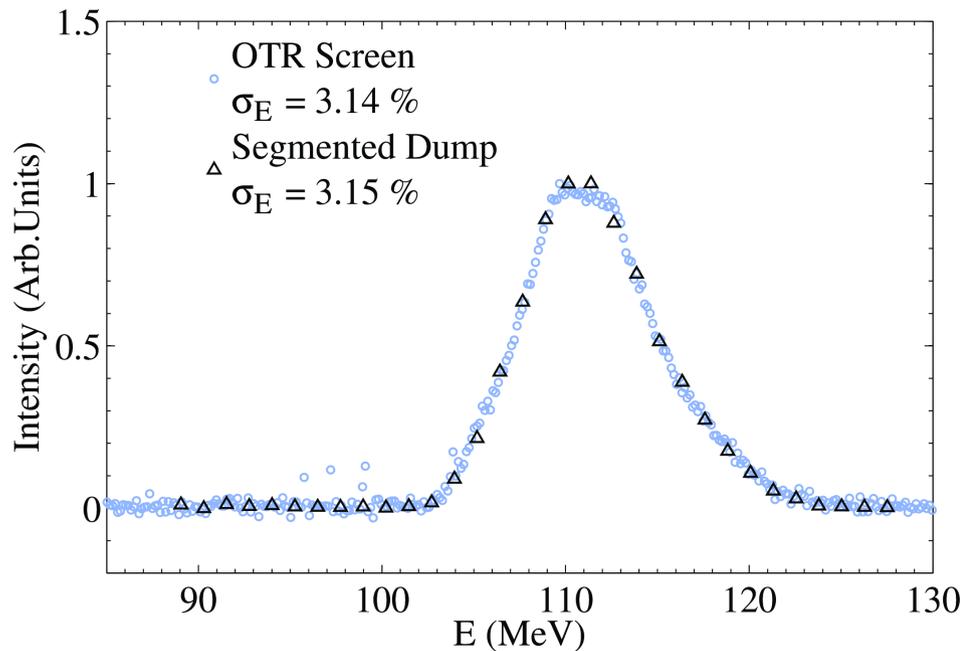
$$\Delta x = 8.2 \text{ mm}$$

-> 56% underestimation
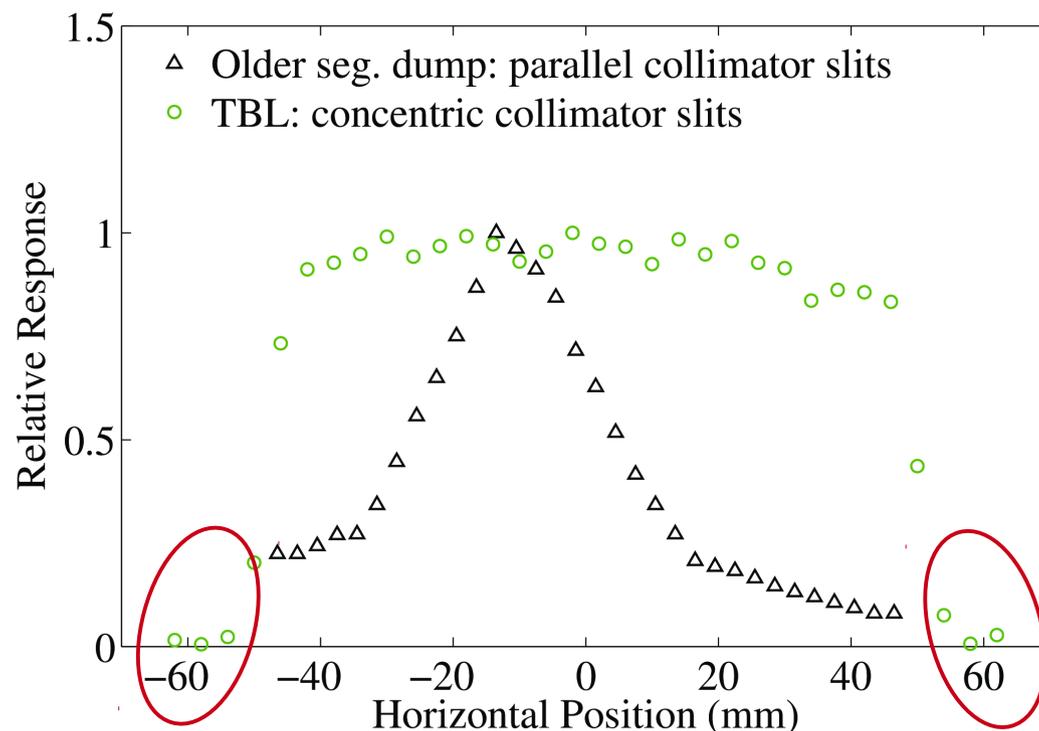