Precise Measurement of the $\pi^+ \longrightarrow e^+\nu$ Branching Ratio

Progress Report and 2009 Beam Request

The PEN Collaboration

Dubna–PSI–Swierk–Tbilisi–Virginia–Zagreb–Zürich

PSI BV40
19 February 2009

Outline

PEN follows the PIBETA experiment

PIBETA program (precision checks of SM and QCD predictions):

- $\pi^+ \longrightarrow \pi^0 e^+ \nu_e$ – main goal
  - SM checks related to CKM unitarity
- $\pi^+ \longrightarrow e^+ \nu_e \gamma$(or $e^+ e^-$)
  - F_A/F_V, π polarizability (χPT prediction)
  - limits on tensor coupling besides $V - A$
- $\mu^+ \longrightarrow e^+ \nu_e \bar{\nu}_\mu \gamma$(or $e^+ e^-$)
  - departures from $V - A$ in $\mathcal{L}_{weak}$

The **PEN** experiment

- $\pi^+ \longrightarrow e^+ \nu_e$
  - e-μ universality
  - pseudoscalar coupling besides $V - A$
  - ν sector anomalies, Majoron searches, m_{h+}, PS l-q's, V l-q's, ...

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$\pi \longrightarrow e\nu$ decay: SM predictions; measurements

Modern theoretical calculations: $B_{\text{calc}} = \dfrac{\Gamma(\pi \to e\bar{\nu}(\gamma))}{\Gamma(\pi \to \mu\bar{\nu}(\gamma))_{calc}} =$

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$$\frac{\Gamma(\pi \to e\bar{\nu}(\gamma))}{\Gamma(\pi \to \mu\bar{\nu}(\gamma))_{exp}} = (1.230 \pm 0.004) \times 10^{-4}$$

PEN goal: $\dfrac{\delta B}{B} \simeq 5 \times 10^{-4}$.

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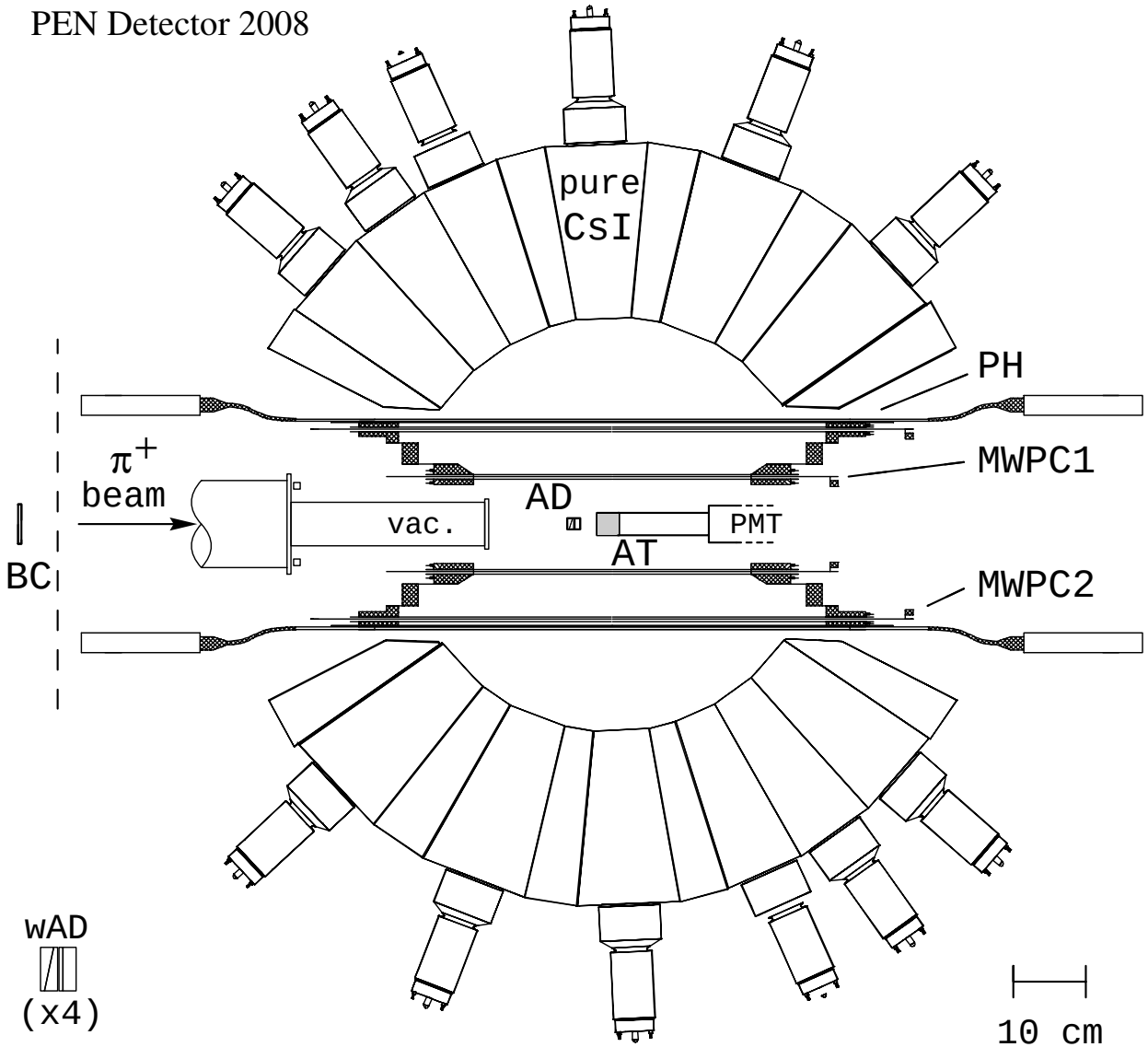
The PEN Apparatus

- stopped π^+ beam
- active target counter
- 240-det. CsI(p) calo.
- central tracking
- digitized PMT signals
- stable temp./humidity



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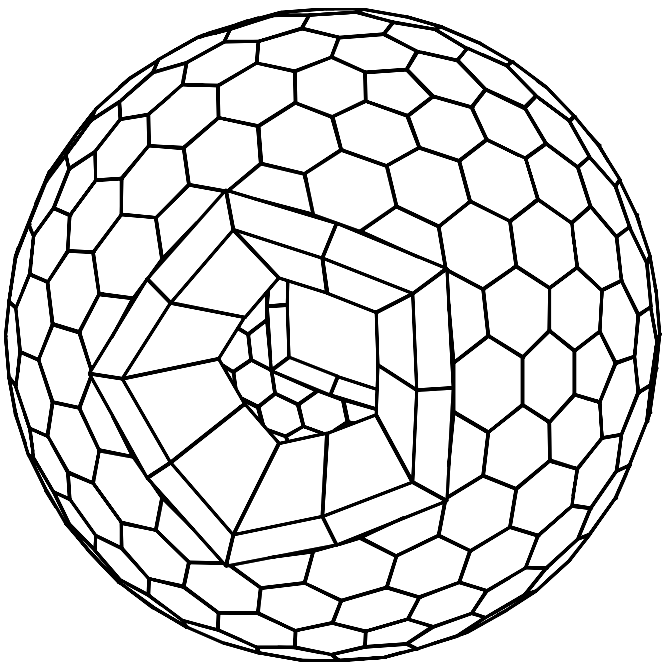

