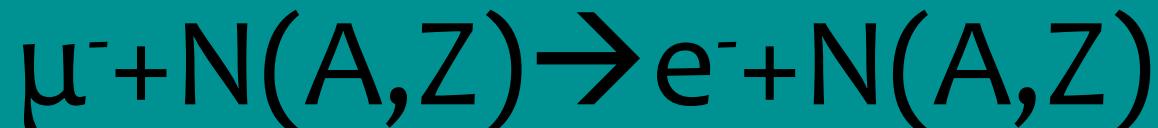


MUSE



# Radiatively corrected generator for



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# Overview

- Recently started looking at  $\mu^- + N(A,Z) \rightarrow e^+ + N(A,Z-2)$  conversion
- Not a coherent process: the daughter nucleus can be either in the **Ground State** and in an excited state
- What is the positron energy ?
  - discrepancies in the numbers floating around
  - want to have a “party line” number, accurate to  $\sim 10$  keV
- Radiatively Corrected generator for electrons and positrons of different energies

# Evaluation of positron energy

$$E_{e^+} = m_\mu - B_\mu - E_{recoil} - \Delta_{Z-2}$$

Muon mass      Muon binding energy      Daughter nucleus kinetic recoil energy      Nuclear masses differences

The diagram shows the formula for positron energy with four terms enclosed in boxes. Arrows point from each term to its corresponding label below the equation: 'Muon mass' points to  $m_\mu$ , 'Muon binding energy' points to  $B_\mu$ , 'Daughter nucleus kinetic recoil energy' points to  $E_{recoil}$ , and 'Nuclear masses differences' points to  $\Delta_{Z-2}$ .

[MeV]	This pres	DocDB-277	DocDB-15078
$B_\mu$	0.4644	0.4732	0.4747
$E_{recoil}$	0.1695	0.1697	0.1712
$E_{e^+}$	92.32	92.38	92.31

- Account for the finite nuclear size ( $\sim 10$  keV), to be consistent with  $\mu^- + N(A,Z) \rightarrow e^- + N(A,Z)$  [Czarnecki et al. article]
- In the following the positron energy used is **92.32 MeV**
- Electron energy was estimated too in the following the value used is **104.97 MeV**

# Radiative correction generator

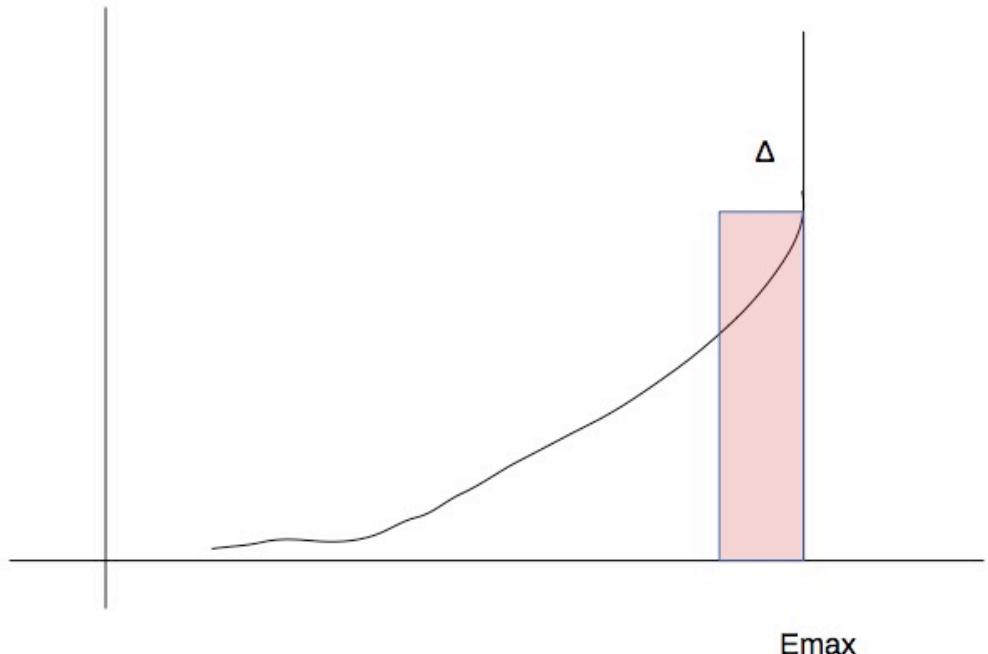
- There are two typologies of Radiative correction:
  - Emission of virtual photons : change the strength of the vertices
  - **Emission of real photons : change the kinematics →Affects the energy distribution**
- Need a generator that **includes radiative corrections** that can affect the final state kinematics
  - Tabulated for conversion electrons already exists
- The probability function used is described in **DocDB-7615** (R.Szafron)