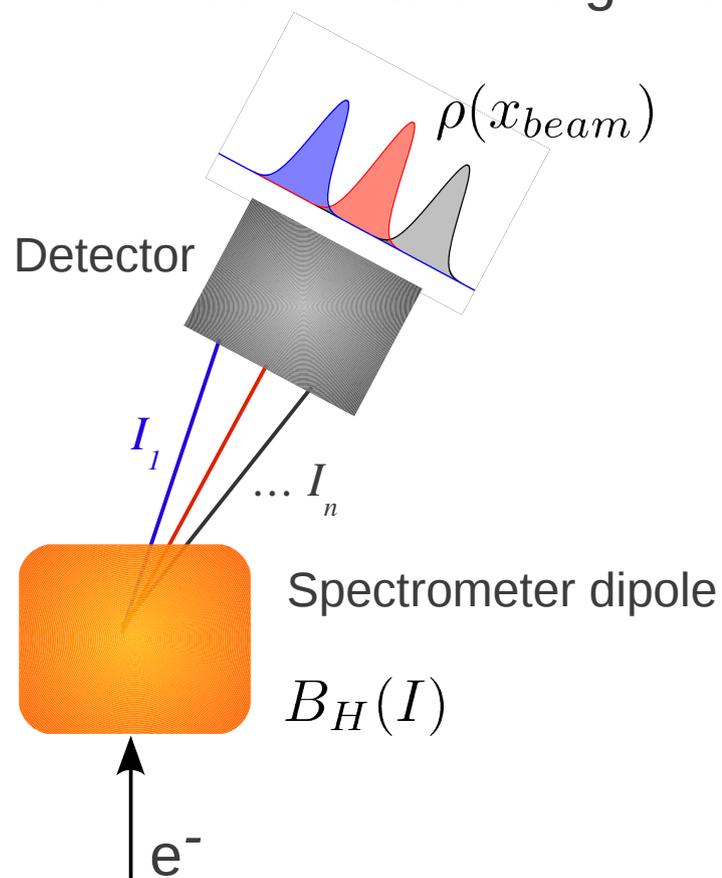
Beam-Based Performance Studies

Cross-calibration with OTR screen:

- Good agreement when energy spread is large
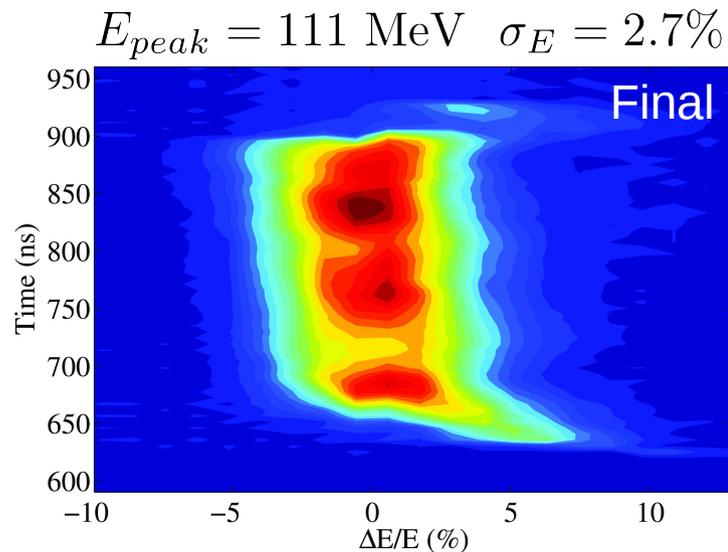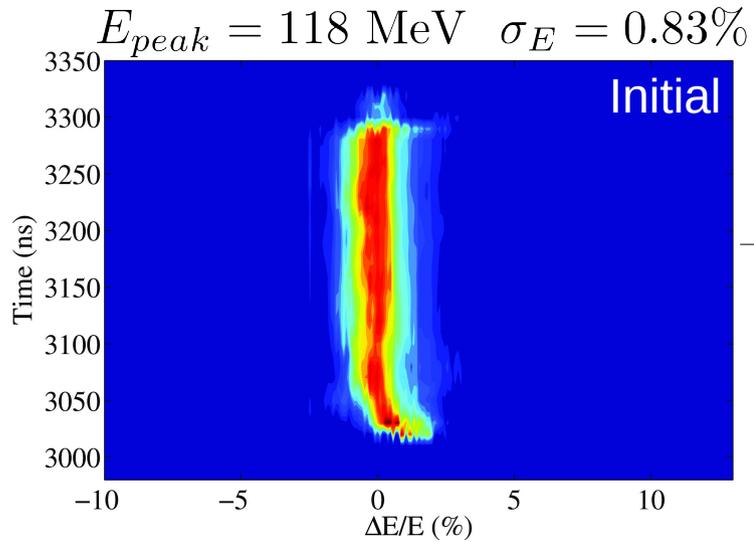- Worse for smaller beams: measured resolution 1.3%

Beam-Based Performance Studies

Response curve calculated from a dipole scan shows big improvement of a concentric collimator geometry.
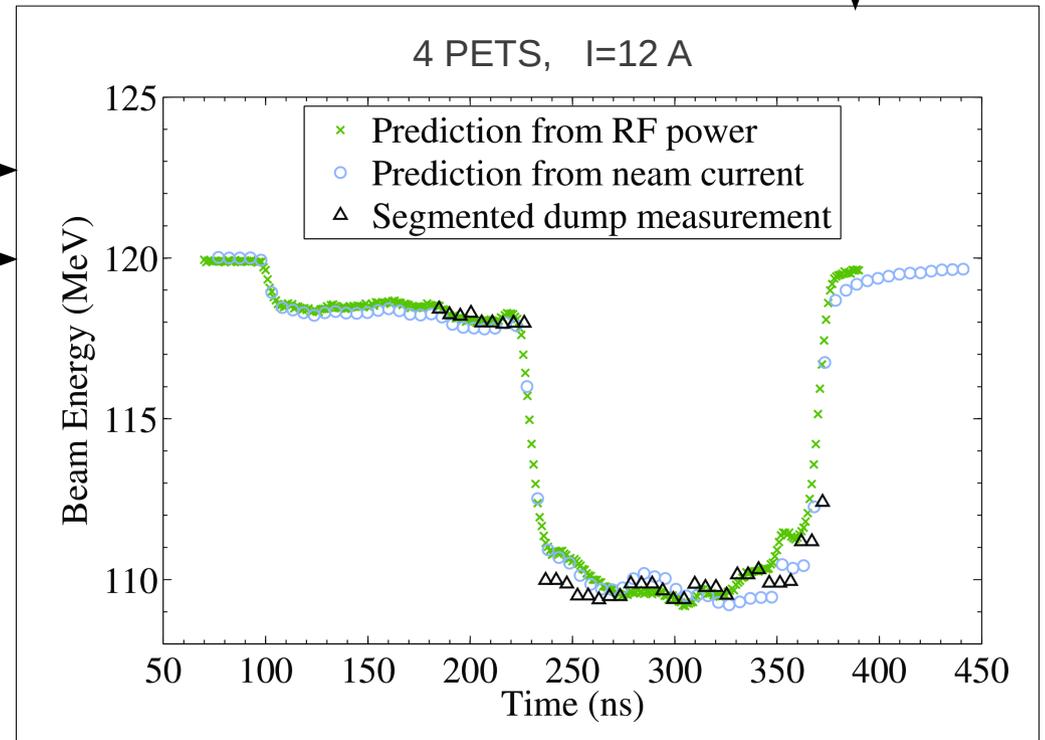