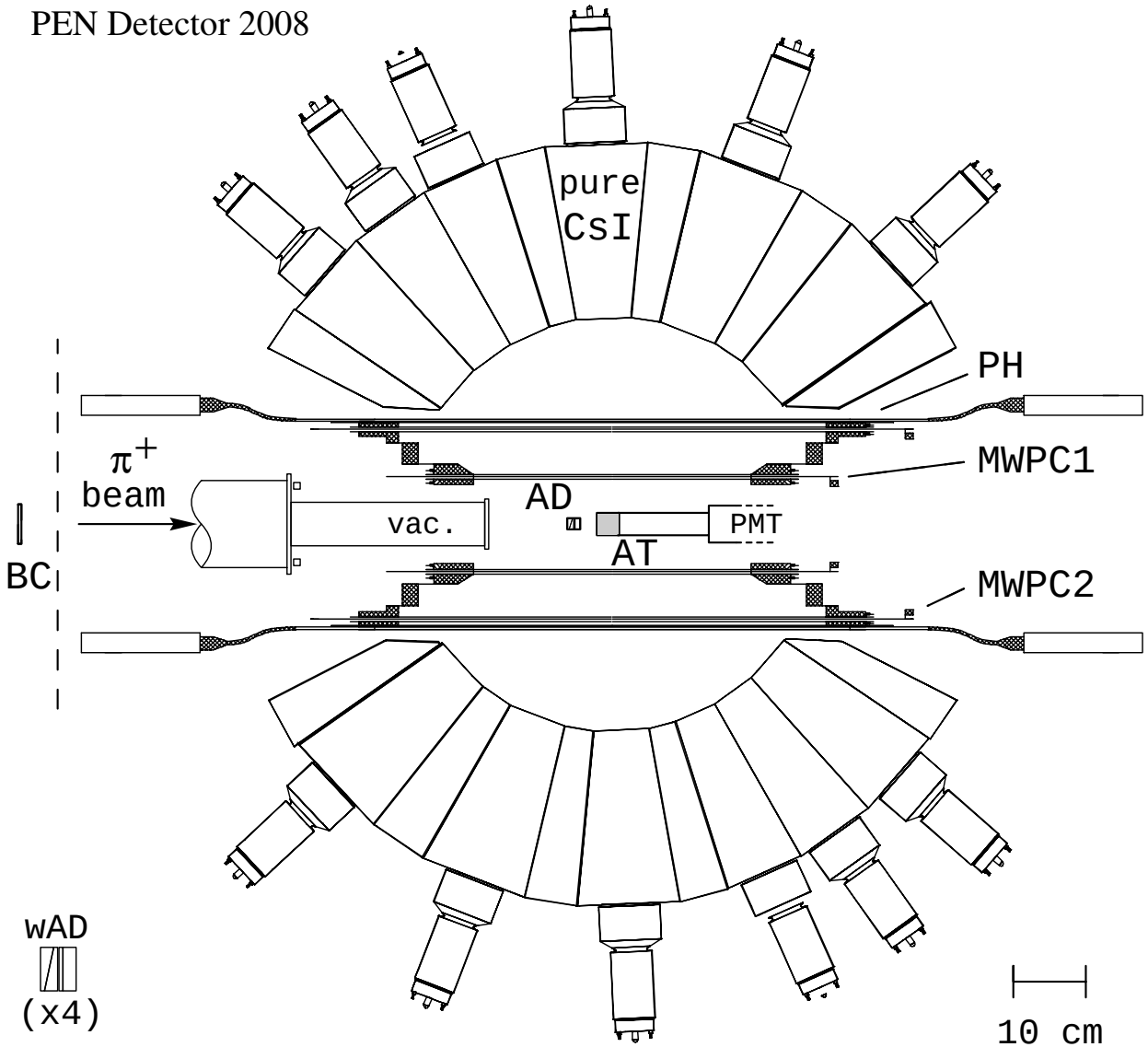

Goals and improvements for 2008

Stated goals of the 2008 run were:

- enable the DAQ system to handle a π_{STOP} rate of $\mathbf{2 \times 10^4}$ π/s , with dead time fraction $< \mathbf{15}$ %, and
- to record at least $\mathbf{4 \times 10^6}$ $\pi \longrightarrow \mathbf{e}\nu$ events with well controlled systematics.

Improvements for the 2008 run:

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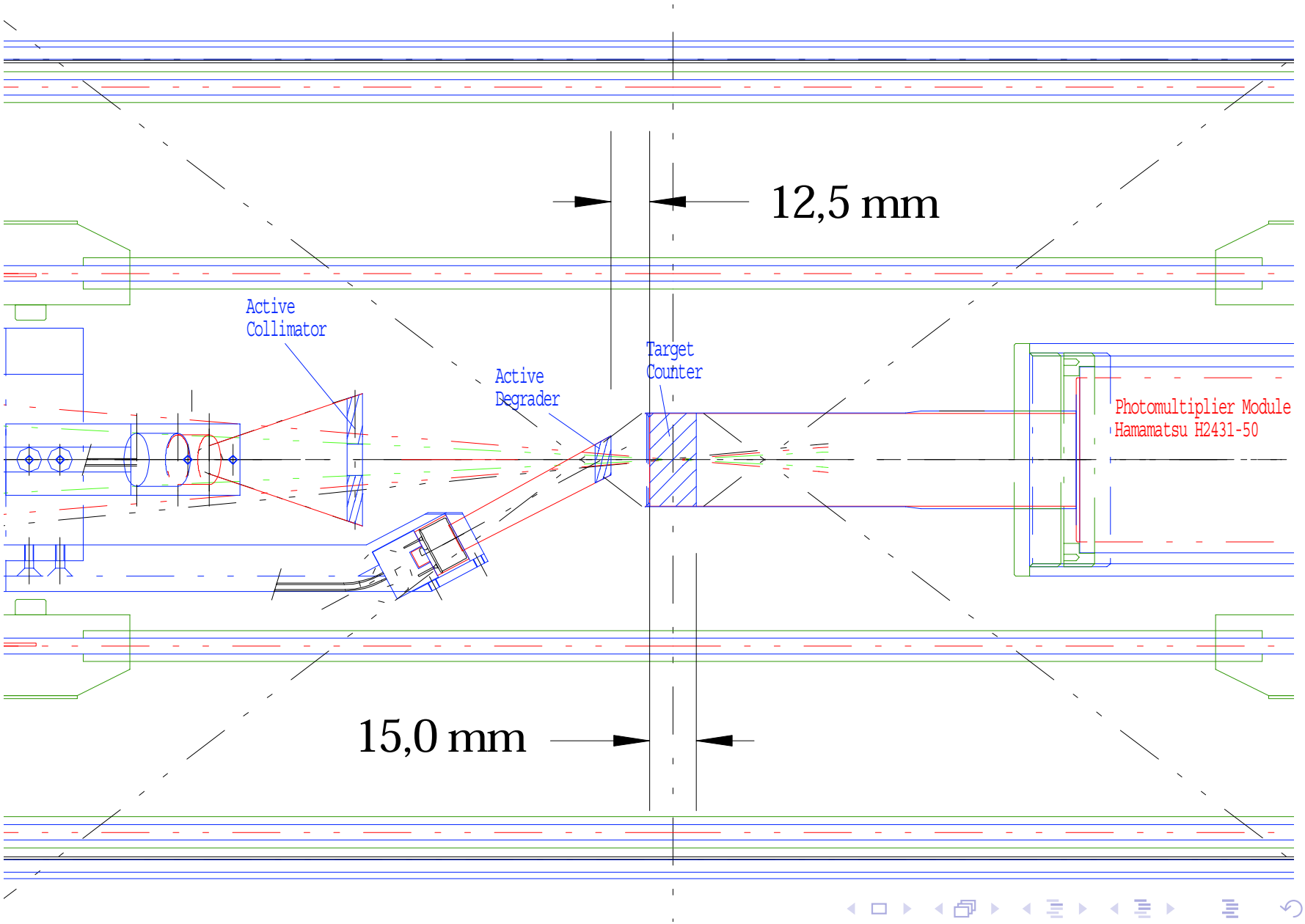
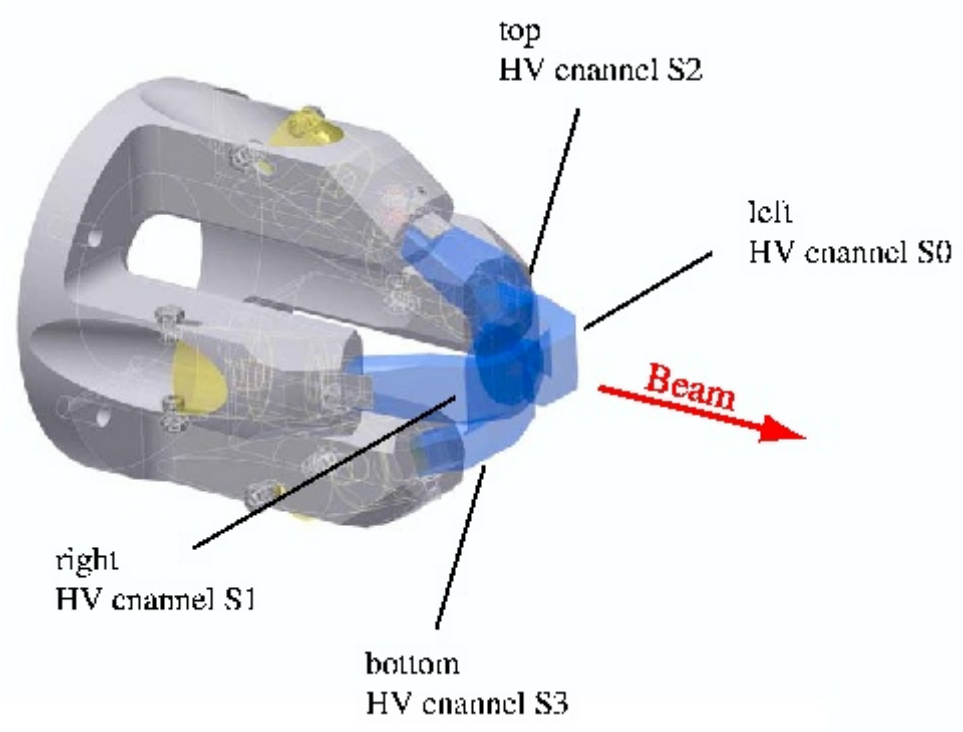
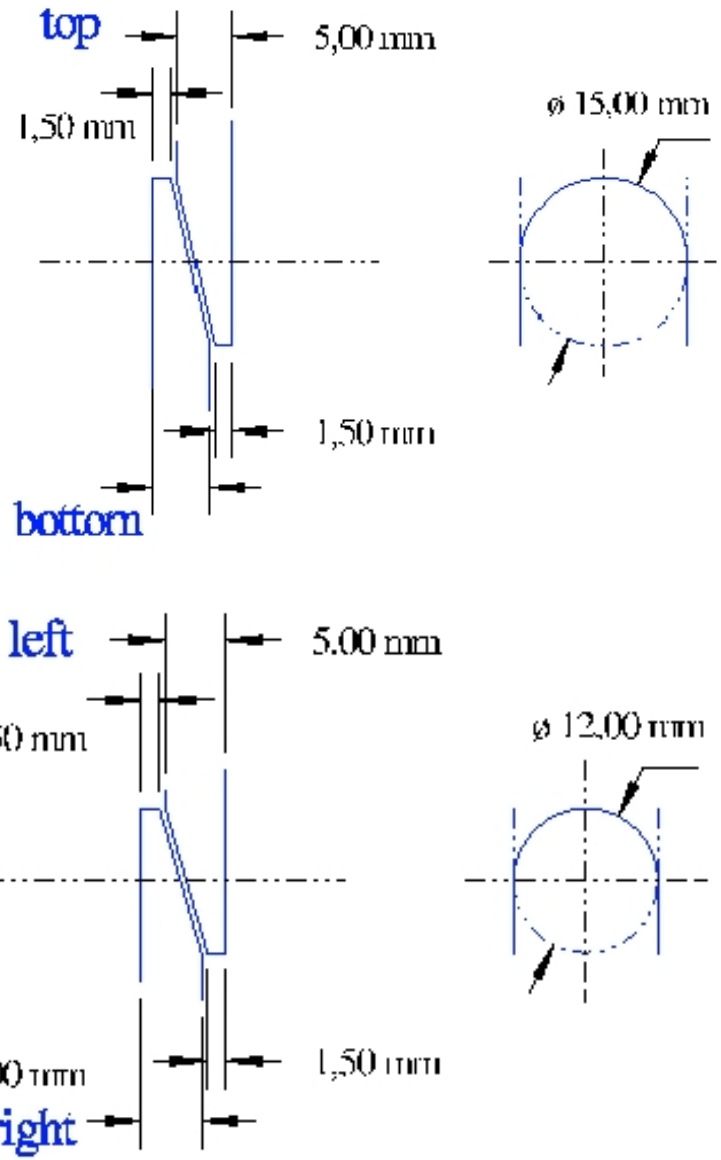
Central detector region in 1st half of 2008 run



