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

Progress Report and 2010 Beam Request

The PEN Collaboration

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

PSI BV41
18 February 2010

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: $$B_{\mathrm{calc}} = \frac{\Gamma(\pi \to e\bar{\nu}(\gamma))}{\Gamma(\pi \to \mu\bar{\nu}(\gamma))}_{calc} =$$

$$\begin{cases} 1.2352\,(5) \times 10^{-4} & \text{Marciano and Sirlin [PRL } \mathbf{71} \text{ (1993) 3629],} \\ 1.2354\,(2) \times 10^{-4} & \text{Finkemeier [Phys. Lett. B } \mathbf{387} \text{ (1996) 391],} \\ 1.2352\,(1) \times 10^{-4} & \text{Cirigliano and Rosell [PRL } \mathbf{99}\text{, 231801 (2007)].} \end{cases}$$

Experiment, world average [current PDG]:

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

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

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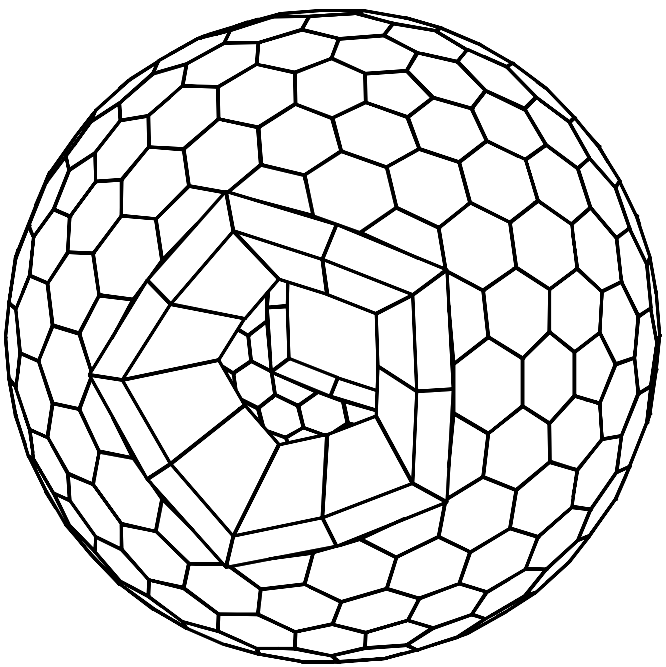
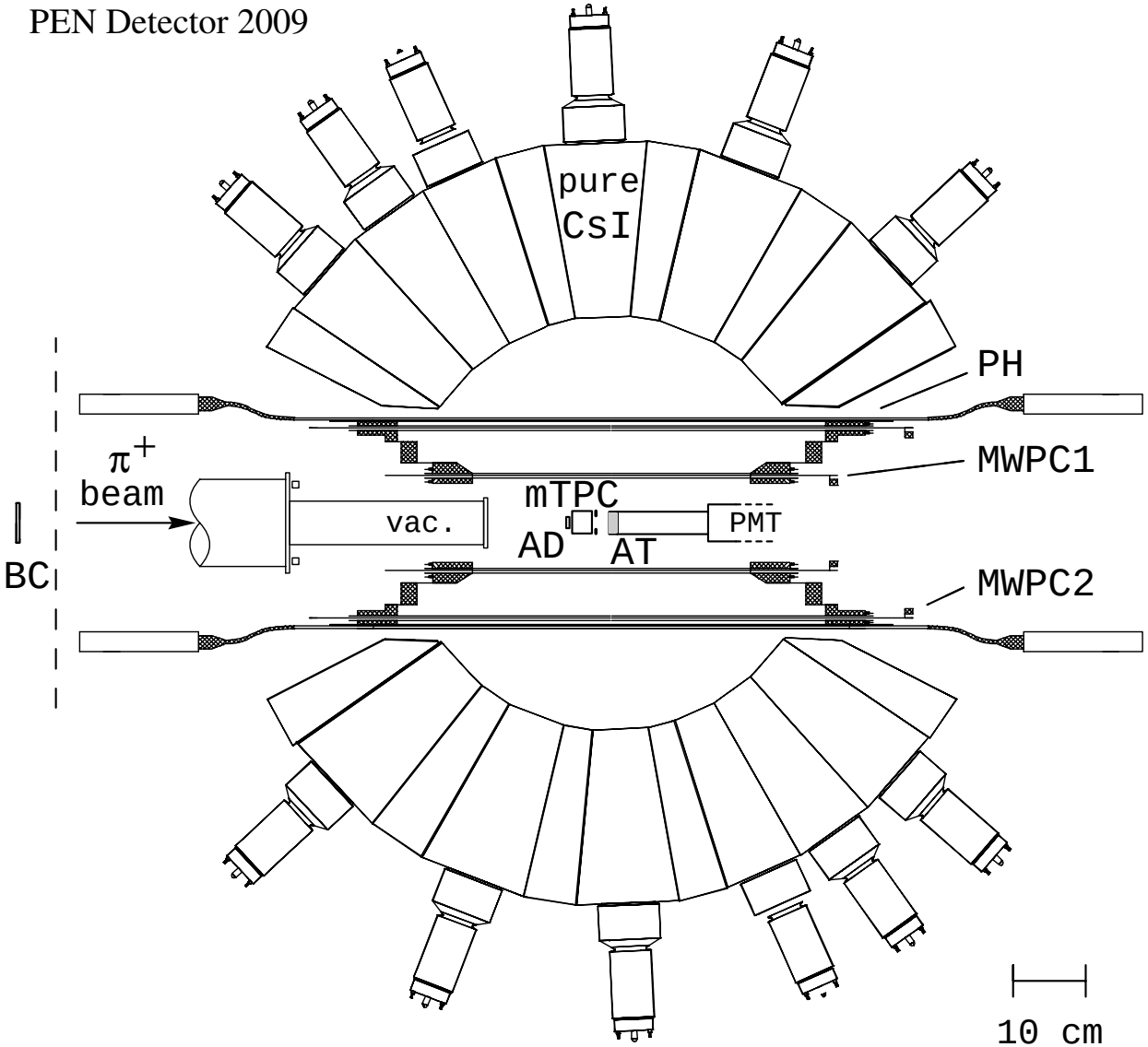
The PEN apparatus

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





Goals and improvements for 2009

Goals and improvements for the 2009 run were:

- Continue and refine analysis of 2008 data.
- Implement a mini-TPC detector to track beam particles.
- Overhaul DAQ electronics and software:
  - implement triggers based on the full calorimeter energy sum and eliminate the unreliable LB102 logic units,
  - replace 0.5 ns LSB FastBus TDC with 100 ps LSB VME TDCs units,
  - implement waveform digitized readout for the new mini-TPC detector.
- Study and optimize shielding.
- Record at least $\mathbf{5 \times 10^6}$ $\boldsymbol{\pi \longrightarrow e\nu}$ events with well controlled systematics.

All of the objectives were fullfilled or exceeded.

In fact, we recorded $\mathbf{10 - 11 \times 10^6}$ $\boldsymbol{\pi \longrightarrow e\nu}$ events.