$\rho(x_{beam})$

Detector

I_1

$... I_n$

Spectrometer dipole

$B_H(I)$

e⁻

Aperture restriction from vacuum chamber

Beam Measurements

$E_{peak} = 118$ MeV $\quad \sigma_E = 0.83\%$

Initial

- Measured energy loss compared to deceleration predicted from ...

  - … Extracted RF power

  - … BPM signals

$E_{peak} = 111$ MeV $\quad \sigma_E = 2.7\%$

Final

4 PETS,   I=12 A

× Prediction from RF power
○ Prediction from neam current
△ Segmented dump measurement

Beam Measurements

$E_{peak} = 118 \text{ MeV} \quad \sigma_E = 0.83\%$

Initial

$E_{peak} = 111 \text{ MeV} \quad \sigma_E = 2.7\%$

Final
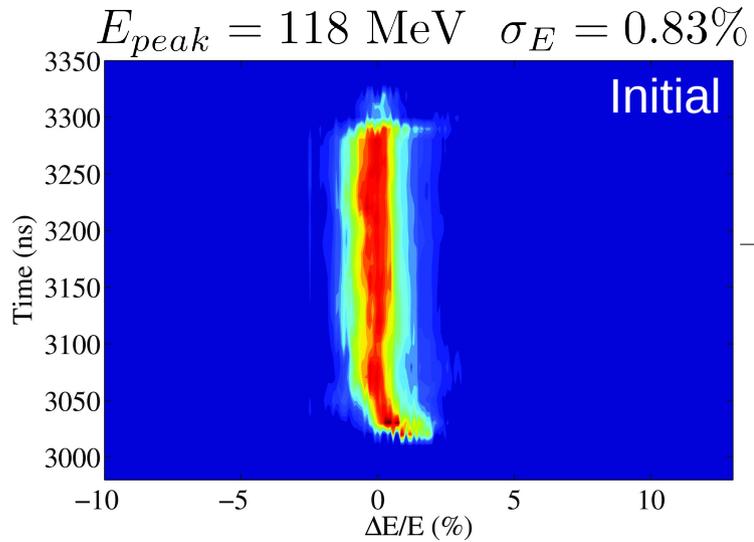
Placet

- Measured energy distribution Vs. simulation
  - Using measurement of incoming beam as simulation input