Wedged Degrader: 2008 Run





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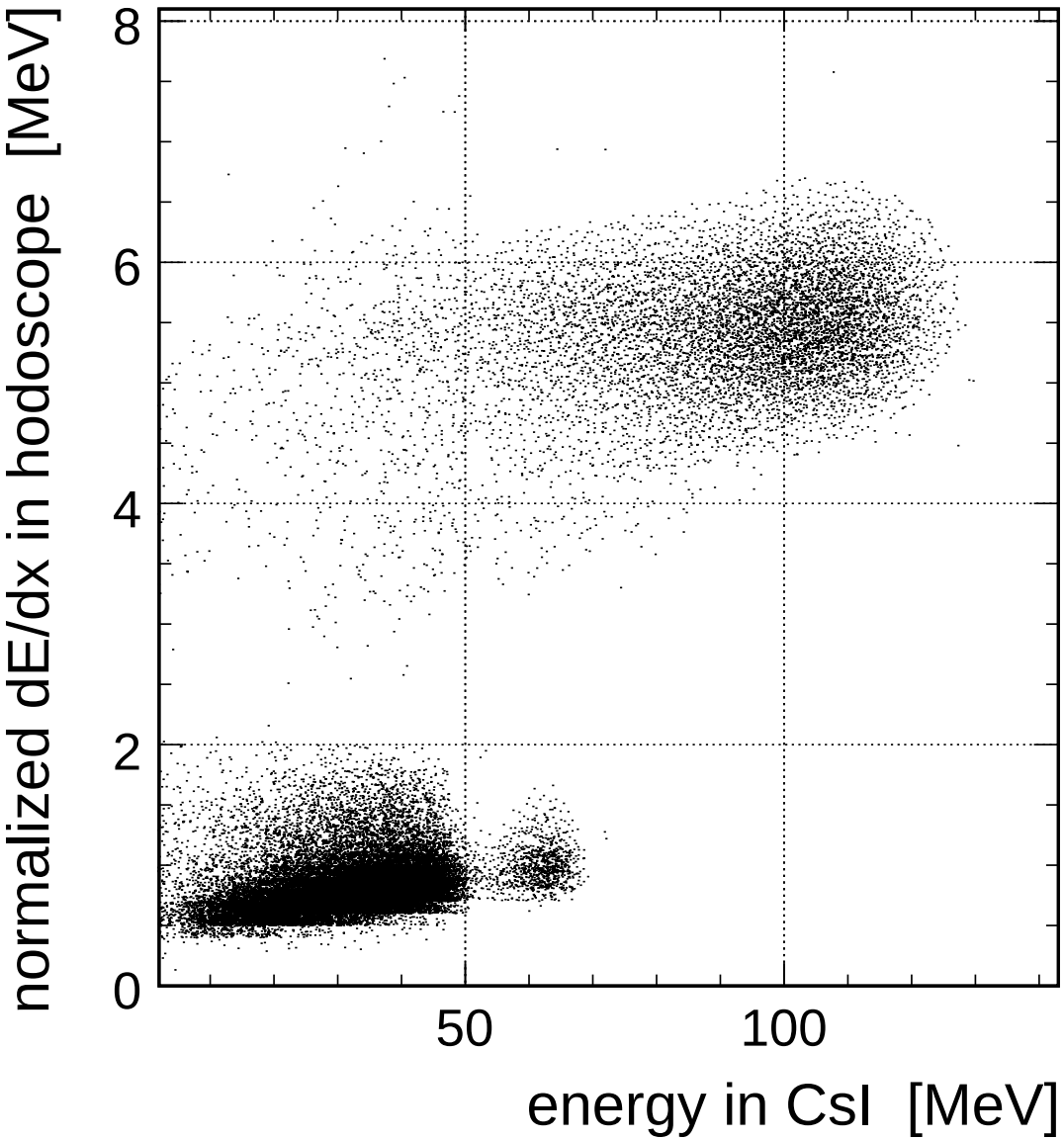
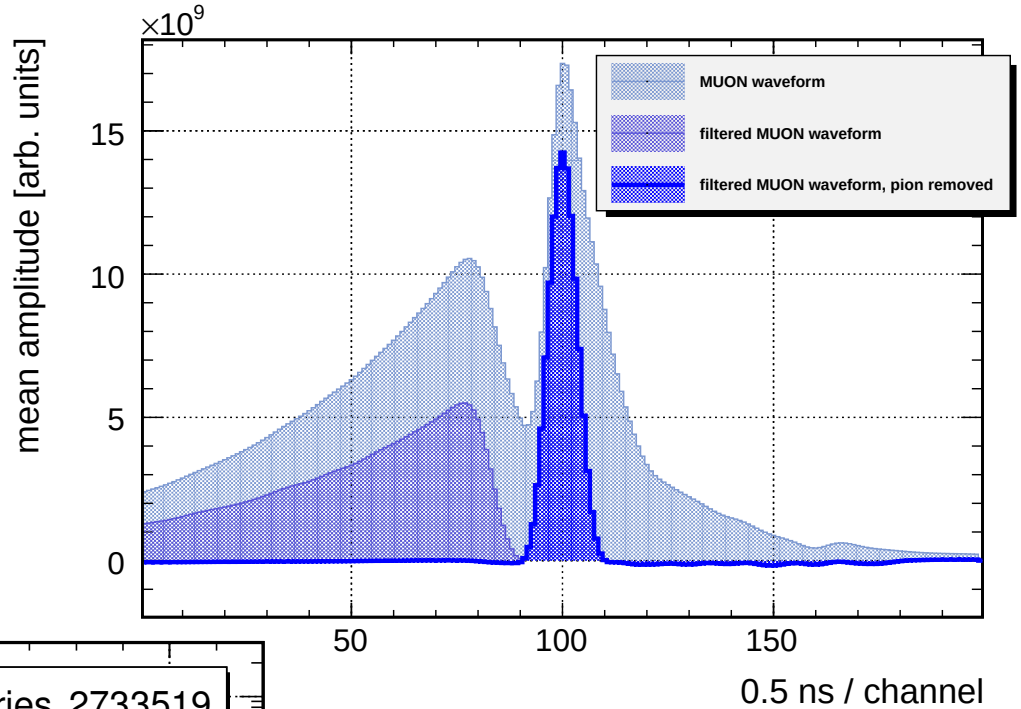
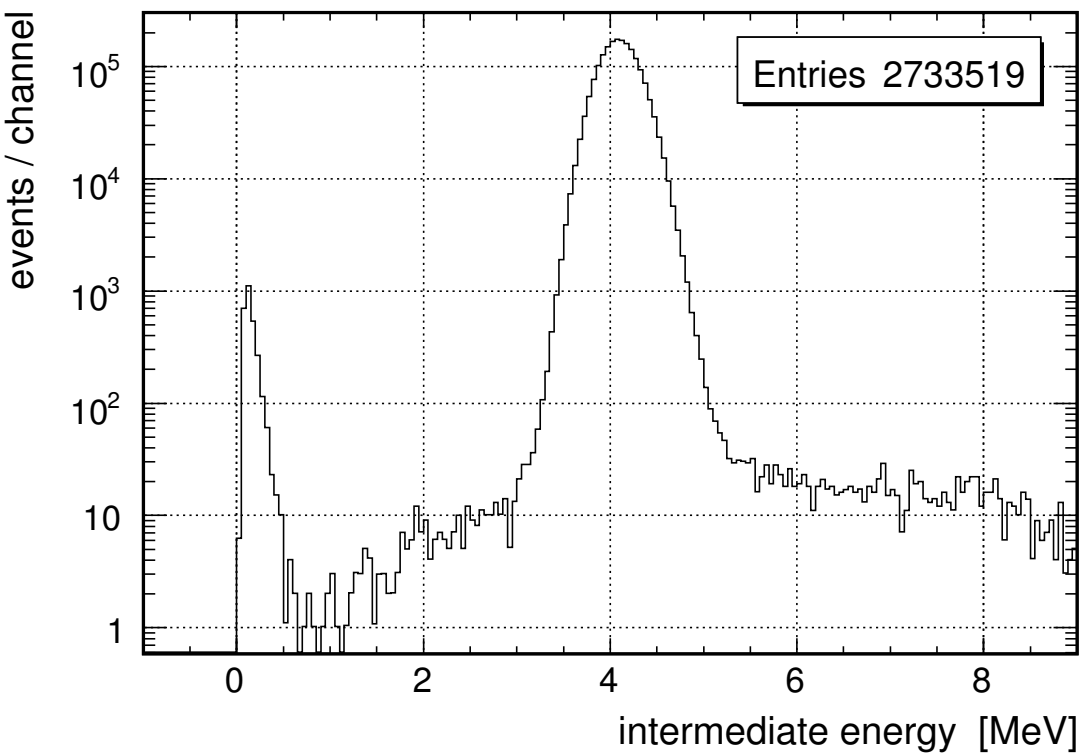
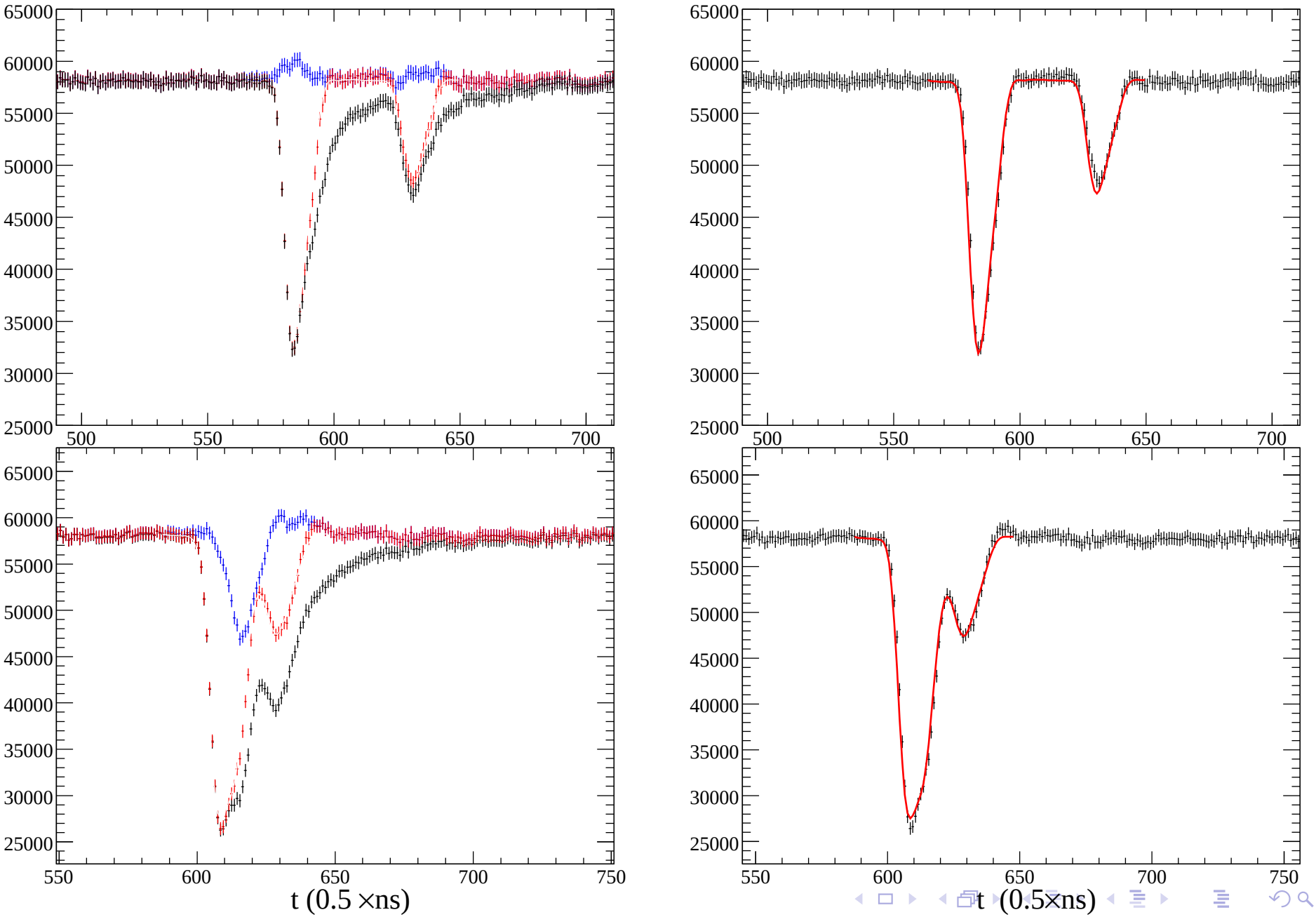


