Looking into the centre of a supernova with LENA

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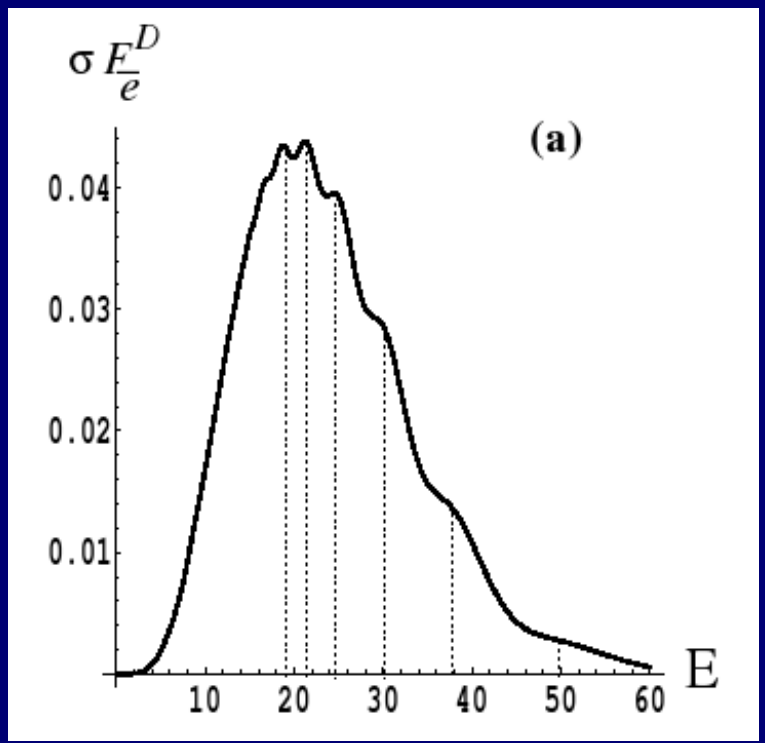
Outline

Goals

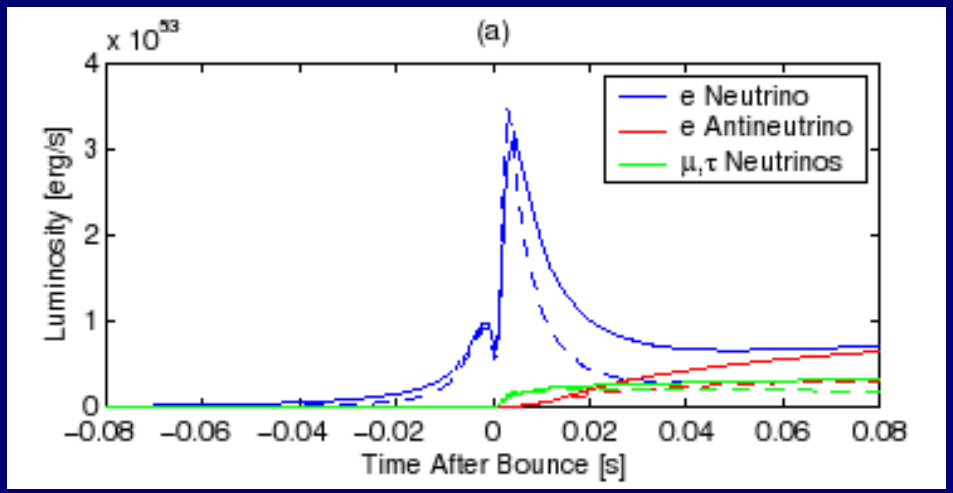
- Information about core collapse SN
  - average ν energies $\langle E_e \rangle$,$\langle E_{\bar{e}} \rangle$, $\langle E_x \rangle$
  - ratio of luminosities
  - overall normalization of the fluxes $\frac{E_b}{D^2}$
- Information about ν properties
  (Skadhauge hep-ph/0611194)
  - mass hierachy
    ($\rightarrow$ Matter Effect in SN)
  - strong bounds on θ_{13}
    ($\rightarrow$ Earth Matter Effect)