$E_{peak} = 109 \text{ MeV} \quad \sigma_E = 1.3\%$

Placet simulation: E_{peak}=108.6 MeV

Measurement: E_{peak}=111.1 MeV
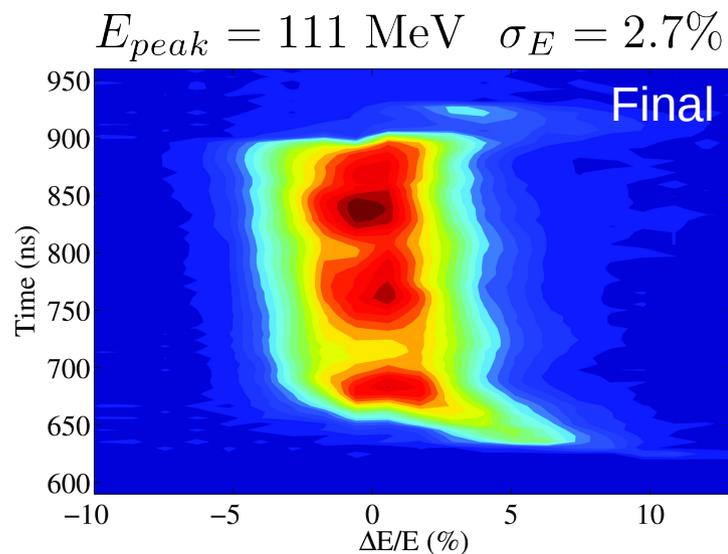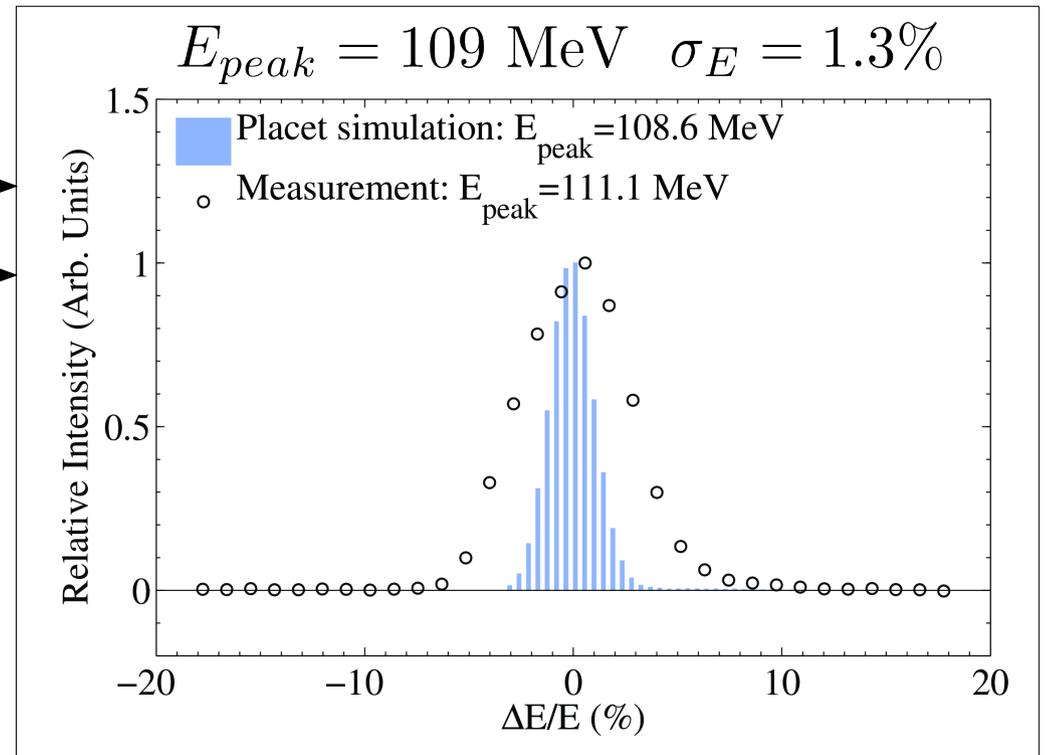
Conclusions and Outlook

- New Segmented Beam Dump for TBL designed, installed and commissioned

  - Performance as expected with 5 ns time resolution and 1.3% resolution on energy spread.

  - Beam measurements at TBL to be continued at higher beam current, and more PETS

- Time-resolved energy measurements for the CLIC Drive Beam decelerator:

  - higher energy, higher intensity, larger energy spread, higher repetition rate

  - Segmented dumps insufficient

    – Time-resolved spectrometry based on Cerenkov radiation

- Copy of new segmented dump for the CTS line, at the end of the CTF3 linac?

Thanks for your attention!

Special thank you to
- William Andreazza - everything!
- Michel Duraffourg - careful and patient soldering
- members of ML section and Co - for fixes and tricks without further notice
- Marek Gasior - last minute connector supply