4.1 MeV Muon signal in the active target





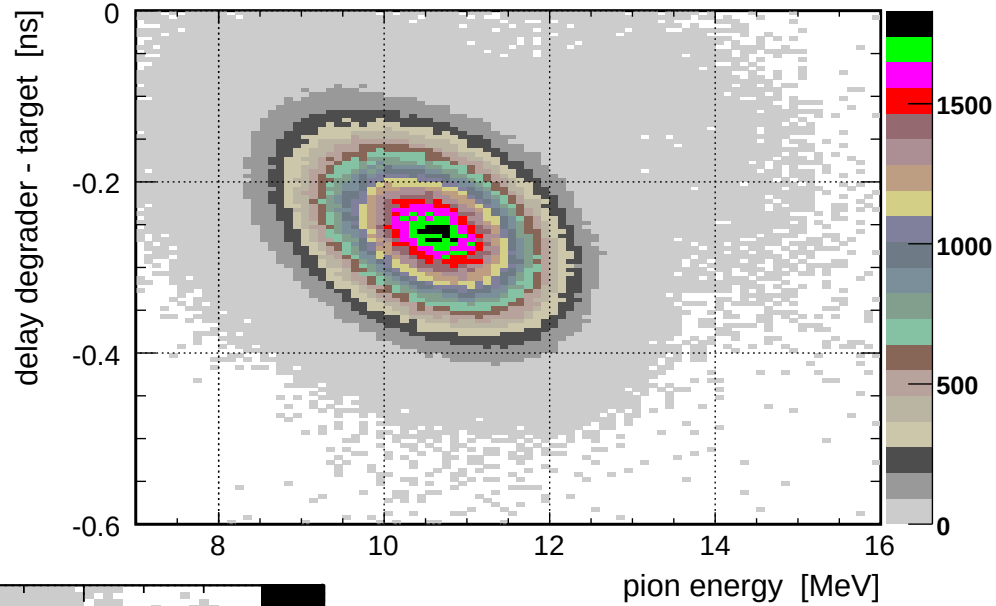
Waveform fitting



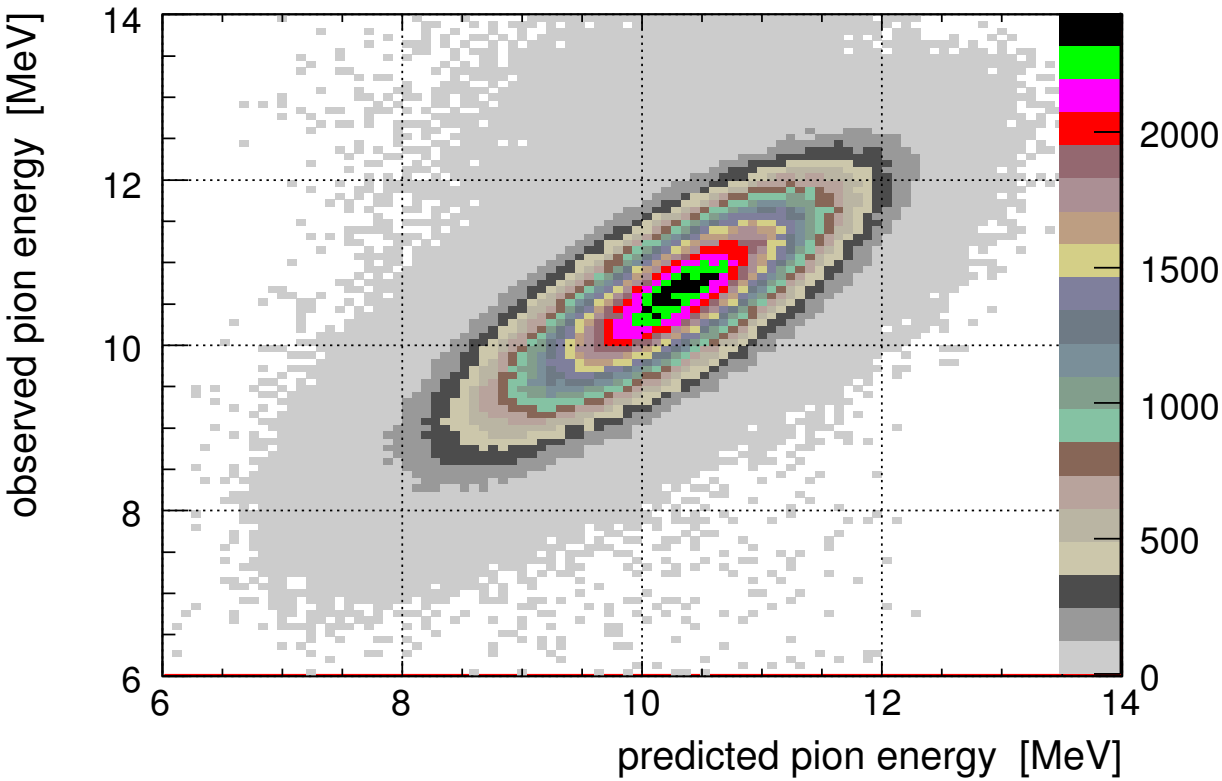
Inputs for waveform fitting:

Pion stop time in TGT

$\sigma_t^{\text{DEG–TGT}} = 62$ ps $\Rightarrow$



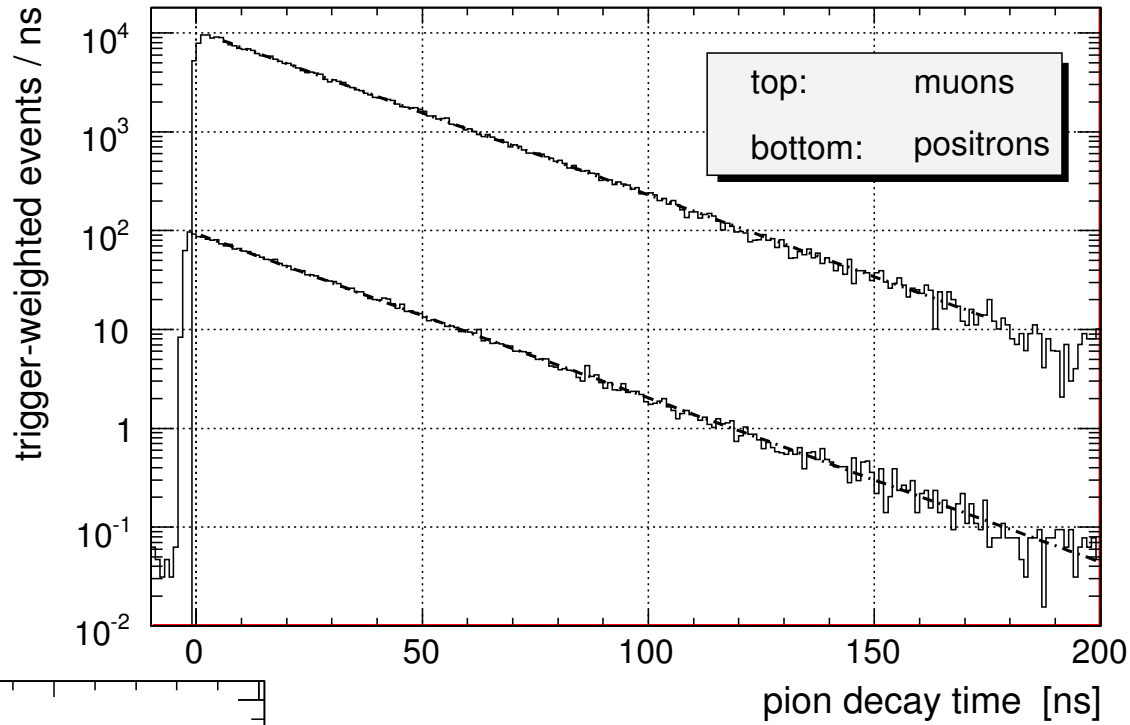
Pion energy in TGT $\Downarrow$

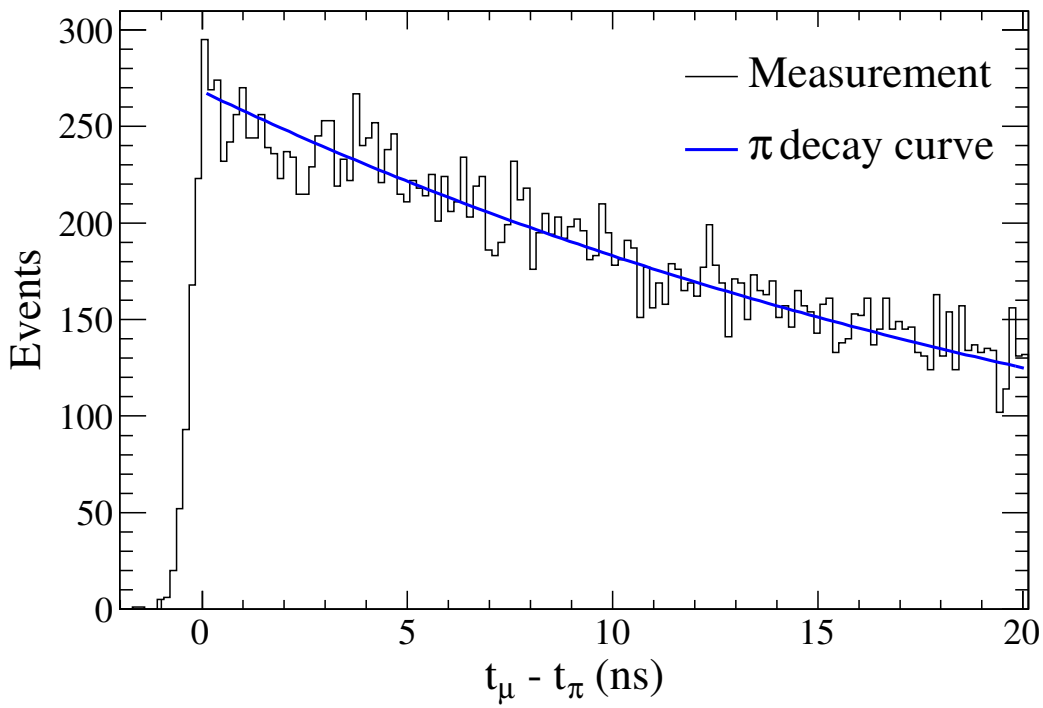


Pion decays in TGT

$\tau_{\pi\to\mu} = 26.21(5)\,\text{ns} \Rightarrow$

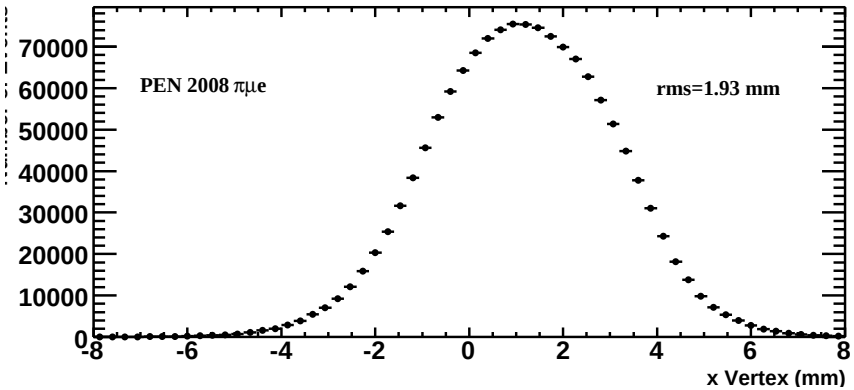
$\tau_{\pi\to e} = 26.02(8)\,\text{ns} \Rightarrow$