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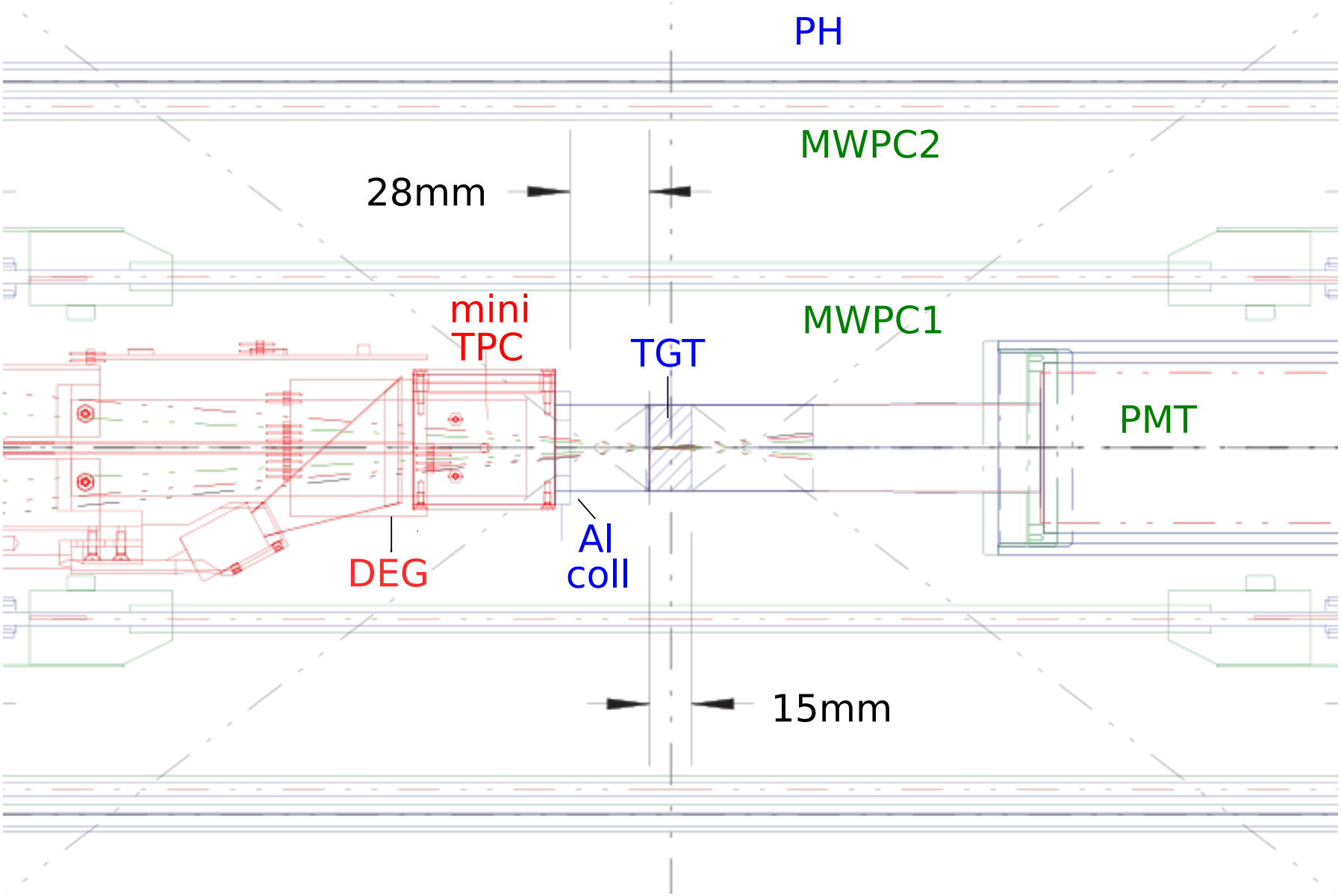
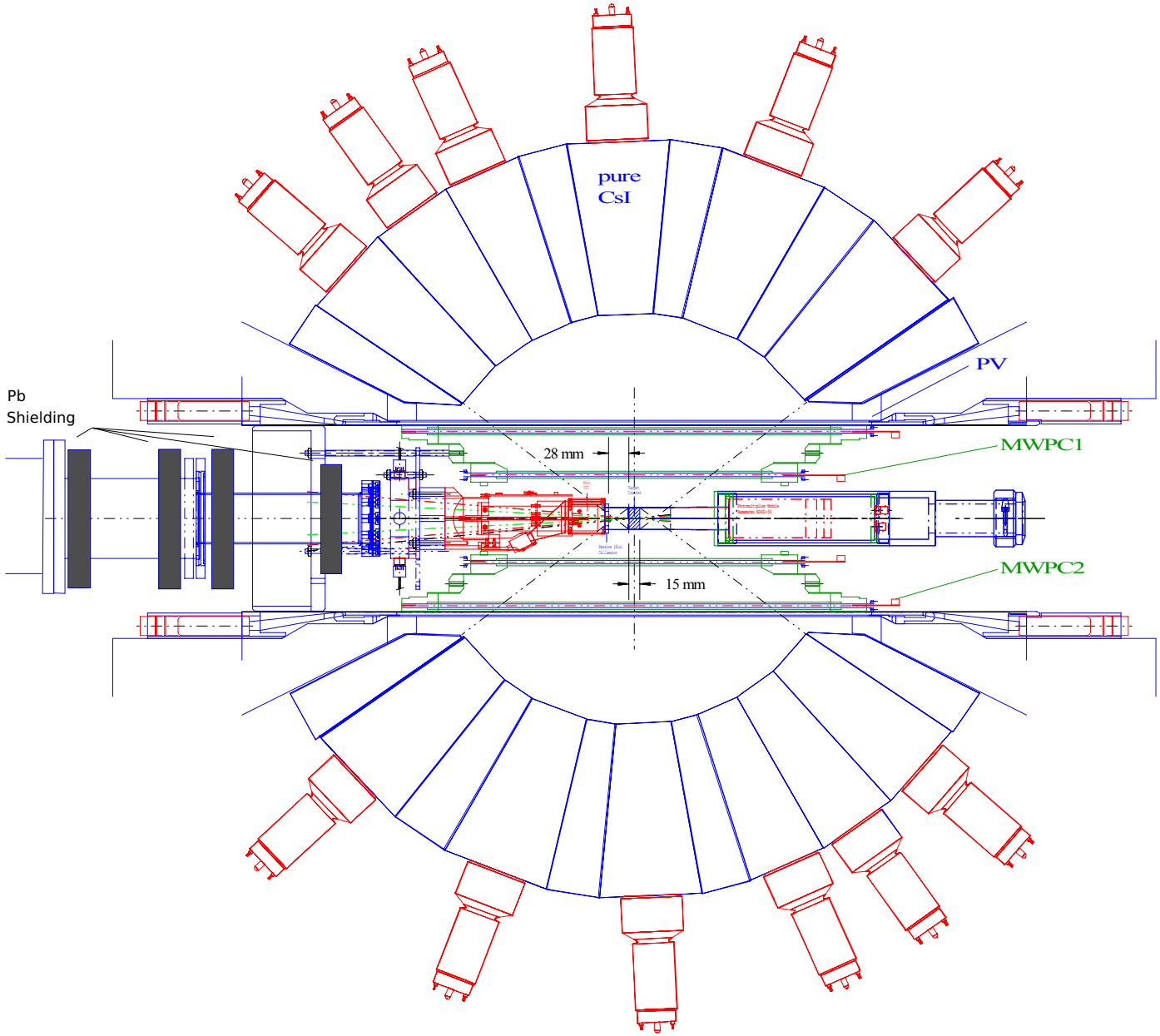
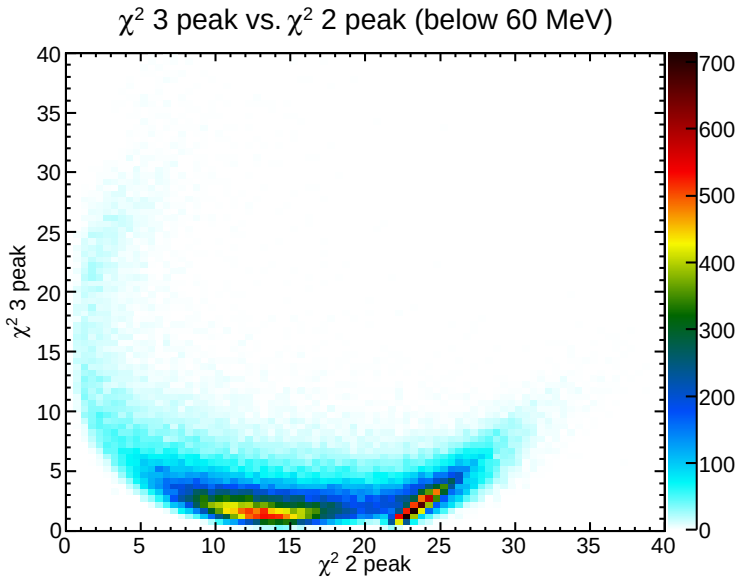
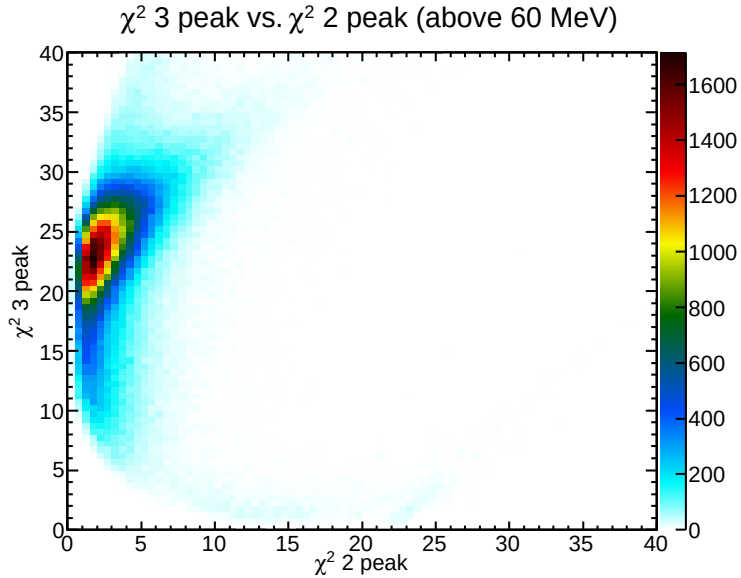
Central detector region in the 2009 PEN run