Dighe, Keil, Raffelt hep-ph/0304150

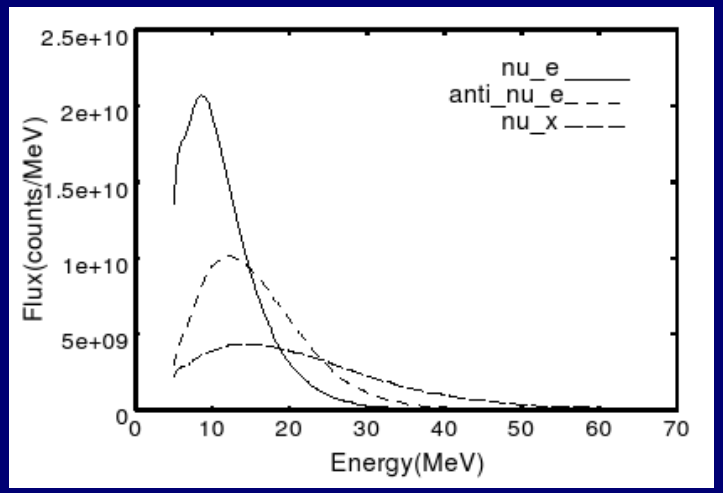
Neutrino Production in Core Collapse Supernovae

time evolution



Liebendoerfer et al. astro-ph/0207036

energy spectra



Totani et al. astro-ph/9710203

- SN at 10 kpc, 8 $M_\odot$
- neutronization: ν_e

- neutrino trapping $\rightarrow$ thermal spectra
- thermalization: all flavours

Reaction Channels I

LENA properties

- Scintillator, $\sim$ 40 kton fiducial volume
- total $\sim$ 20,000 events for a SN @ 10 kpc

Charged Current Interaction

- $\overline{\nu}_e + p \rightarrow n + e^+$

  $n + p \rightarrow d + \gamma$ (2.2 MeV)

  $\sim$8700 events: delayed coinc.

  mean capture time $\tau \approx 250 \mu s$

- $\overline{\nu}_e + {}^{12}\mathrm{C} \rightarrow {}^{12}\mathrm{B} + e^+$

  ${}^{12}\mathrm{B} \rightarrow {}^{12}\mathrm{C} + e^- + \overline{\nu}_e$

  $\sim$500 events: delayed coinc.

  lifetime $\tau = 20.20 ms$

- $\nu_e + {}^{12}\mathrm{C} \rightarrow {}^{12}\mathrm{N} + e^-$

  ${}^{12}\mathrm{N} \rightarrow {}^{12}\mathrm{C} + e^+ + \nu_e$

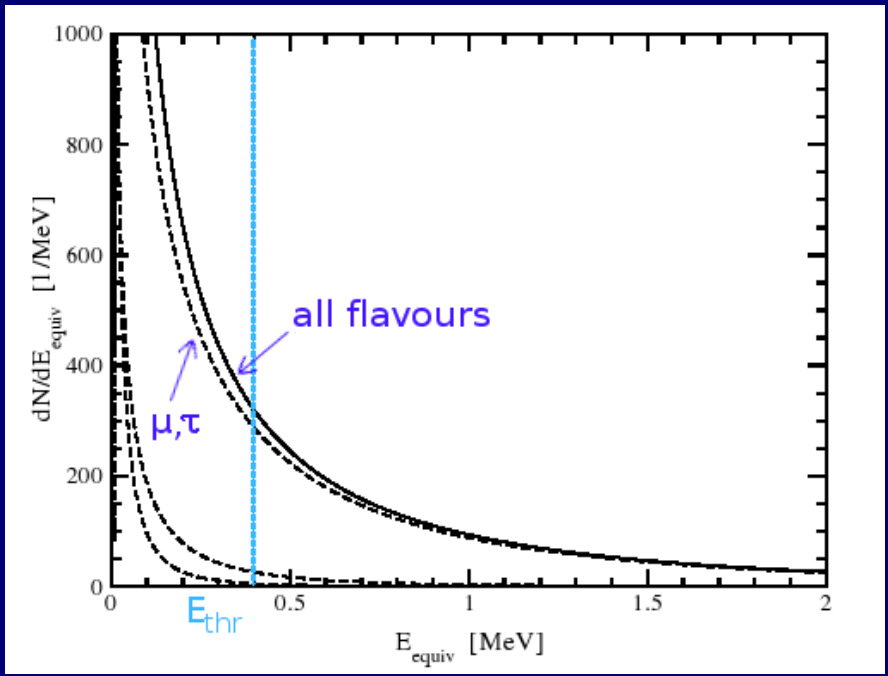
  $\sim$85 events: delayed coinc.