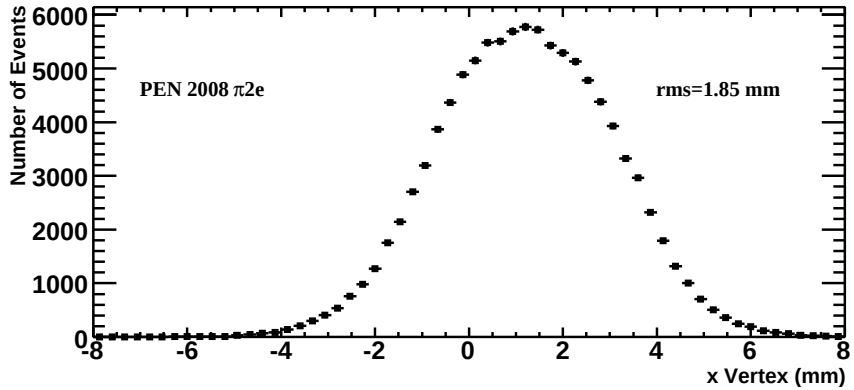


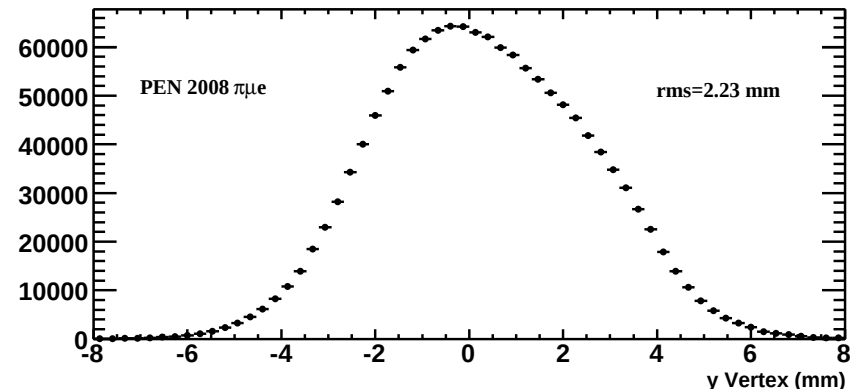


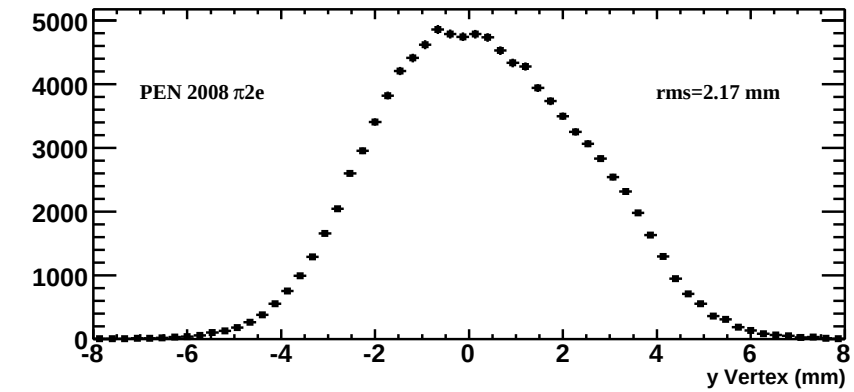
⇐ Pion–muon time separation in TGT in the first 20 ns (from waveform fitting).

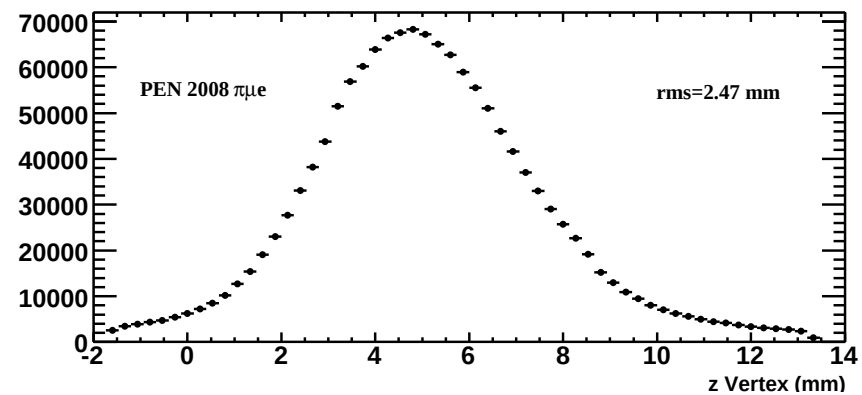
Wedged degrader performance

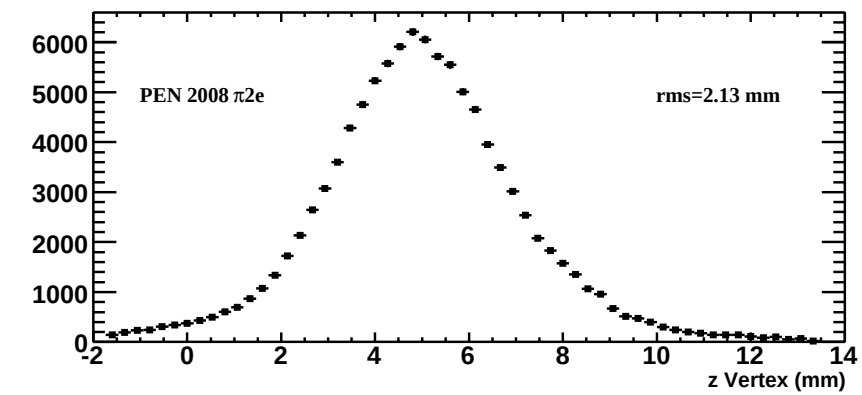






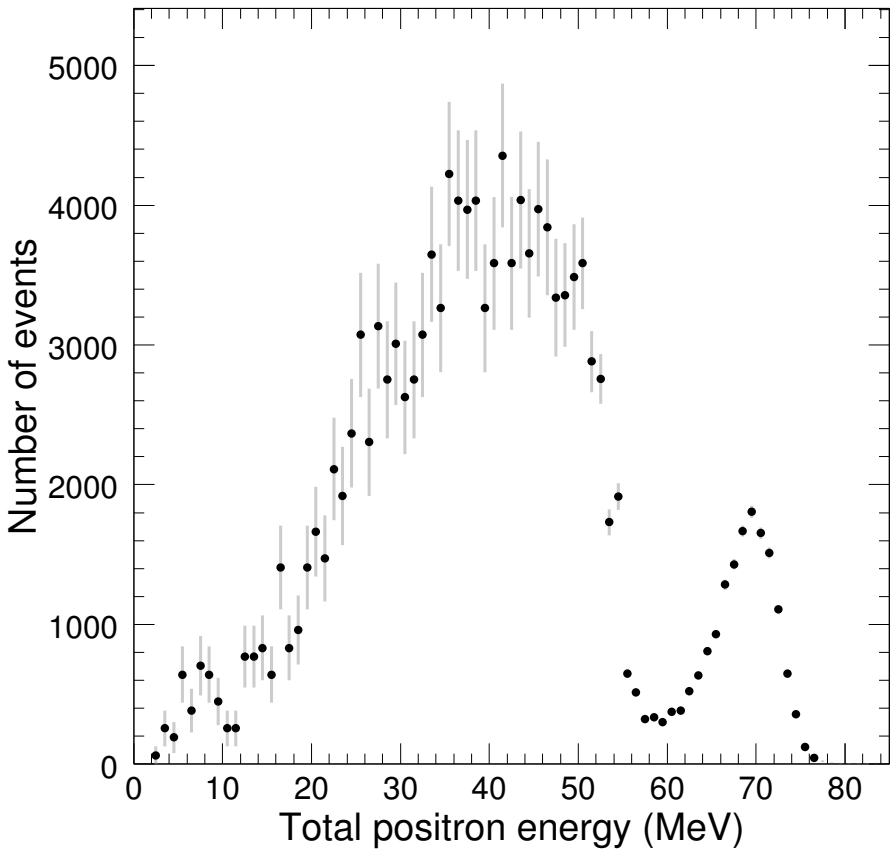




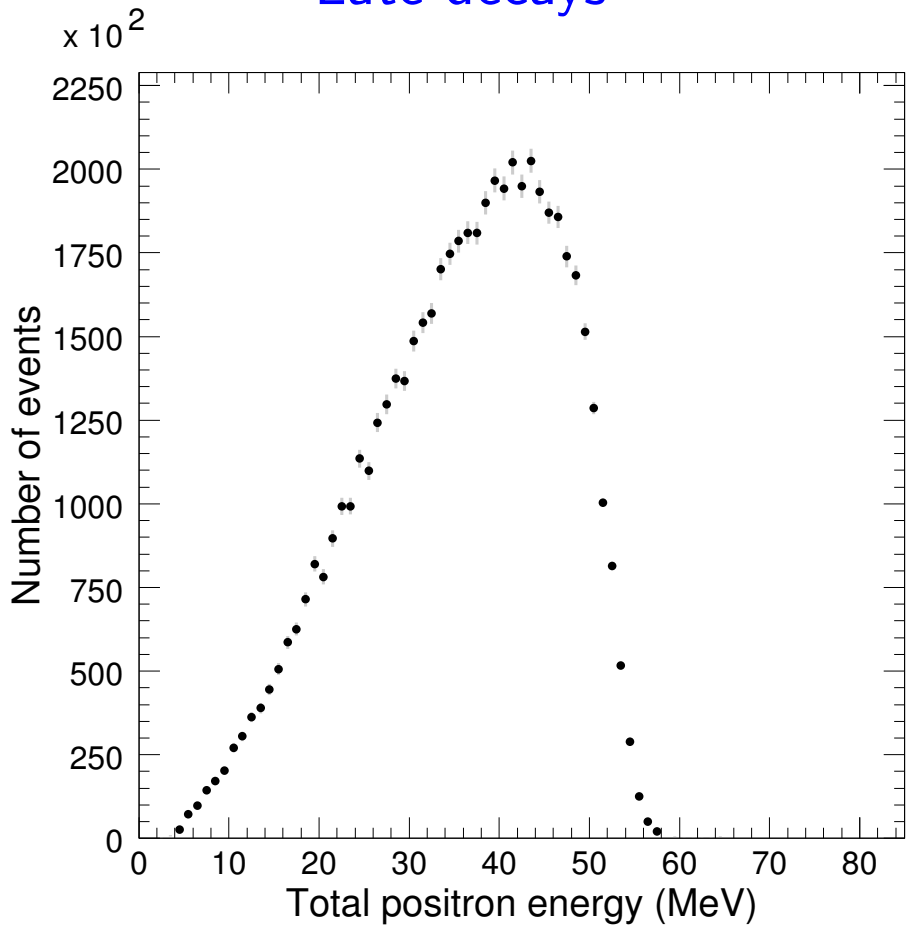


Total positron energy (preliminary)