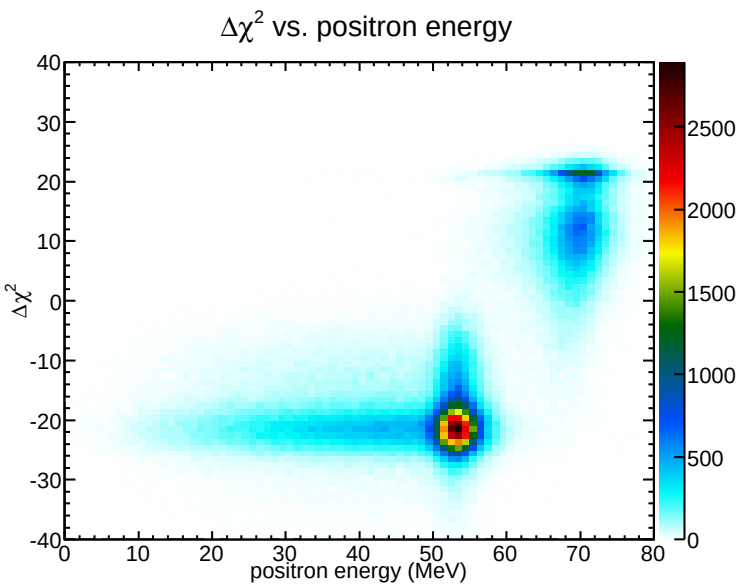


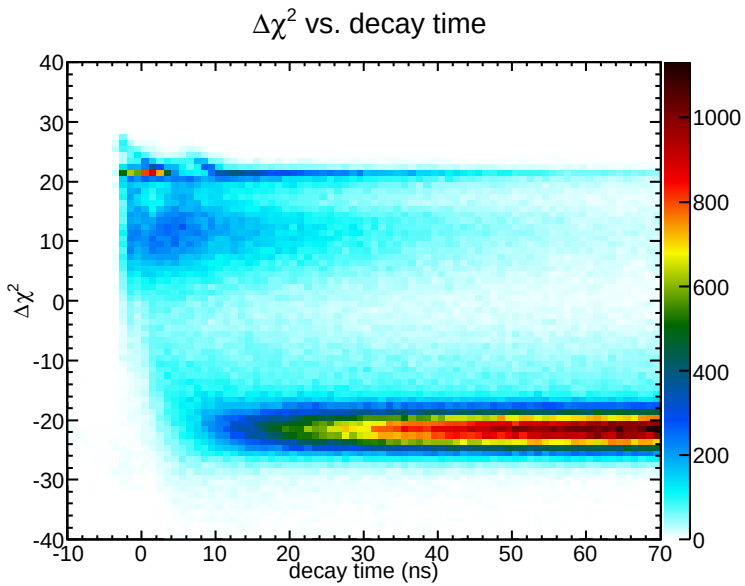

pure
CsI
PV
Pb
Shielding
28 mm
MWPC1
MWPC2
15 mm

Target waveform analysis

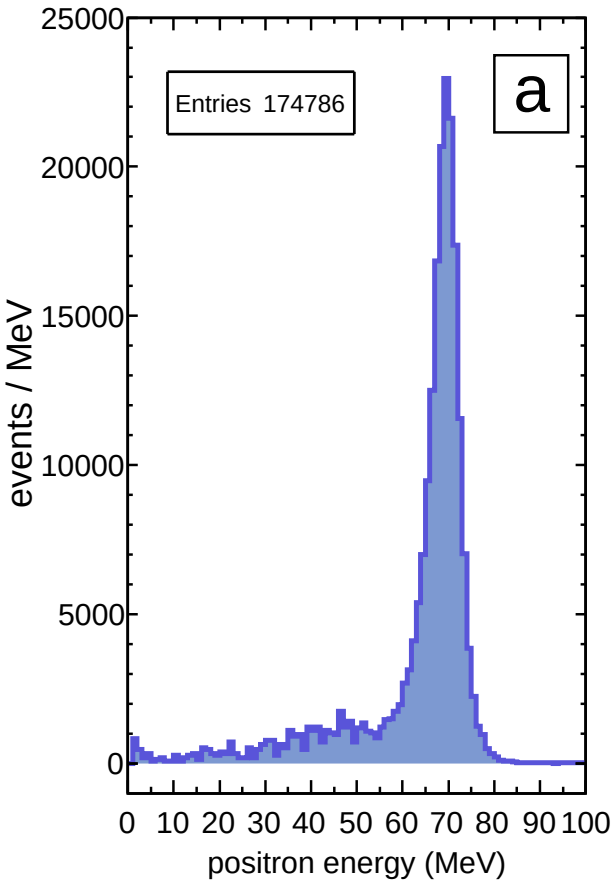




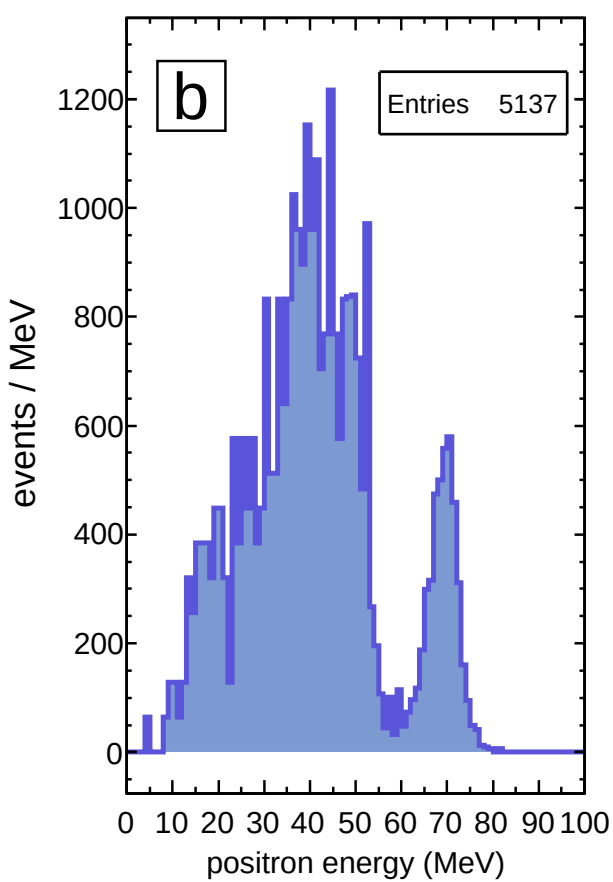




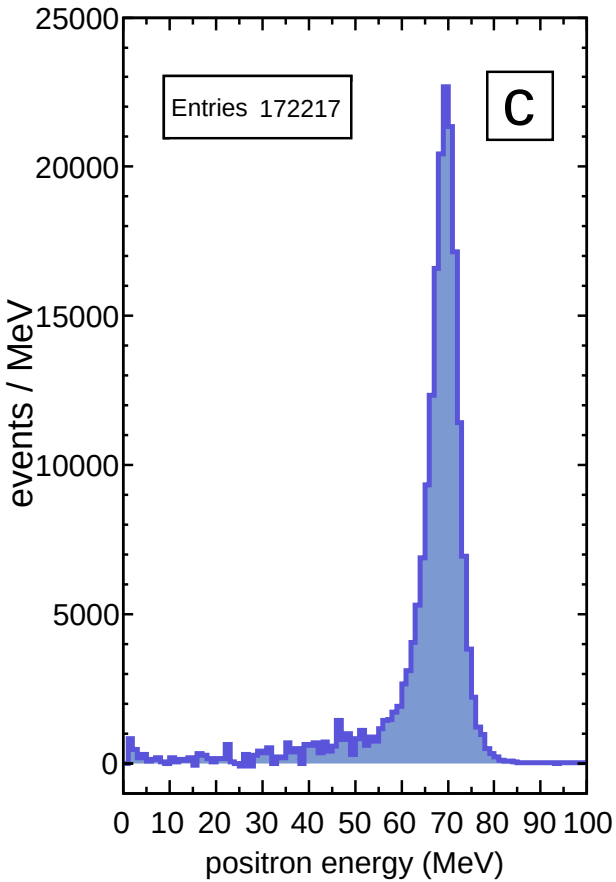
