Detector R&D Overview for Mu2e-II

Detector Environment

	Mu2e	Mu2e-II	detector impact
Average Power	8KW	~100KW	10x total radiation dose (?)
Nominal peak power	24KW	~100KW	~3-4x higher radiation rate (SEU, charge load, flash,
Peak power variation	~50%	<10%	less DAQ headroom needed
Proton pulse width	250ns	<100ns	more intense flash (?) < π^- background
stopped mu/sec	$1.5x10^{10}$	$\sim5x10^{10}$	~3x accidental rate from μ nuclear captures (n, p, γ)
stopped mu (total)	$6.7x10^{17}$	$\sim10^{19}$	~10x DIO background

PS, TS, Production Target Detector impact R&D

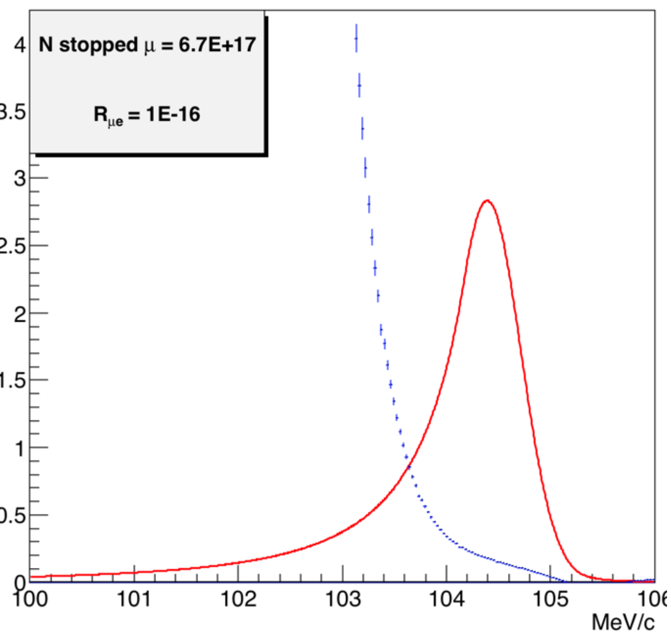
- Flash spectrum and rate
  - Affects many detectors (tracker, STM, …)
  - Assumed to scale with power in this talk (~10x)
- μ^- energy spectrum + spatial distribution
  - collimation?
- lower PS (+TS) field for 800 MeV beam ?
  - μ^- transport and collimation
- Extinction Monitors?

Tracker R&D

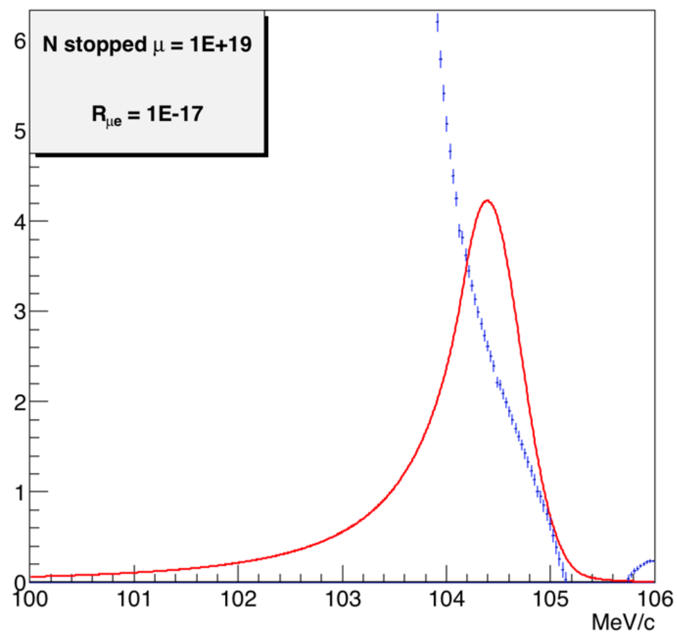
- SES/10 ⇒ ~1/2 momentum resolution
  - Dominated by energy straggling (target, IPA, straws)