$$\frac{1}{\Gamma_0} \frac{d\Gamma}{dE_e} = \frac{1}{E_{max}} \left[ \left( \ln \frac{4E_e^2}{m_e^2} - 2 \right) \frac{E_e^2 + E_{max}}{E_{max}(E_{max} - E_e)} + P(E_e) \right]$$

- $E_{max}$  : energy if no photon emission
  - 104.97 MeV for the regular conversion
  - 92.32 MeV for the muon to positron conversion
- **Universal part** + model-dependent part
  - Universal part: photon emission by a free electron
  - Model-dependent part accounts for electron being not free, small

# Model-dependent part is small

- In DocDB-7615 the integral of the integral of the probability function is performed in a interval  $\Delta$  around the maximum energy  $E_{\max}$
- Effect of the different model is negligible



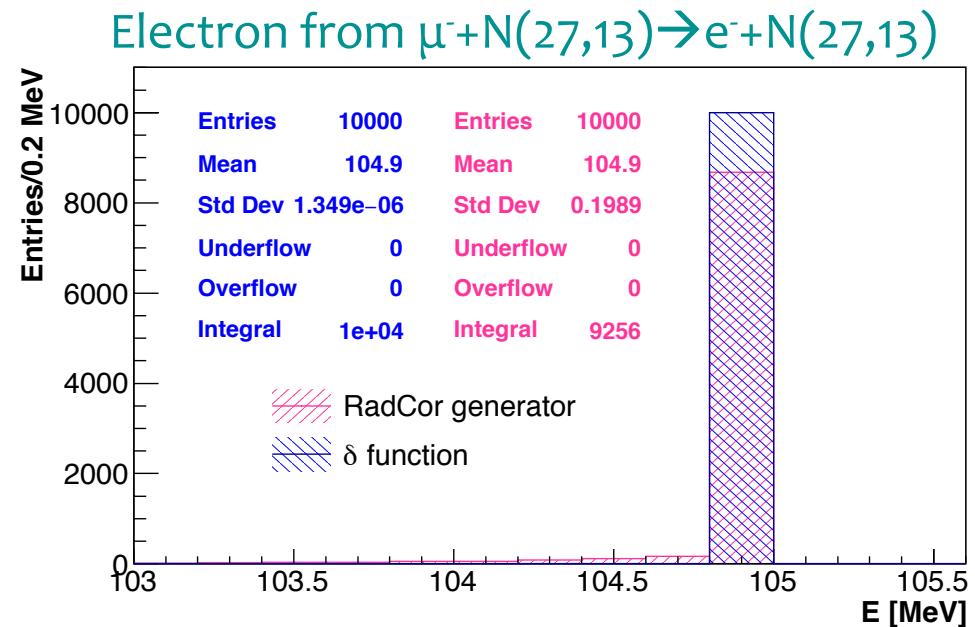
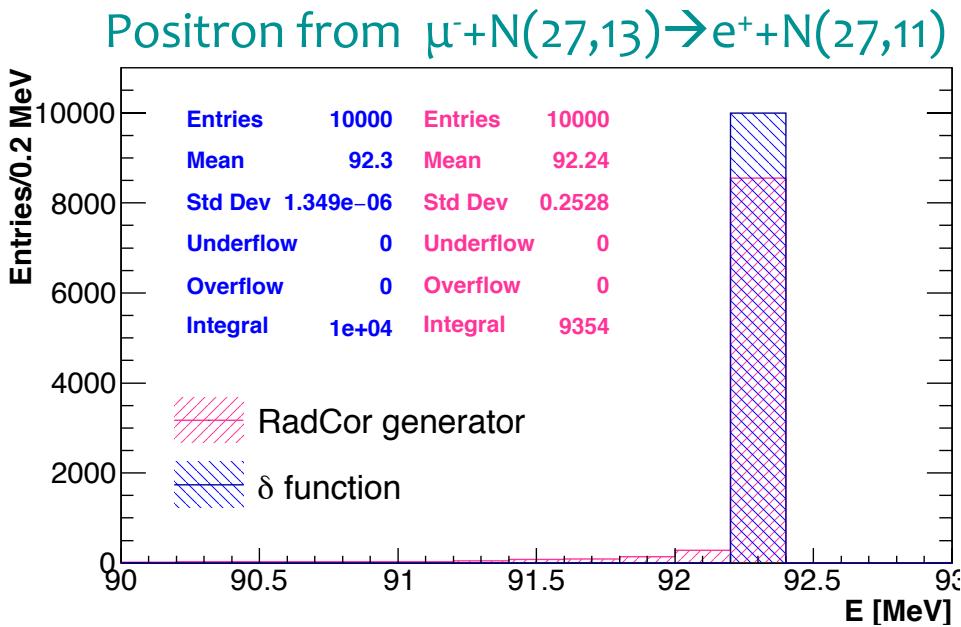
Signal window [MeV]	0.1	1.5	2.0
Universal part	0.861	0.923	0.930
Model I	0.861	0.923	0.930
Model II	0.861	0.924	0.930
Model III	0.858	0.921	0.927