  lifetime $\tau = 11.00 ms$

Reaction Channels II

Elastic Scattering

- $\nu_x + e^- \rightarrow \nu_x + e^-$ ~610 events
- $\nu_x + p \rightarrow \nu_x + p$ ~5000 events



- quenched proton recoil spectra
- $E_{thr} = 0.4 MeV$
- mainly ν_x
  (Beacom hep-ph/0205220)

Reaction Channels III

Neutral Current

- $\nu_x + {}^{12}\mathrm{C} \rightarrow {}^{12}\mathrm{C}^* + \nu_x$ ~2900 events
  $\quad {}^{12}\mathrm{C}^* \rightarrow {}^{12}\mathrm{C} + \gamma$ 15.11 MeV γ

Reactions on ^{13}C (abundance $\sim$ 1%)

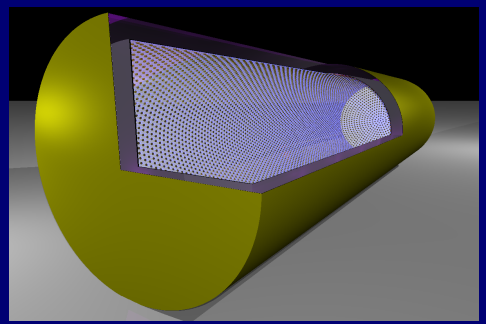
- $\nu_x + {}^{13}\mathrm{C} \rightarrow {}^{13}\mathrm{C}^* + \nu_x$ 3.68 MeV γ
  $\quad {}^{13}\mathrm{C}^* \rightarrow {}^{13}\mathrm{C} + \gamma$

- $\nu_e + {}^{13}\mathrm{C} \rightarrow {}^{13}\mathrm{N} + e^-$ delayed coinc.
  $\quad {}^{13}\mathrm{N} \rightarrow {}^{13}\mathrm{C} + \nu_e + e^+$ $E_{thr} = 2.22$ MeV

Monte Carlo Simulation with Geant4

Channel discrimination

- various signatures: delayed coincidence, monoenergetic gamma, proton recoil
- $\sim$ 20,000 events in 10s $\rightarrow$ Spatial Reconstruction



Monte Carlo Simulation

- Geometry:
  - ▷ length 100m, radius 13m
  - ▷ $\sim$ 13500 PMTs ($\varnothing$ 50cm)
    $\rightarrow$ 30 % surface coverage
  - ▷ PMTs: time jitter 1ns, efficiency 20 %
- Scintillator Physics
  - ▷ Scintillator parameters from experiments at TUM (talk M.Wurm)
- Output:
  - ▷ PMT Number, Hit time, No. of Hits

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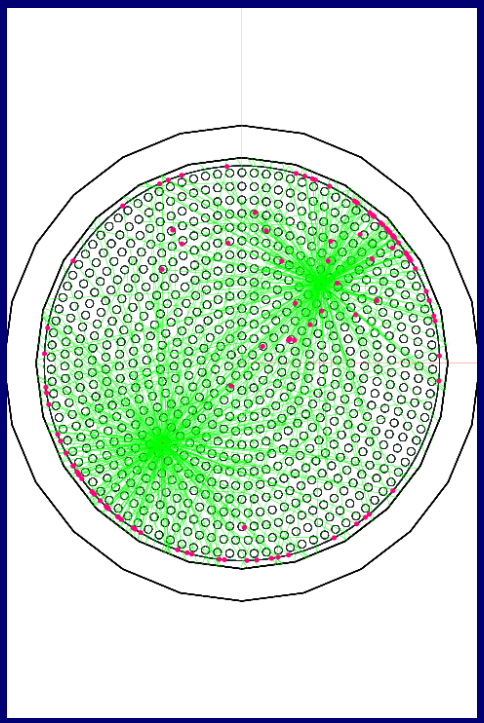