Positron energy "tail" determination



$t \leq 25\,\text{ns}$

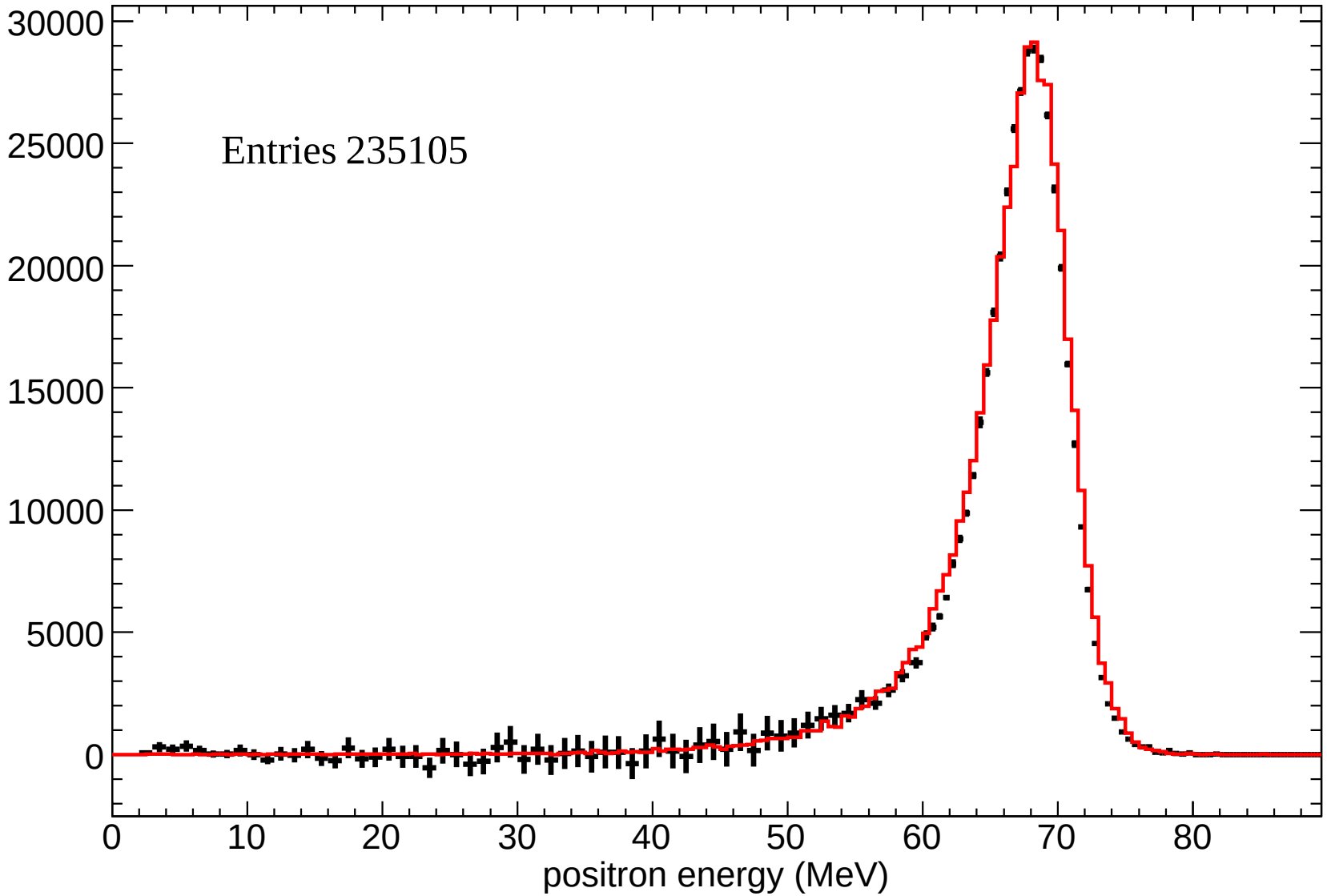


$100 \leq t \leq 150\,\text{ns}$



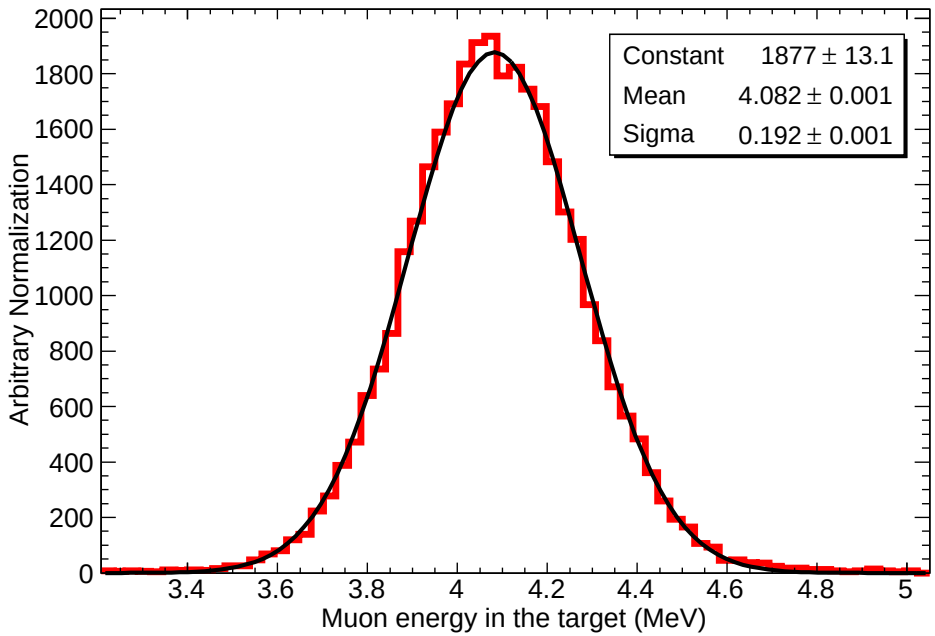
normalized difference

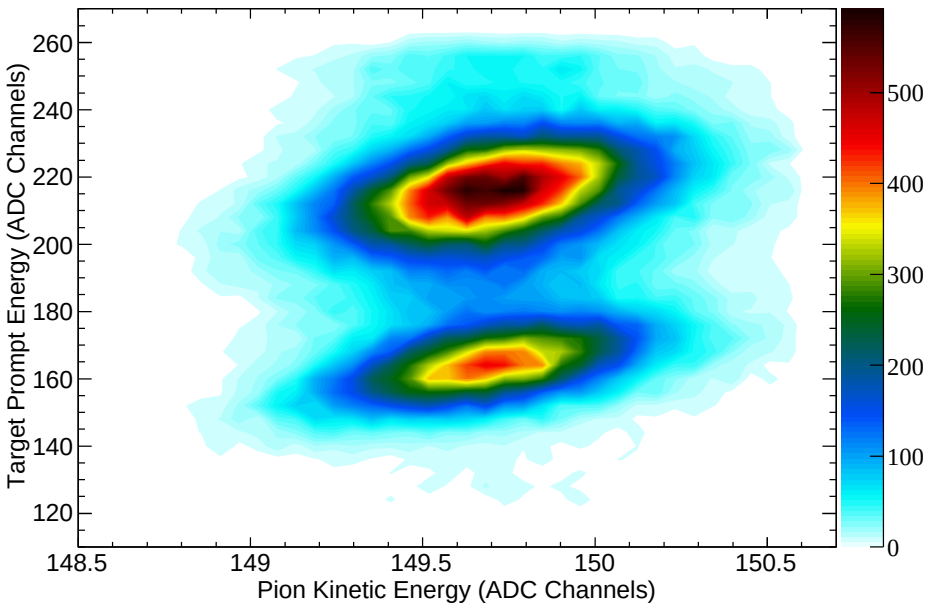
cont'd (work in progress)