# Implementing rad-corrected spectrum

- Take probability function from DocDB-7615 and make a binned spectrum out of it
  - Bin size chosen: 0.1 MeV comparable with the tracker resolution in the experiment
- Probability function is negative at very low energy
  - Start the spectrum at 0.7 MeV
- Infrared divergence at  $E \rightarrow E_{\max}$  ( very small  $q^2$ )
  - Integrate up the second last bin the function. At this point the integral of the last bin will be:

$$1 - \int_{0.7}^{n-1} f(E) dE$$

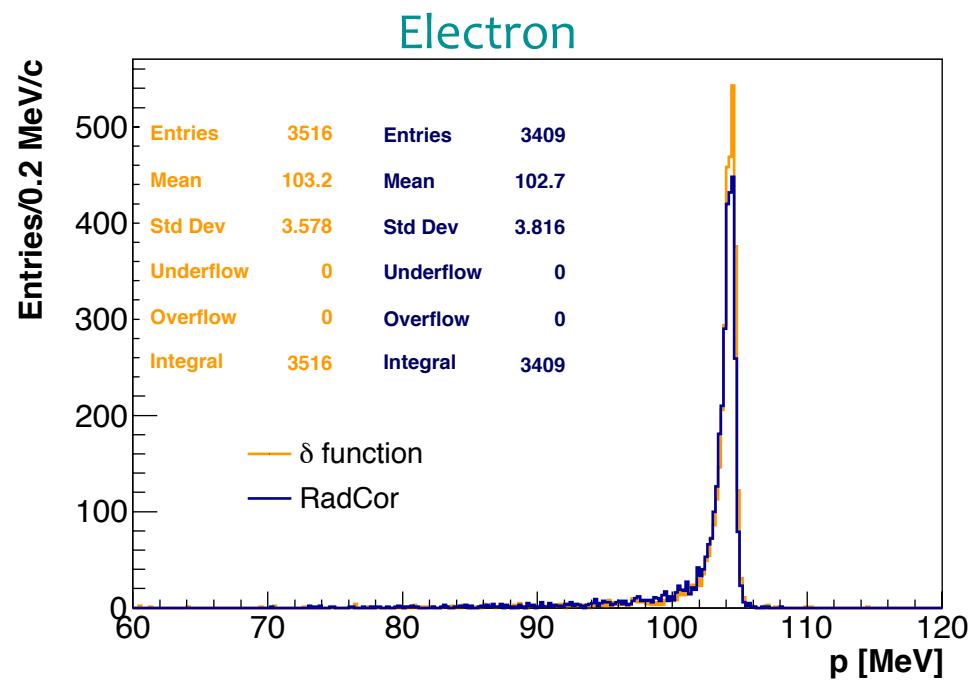
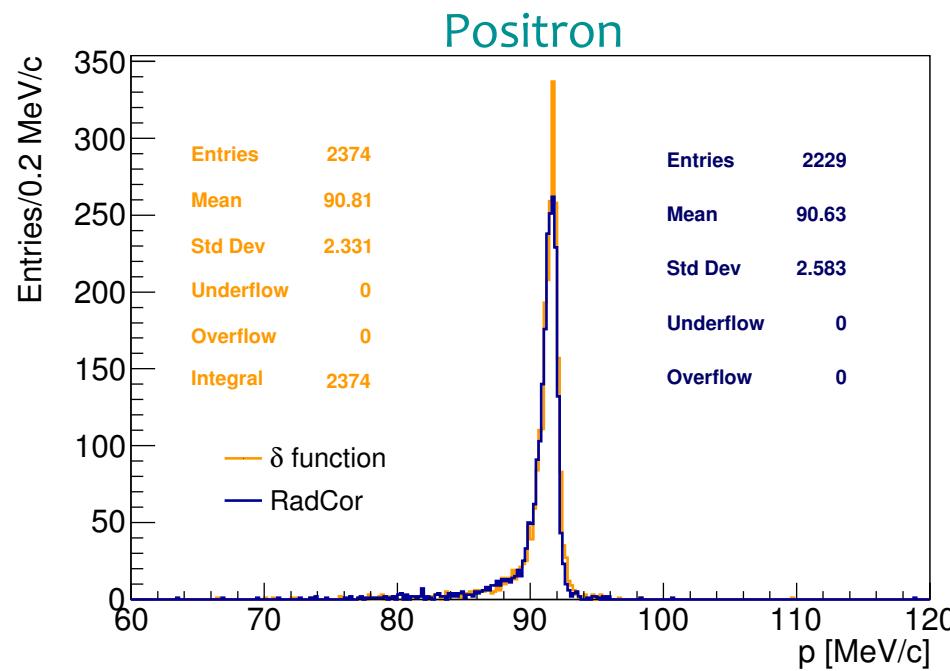
# Shape comparison



- Energy spectrum for positrons and electrons from conversion on Al
- Radiation corrections introduce tails in the distribution
- Tails represent ~ 15% of the whole sample both for electrons and positrons