Tracker Resolution toy MC study

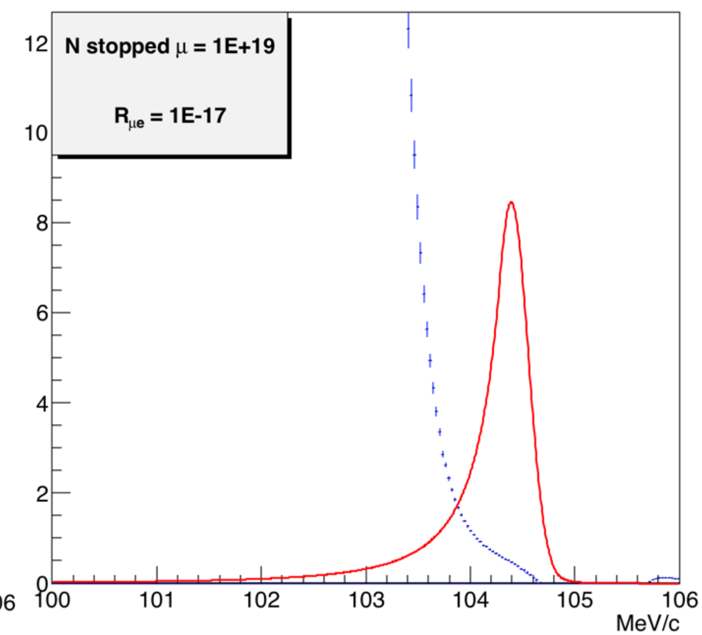
Mu2e



Mu2e-II



Mu2e-II 1/2 resolution



More Tracker R&D

- Straw charge load (naively) increases by ~10x
  - 50% of active volume will integrate > 1 C/cm (current test limit)
  - 2 % > 5 C/cm
- Straw space charge increases by ~3x
  - Effect on gain not known: test in progress
- Resolution, radiation effects proportional to straw mass ⇒ **need thinner straws**
- Thinner straws R&D questions
  - gas leak, mechanical, manufacturing, Panel assembly, …
- Electronics radiation dose increases by ~10x
  - Increased shielding?
  - PolarFire FPGA? Custom readout ASIC? Other components?

Stopping Target and IPA R&D

- ~2/3 the mass (momentum resolution)
  - ~1/3 from stopping target, ~1/3 from IPA
- Stopping Target optimization
  - material, mass, geometry, density, …
- Active target or IPA?
  - Improves momentum resolution by defining the trajectory near the target
  - Si is an interesting ST material choice for $\mu^- \rightarrow e^+$
- Helical IPA (Gollin)?
  - might make sense if we're exploring an observation

Calorimeter R&D

- PID, track seeding require good timing, modest energy resolution
  - Must be able to identify CE clusters
- 3x higher accidental rate, background energy
  - Faster crystal and/or readout R&D
- 10x integrated dose
  - Crystal damage R&D
  - Alternate technologies?

CRV R&D

- Cosmic rates, integration time unchanged
  - Performance specs unchanged
- Instantaneous accidental rate ~3x (?)
  - 3/4 coincidence sufficient?
- Integrated radiation ~10x (?)
  - Will scintillator survive?
    - RPCs?
  - R&D on rad-hard sensors

TDAQ R&D

- Algorithm efficiency/rejection tested to > Mu2e nominal
  - Scaling behavior is adequate
  - Necessary research is/will be done for Mu2e
- Rad-hard optical transceivers
  - piggy-back on HLLHC R&D (?)
- Data throughput
  - 3x higher rate
  - FPGA processing to reduced data payload?
    - compute tracker hit charge vs ADC waveform (50% reduction)
- Need 10x computation speed improvement for trigger
  - Moore's law?
  - Algorithm improvements?
  - GPU or other hardware?

Muon Counting (STM) R&D

- Ge sensors at/near dose limit for Mu2e, how can it be reduced?
  - Compton scattered electrons?
  - Beam bending crystals?
  - Other sensors?
- Prompt x-rays for other target materials?
- Muon capture product (p) reconstruction?
  - Relies on AlCap results (10%)

Conclusions

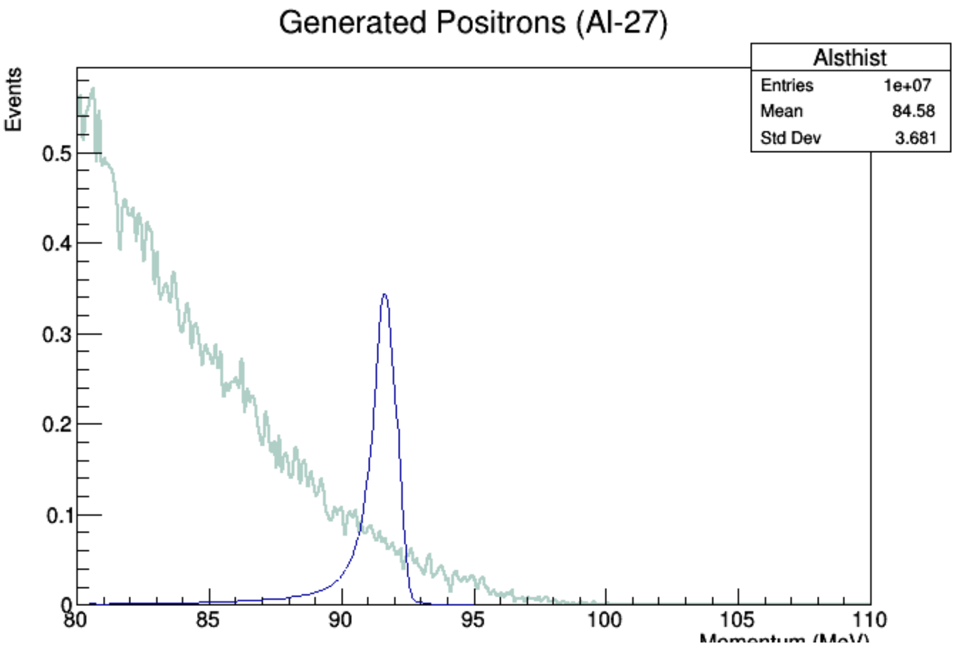
- Lots of interesting detector R&D topics to explore
- More details in following talks