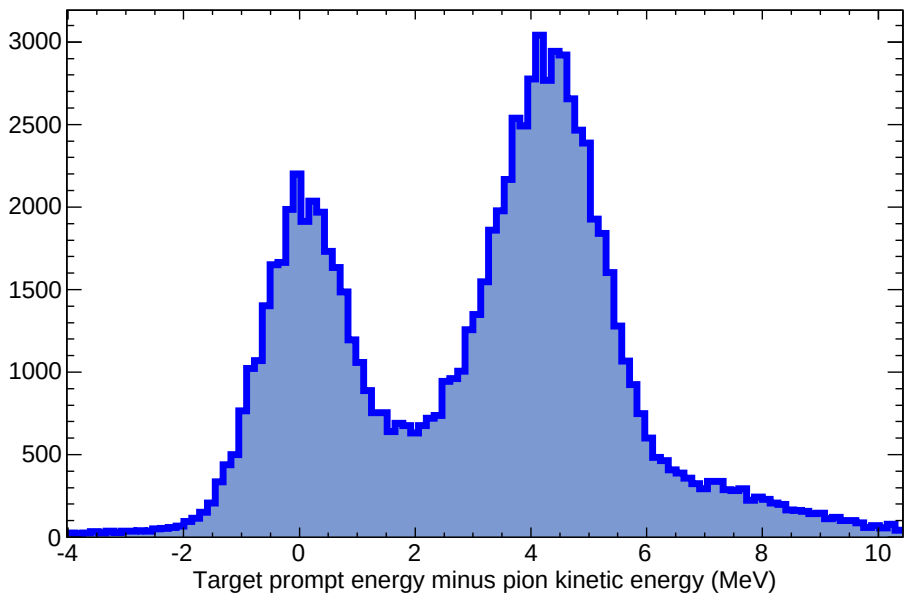


Target energy resolution

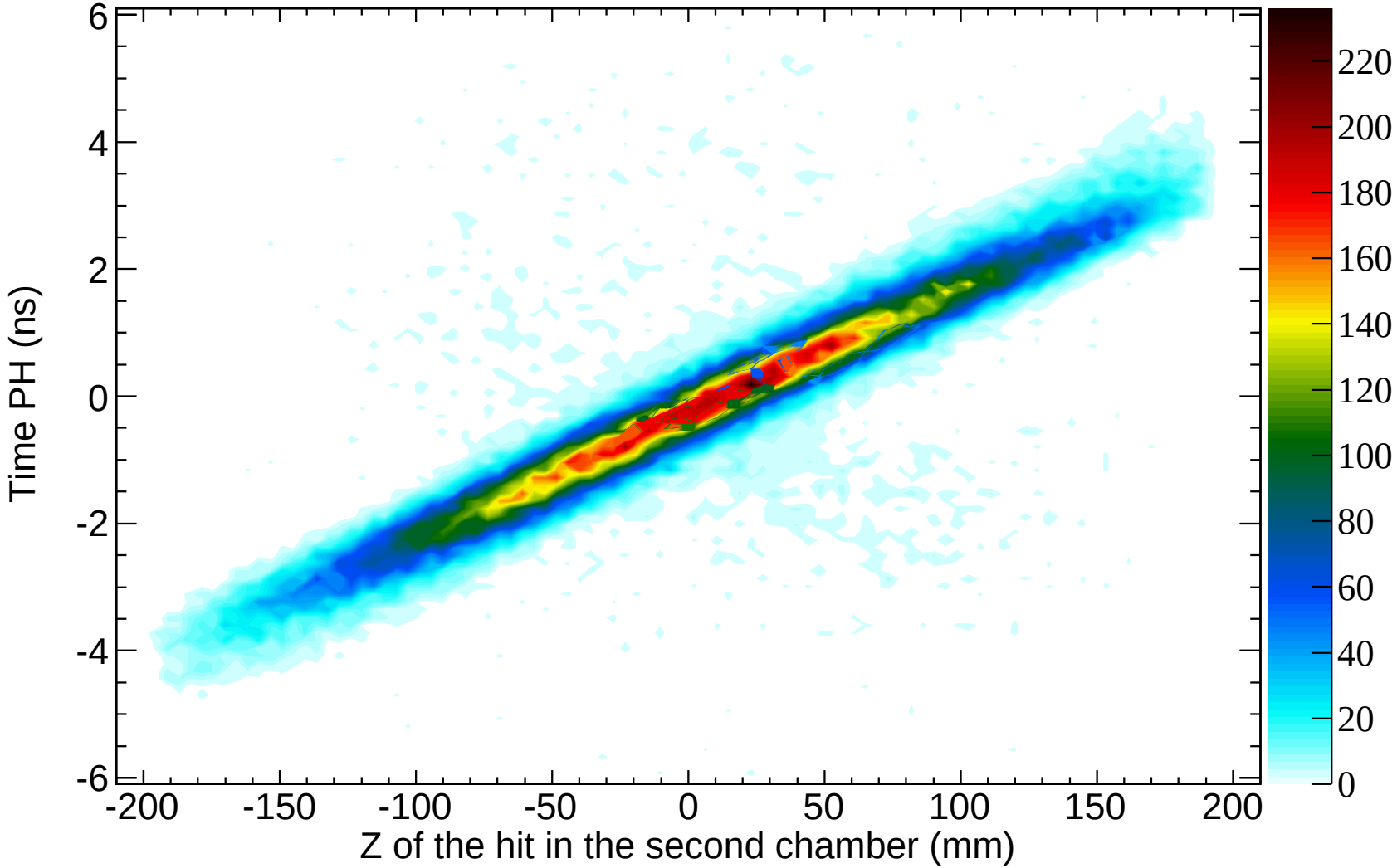
Energy spectrum of 4.1 MeV muon from $\pi \longrightarrow \mu \longrightarrow \mathbf{e}$ seq. decay in TGT: (2009 data)







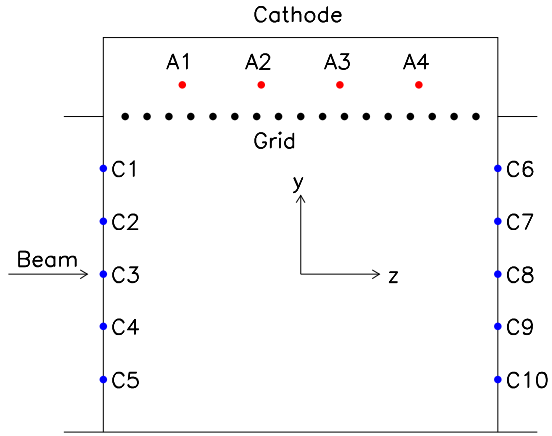
Plastic hodoscope timing resolution

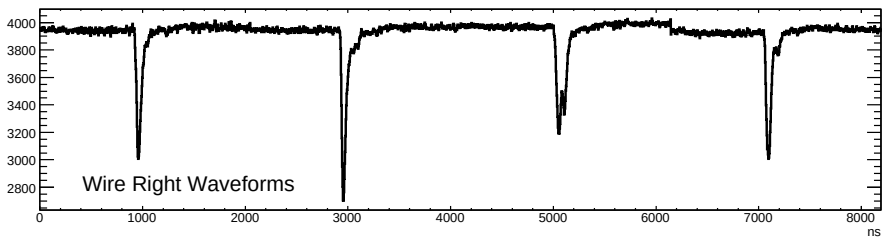


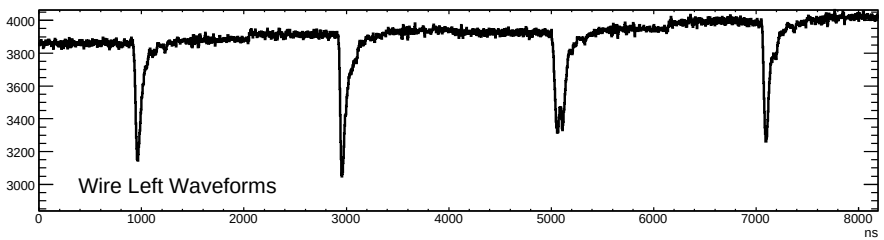
Intrinsic $\sigma_t \simeq 0.25$ ns (compared with ≥ 0.35 ns before).