Early decays



Late decays



Planned modifications for 2009

Mini TPC: Replace the **WD** with a **mini-TPC**
$\Rightarrow$ achieve superior beam particle tracking
$\Rightarrow$ improve pion DIF suppression.

DAQ upgrade: Replace **FastBus** TDC's with **VME** ones.
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Implement VME digitizer readout for the **mini-TPC**.

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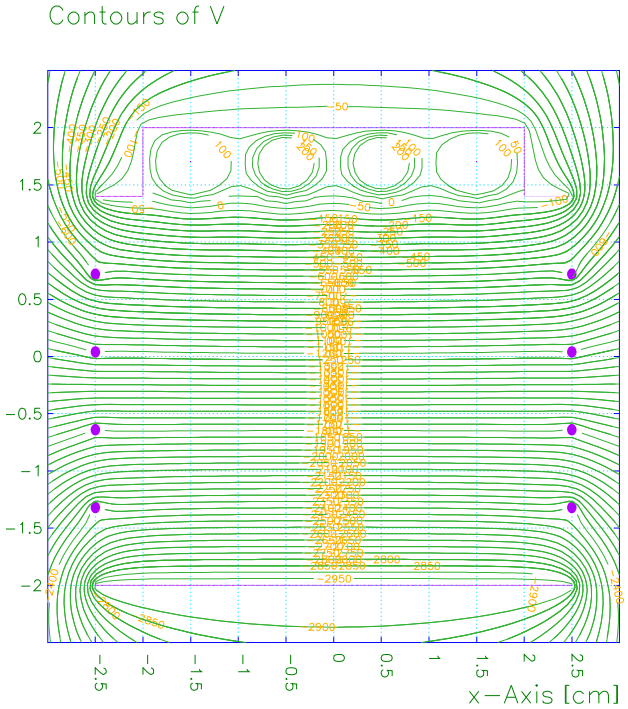
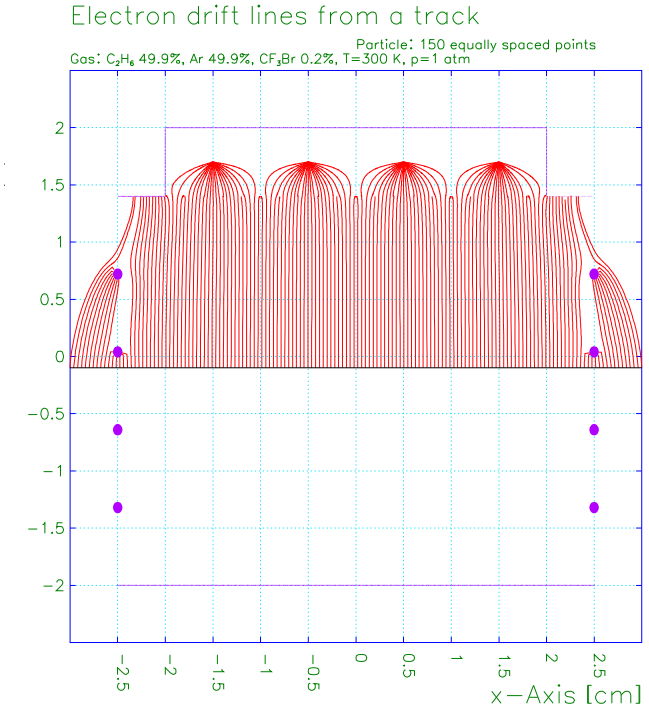
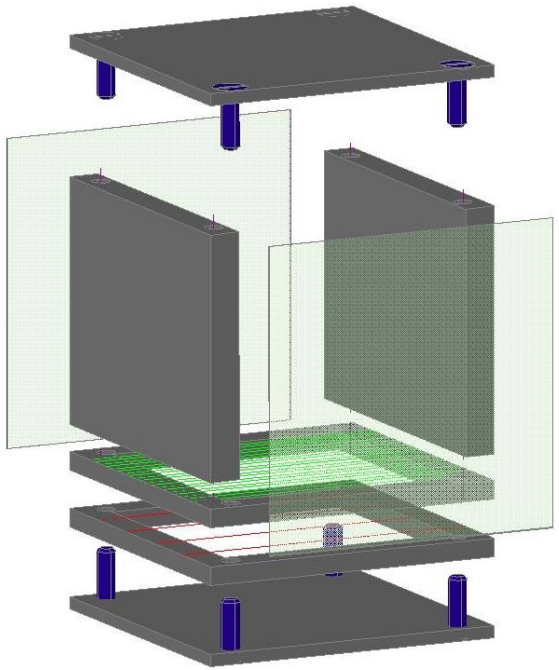
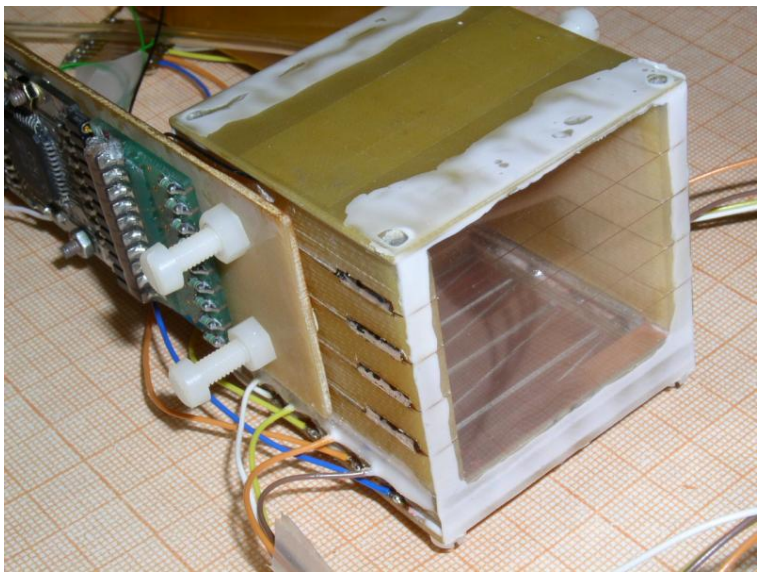
Dubna mini-TPC: Design and construction









Beam time request for 2009

Plans for the 2009 run:

- Prior to run implement the planned mini-TPC and DAQ upgrades.
- Run with approx. 15k pion stops/s.
- Run for 15 weeks (plus 4 weeks of set-up and calibration) starting in mid-August, until the end of the 2009 RA beam period.
- Complete the event statistics needed to reach $(\delta B/B)_{\text{stat}} \simeq 3 \times 10^{-4}$

Resources requested are modest, similar to the 2008 level:

- material costs of operating the detector (MWPC gas, other supplies and consumables),
- partial support for local expenses for collaborators from former socialist countries.

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Experiment R-05-01 (PEN) collaboration members:

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