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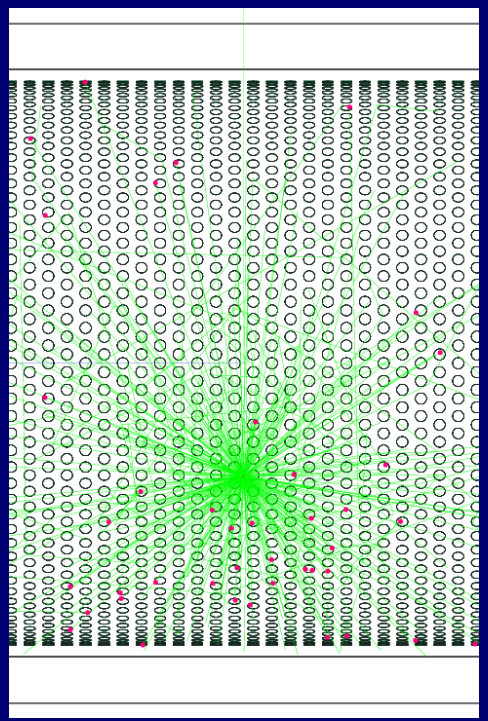

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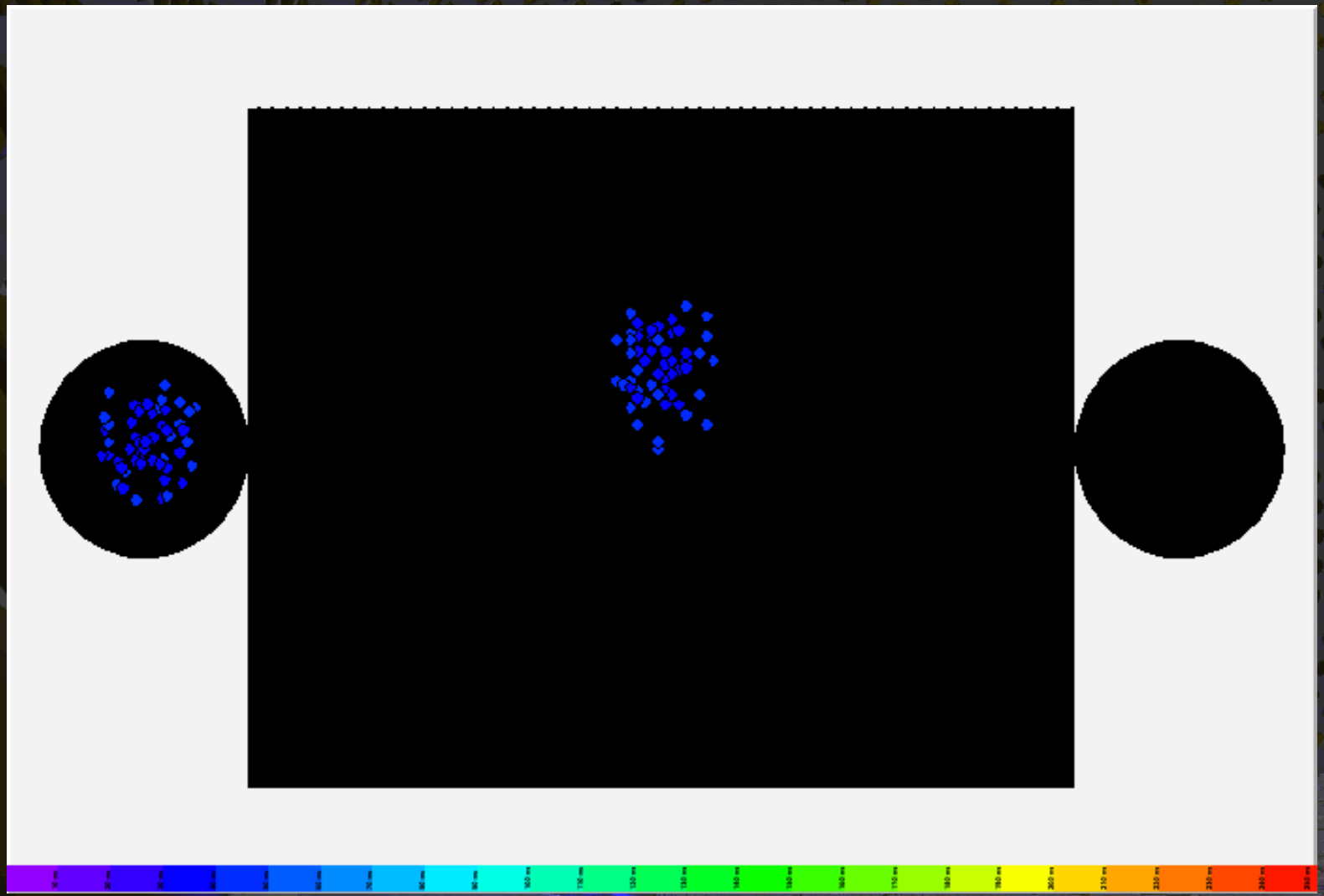
Visualization; Example: e^- *and* e^+