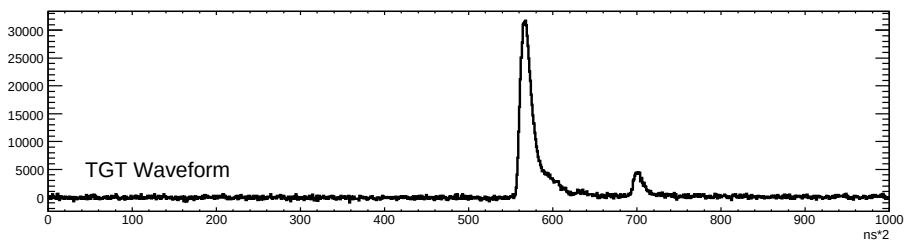
Mini-TPC waveforms

mini-TPC schematic diagram $\Longrightarrow$

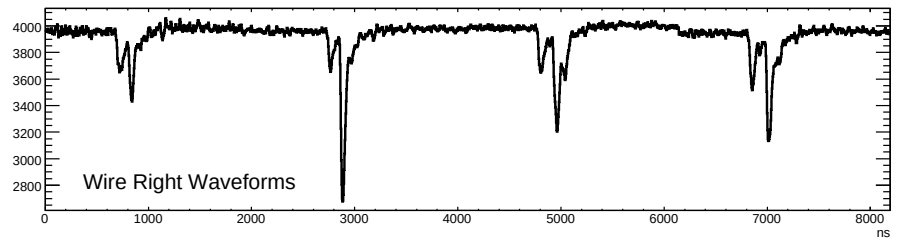


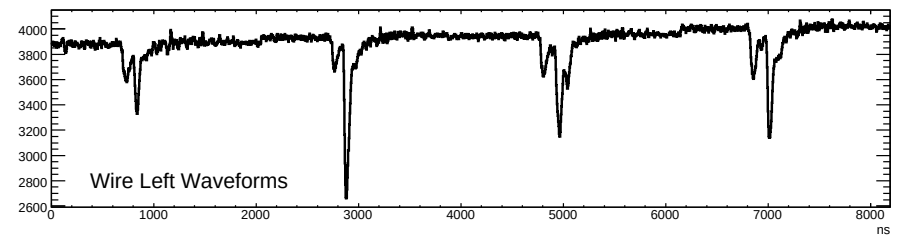


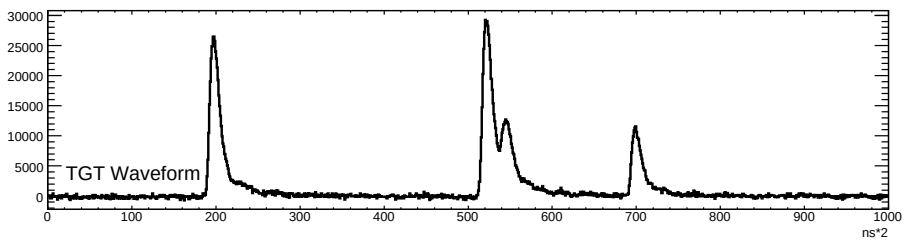




A single beam particle.



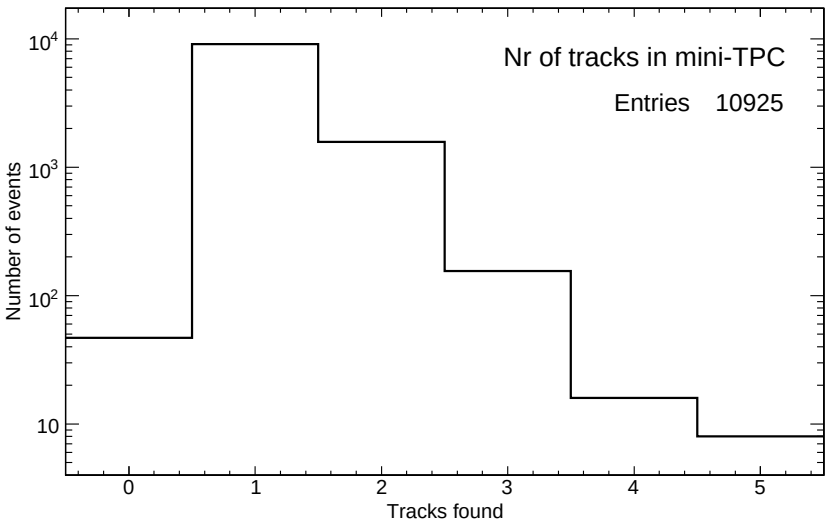




A pion stop preceded by a beam particle $\sim$160 ns earlier.