A Segmented Beam Dump for the Test Beam Line at CTF3

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Further reading:
"Commissioning Status of the Decelerator Test Beam Line in CTF3"
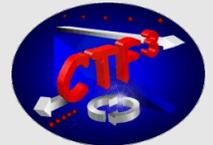 MOP018, LINAC'10, Tsukuba (2010), S. Doebert *et al.*
"A Study of the Beam Physics in the CLIC Drive Beam Decelerator"
  PhD thesis, University of Oslo, Norway (2009), E. Adli
"*Spectrometry in the Test Beam Line at CTF3*"
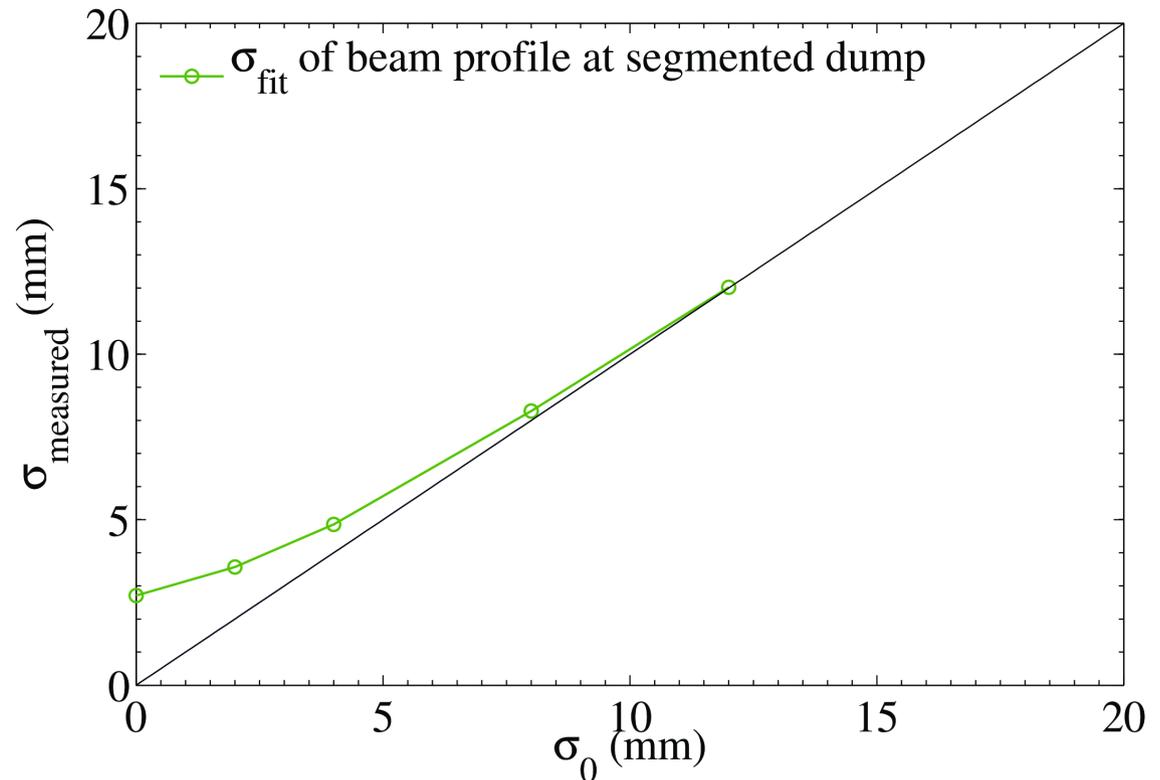 MOPE60, IPAC'10, M Olvegaard *et al.*
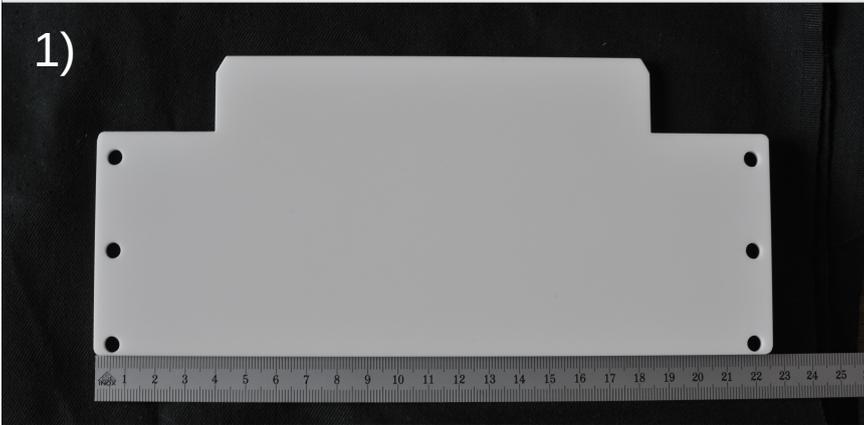
Extra slides

Broadening from scattered particles

Broadening from particle crosstalk between segments and from scattering in foils is a systematic effect that can be compensated for.