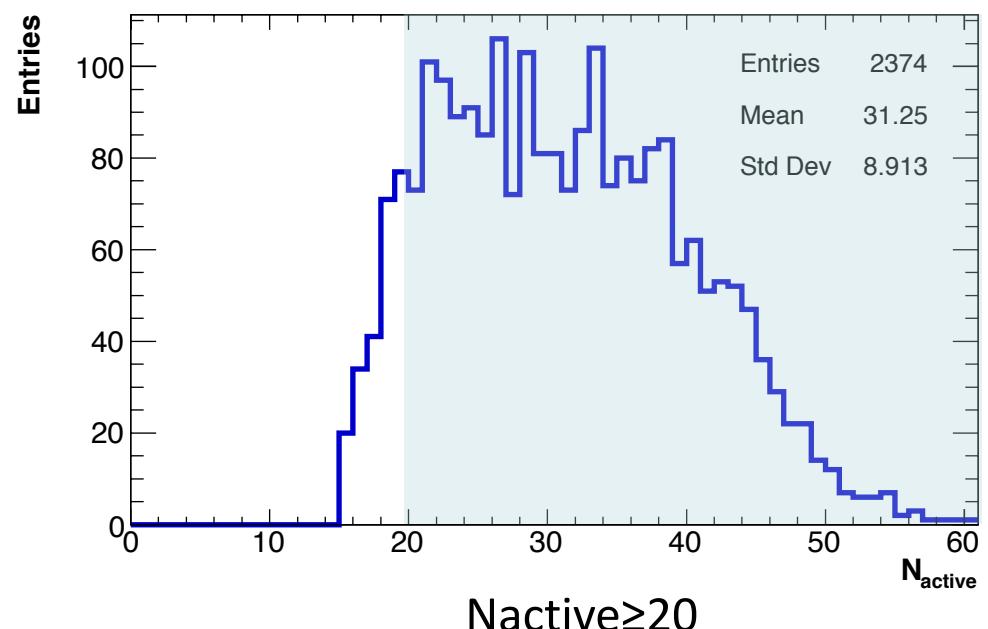
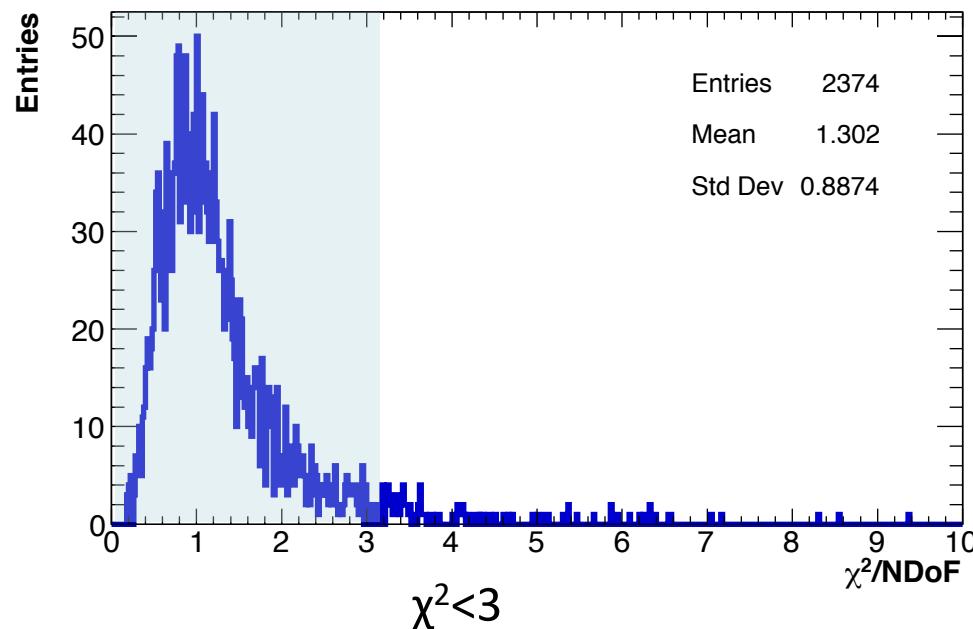
# No selection cuts – Momentum distribution

- Rad-correction generator implemented in the Offline
- Validating the generator reconstructing events and looking at the reconstructed quantities
- Reconstructed track momentum distribution from positrons and electrons in conversion in Al
- **No background included**



# Initial thoughts on selection cuts

- At the moment there are not optimized cut for  $\mu^- + N(A,Z) \rightarrow e^+ + N(A, Z-2)$
- Positrons from Al conversion have lower energy → lower acceptance
- Signal more affected by backgrounds
- Loose cuts to start