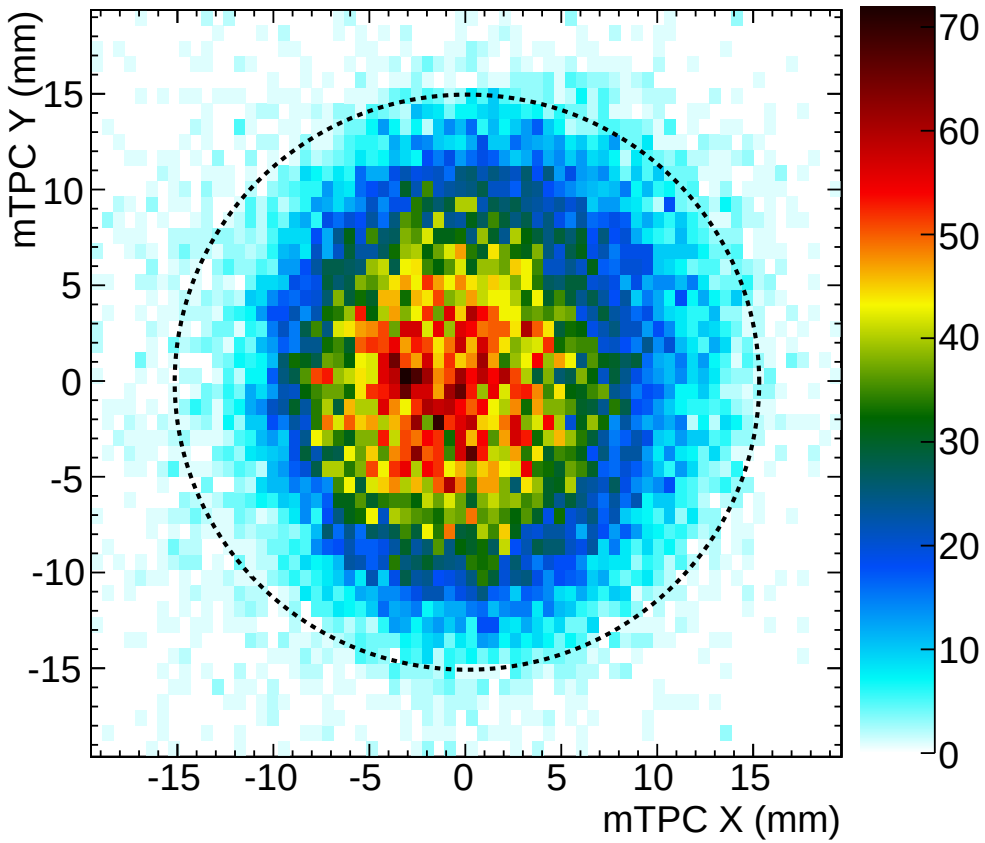
Mini-TPC performance

Track multiplicity



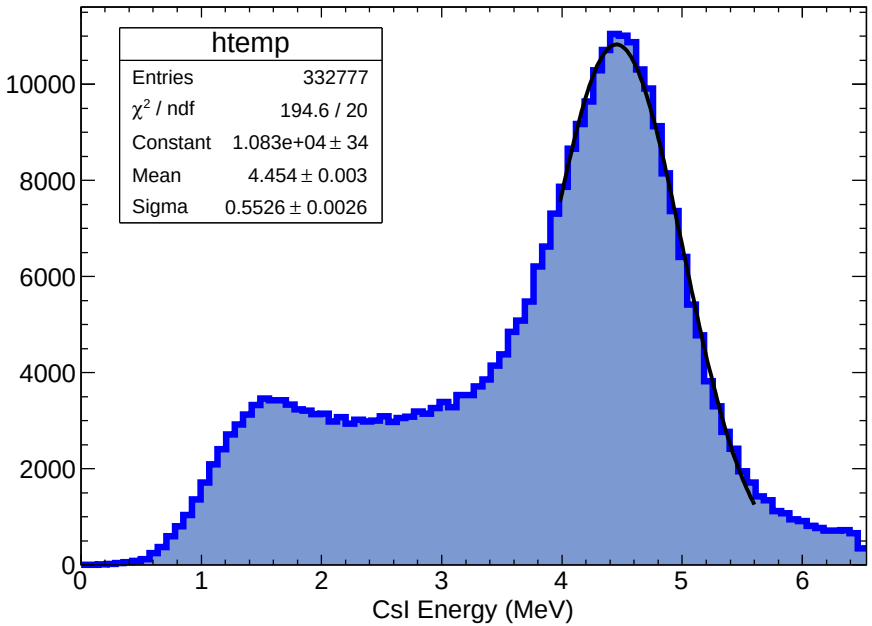
Track inefficiency:
$\approx \mathbf{5 \times 10^{-3}}$.

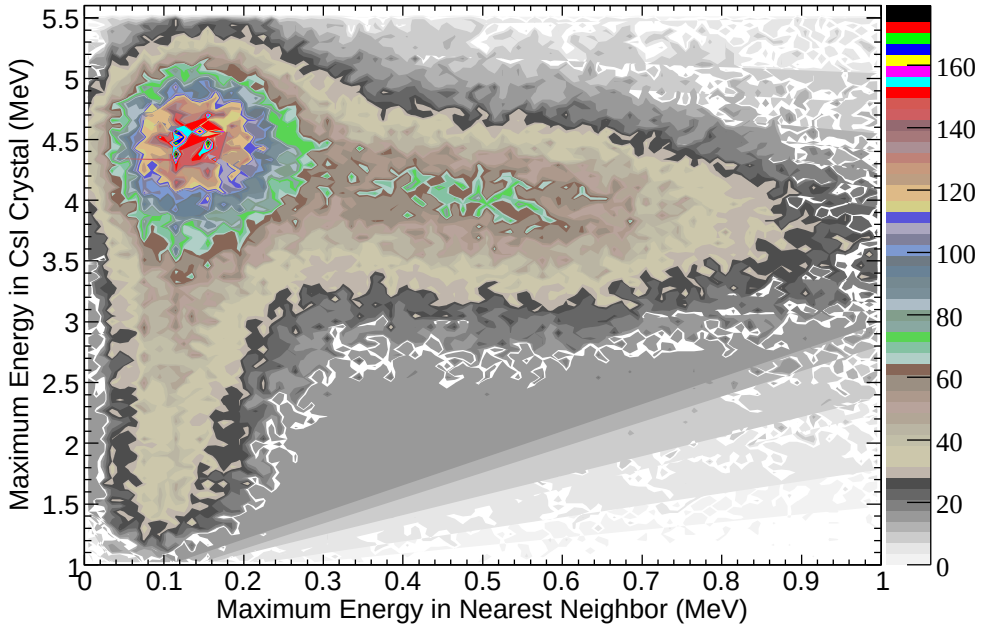
Decay vertex prediction



$\delta \mathbf{x} \leq \mathbf{1.3}$ mm (charge division)
$\delta \mathbf{y} \leq \mathbf{0.35}$ mm (drift time)

CsI calorimeter with AmBe source





- **$\Delta E/E \simeq 0.12$** for the 4.4 MeV line.
- **511 keV** photons well resolved.

Plans and beam time request for 2010

Plans for the 2010 run:

- Implement new low-mass mini-TPC, positioned against the target.
- Further improve shielding.
- Improve DAQ with new sync. mode of frontend computers.
- Run at slightly higher $\mathbf{p}_{\mathrm{beam}}$ with $\sim \mathbf{2}\times$ signal rates of 2009.
- Lower the CsI temperature for improved **E** and **t** resolution.
- Aim to collect $\sim \mathbf{25} \times \mathbf{10}^{\mathbf{6}} \boldsymbol{\pi}_{\mathbf{e2}}$ events with room for systematics.