FLUKA simulation of beam distributions as measured by segmented beam dump: beam width of measured distribution as a function of true width
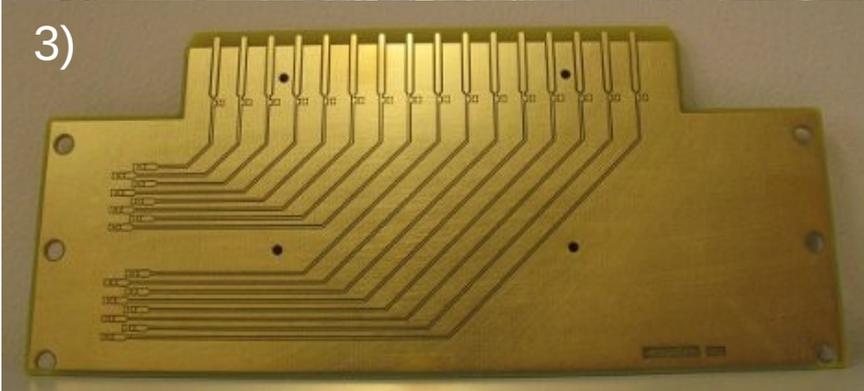
Technical difficulties

1) Originally foreseen to have a PCB of alumina for radiation hardness.

2) Problem in the preparation forced us to choose another (temporary) solution.

3) Normal plastic PCB supported by aluminum plate, easy to remove and replace when needed.

Beam Measurements

- **Measure beam current**

  - Adjust by "form factor" for bunch length and bunch combination efficiency

- **Measure RF output power from PETS**

  - 15% error marginal on calibration of RF signals

- **Correlate with energy measurements**
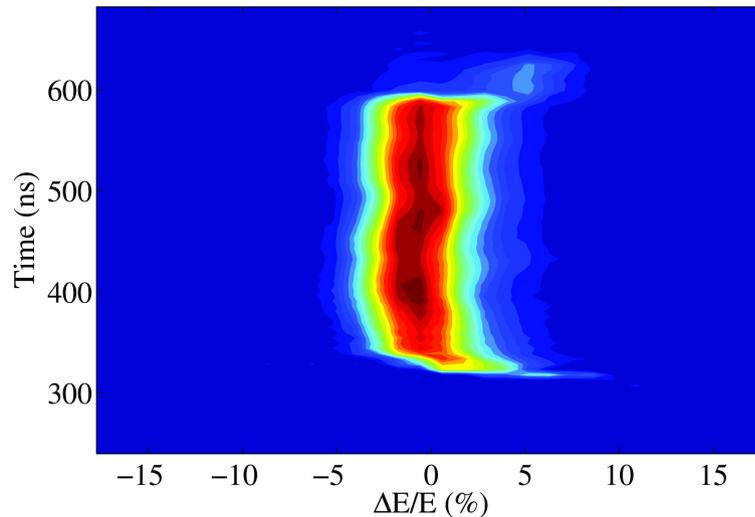
  - ~2% error on absolute energy