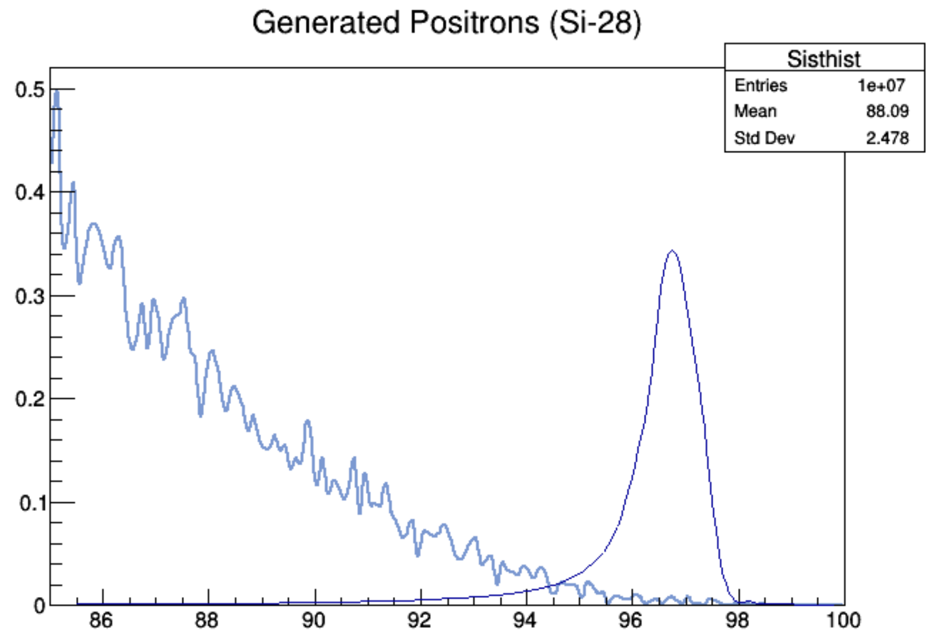
Backup

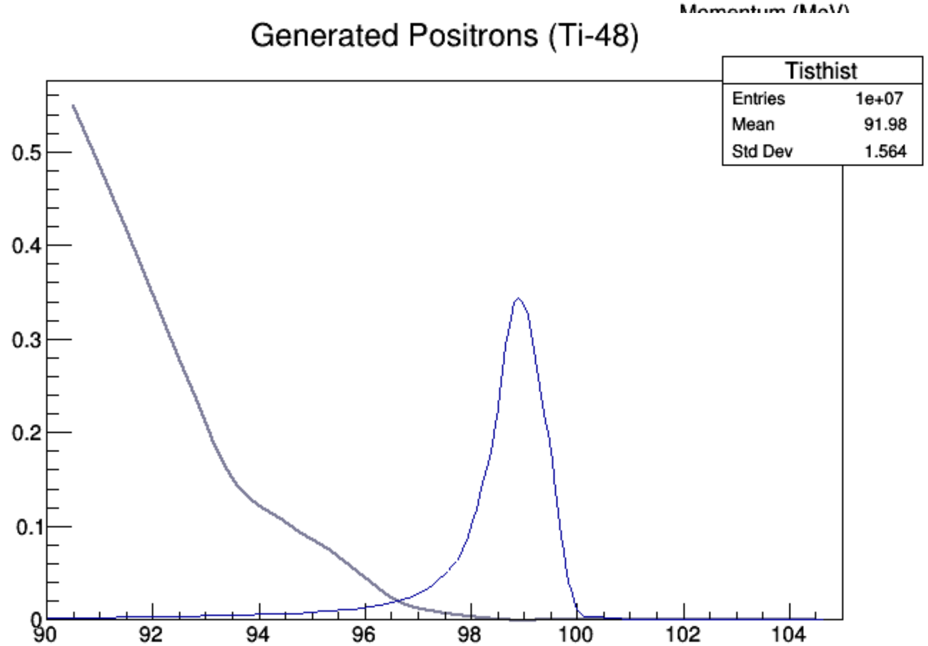
Safety Factors

- Mu2e: ~X10 on dose, ~X3 on rates
- Mu2e measurements will reduce some uncertainties
  - Simulation uncertainty (X3) on rates
  - Charge tolerance of Mu2e straws
  - Production variability (?)
- R&D might start before Mu2e operations
  - Conservative option: keep Mu2e factors

$\mu^-(Z) \rightarrow (Z-2)e^+$ (W. Soong, Y. Kolomensky)







	Aluminum-27	Silicon-28	Titanium-48
Mu2e Lifetime	SES: 1.175e-16 90% CL: 6.019e-14	SES: 4.685e-17 CL 90%: 1.171e-14	SES: 3.925e-17 CL 90%: 3.294e-15