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- Run for 15 weeks (plus 3 weeks of set-up and calibration): end of April through August 2010.

Requested PSI resources are modest, similar to the 2009 level.

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- Aim to collect $\sim \mathbf{25} \times \mathbf{10}^{\mathbf{6}} \boldsymbol{\pi}_{\mathbf{e2}}$ events with room for systematics.

Beam time request:

- Run for 15 weeks (plus 3 weeks of set-up and calibration): end of April through August 2010.

Requested PSI resources are modest, similar to the 2009 level.

Plans and beam time request for 2010

Plans for the 2010 run:

- Implement new low-mass mini-TPC, positioned against the target.
- Further improve shielding.
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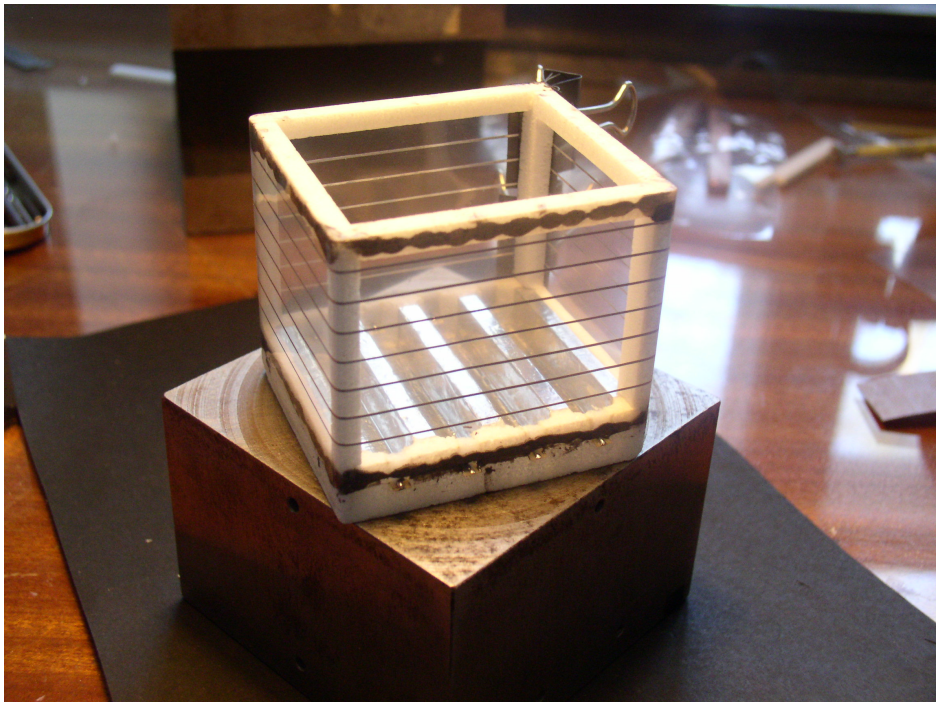
New, low-mass mini-TPC



Recent photos of the mark-II low-mass mini-TPC (Dubna group).

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