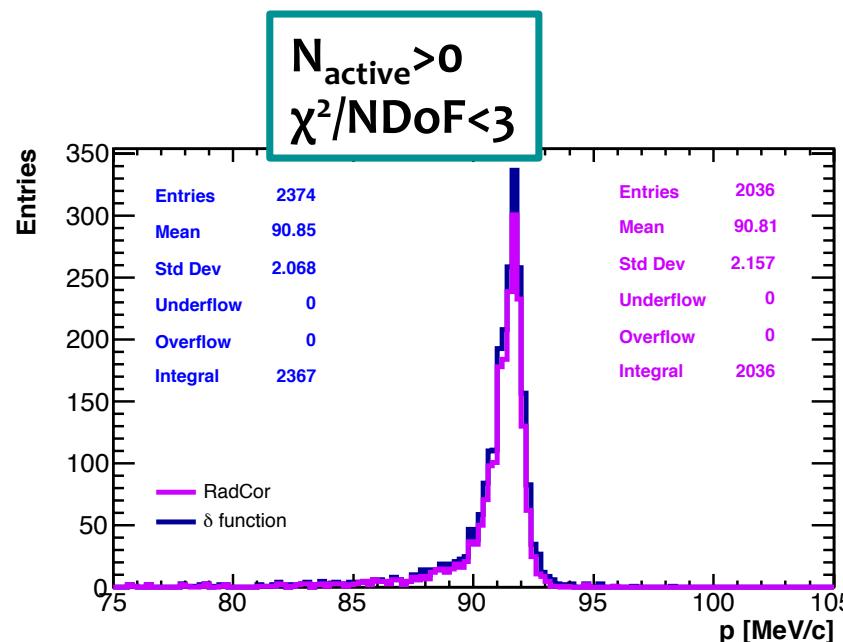
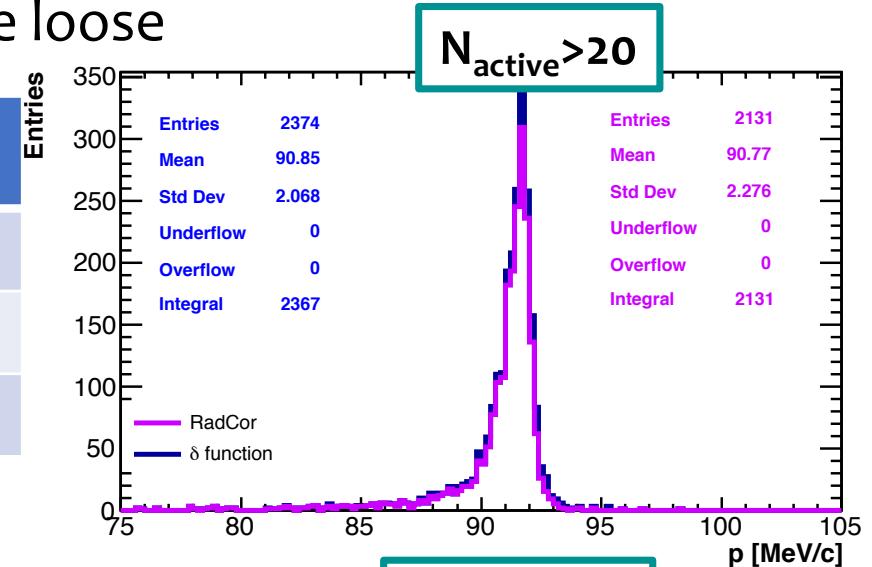


Accepted region

# Initial cut selection for $\mu^- + N(A,Z) \rightarrow e^+ + N(A,Z-2)$ (1)

- At the moment there are not optimized cut for  $\mu^- + N(A,Z) \rightarrow e^+ + N(A,Z-2)$
- For the initial study the cut selected are loose

Cut applied	Efficiency a signal region of $92.32 \pm 1.5$ MeV
$N_{\text{active}} >= 20$	$89.9 \pm 0.6$
$\chi^2/\text{NDoF} < 3$	$96.7 \pm 0.4$
$N_{\text{active}} > 20 + \chi^2/\text{NDoF} < 3$	$87.1 \pm 0.9$



# Conclusion

- Have a “party line” number for e+ conversion energy; **92.32 MeV**
- Radiative corrections implemented in the Mu2e offline for conversion electrons and positrons
- First validation steps done
- Next : generation of the “mixed” e+ dataset with rad corrections