Reasonable results so far (4 PETS). To be continued for 9 PETS and higher beam current.
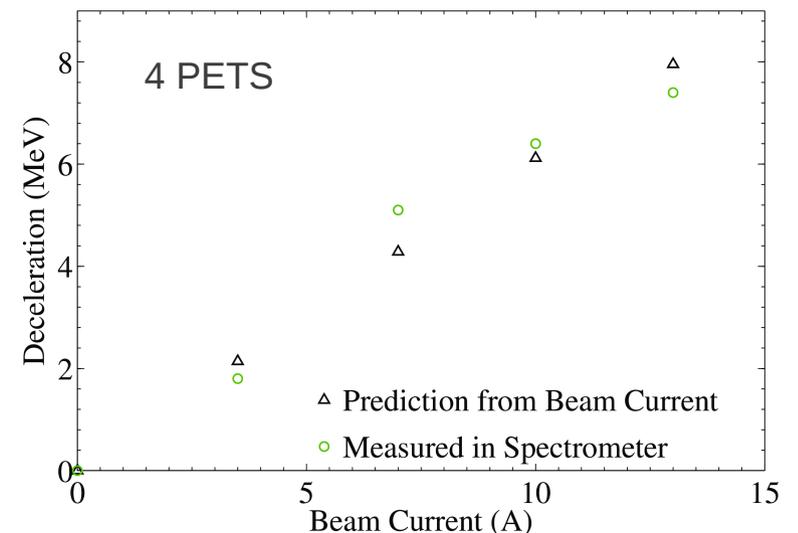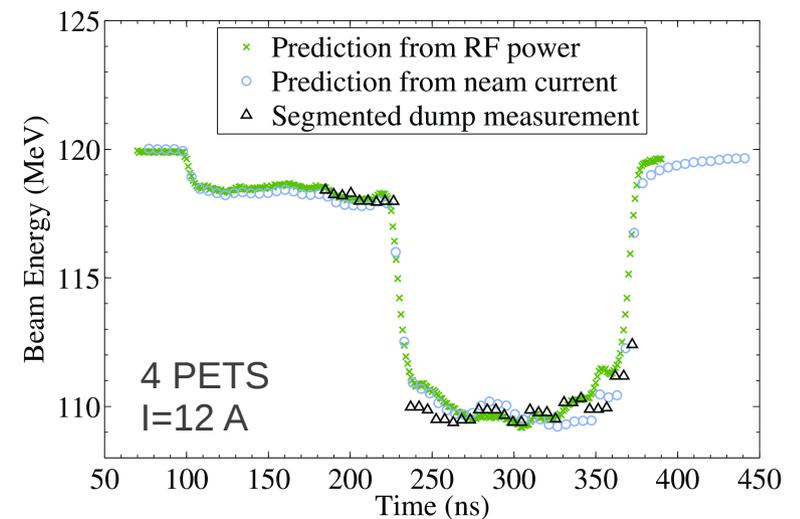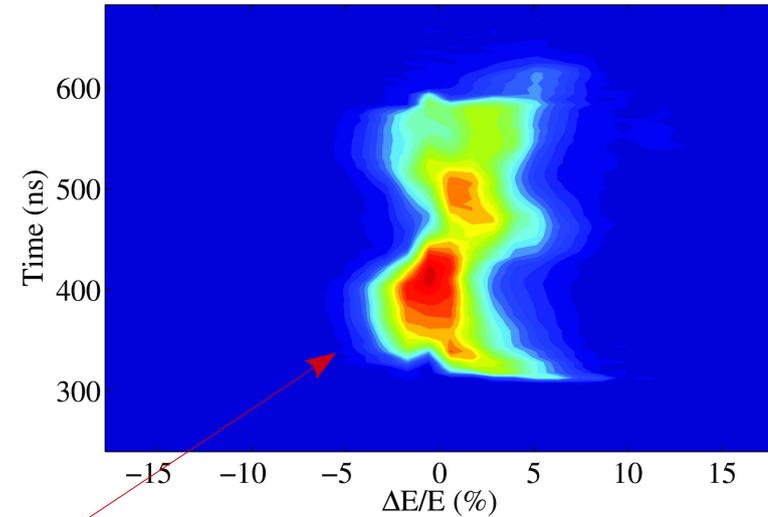
Single-shot 1-0 Multi-shot

Single-shot important to capture rapid changes (such as a breakdown in a PETS) and to avoid sensitivity to them.

$$I_{beam} = 11.5 \text{ A}$$
$$E_{peak} = 108.9 \text{ MeV}$$

$$I_{beam} = 11.0 \text{ A}$$
$$E_{peak} = 110.3 \text{ MeV}$$

Breakdown in PETS?