(10 MeV each)



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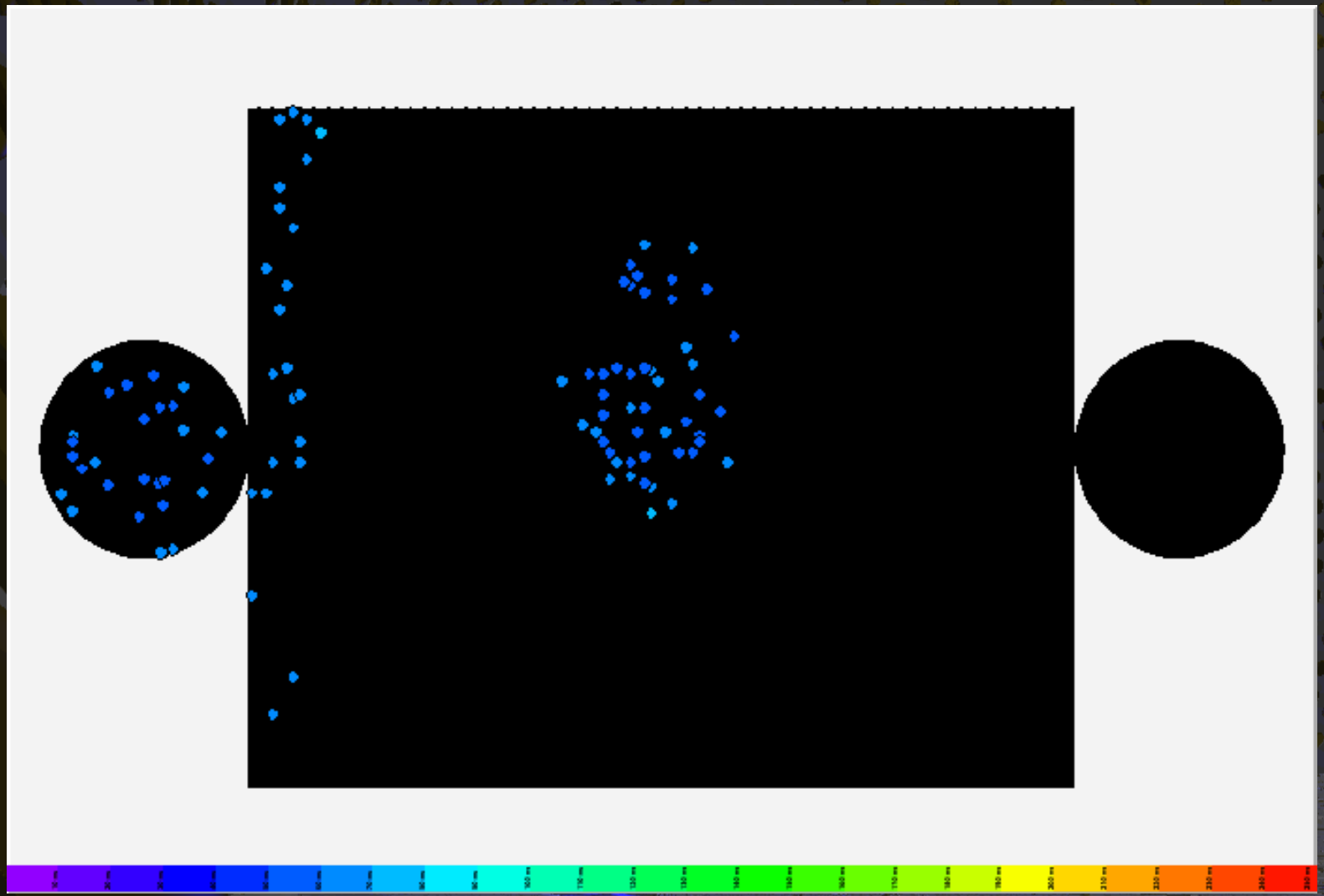

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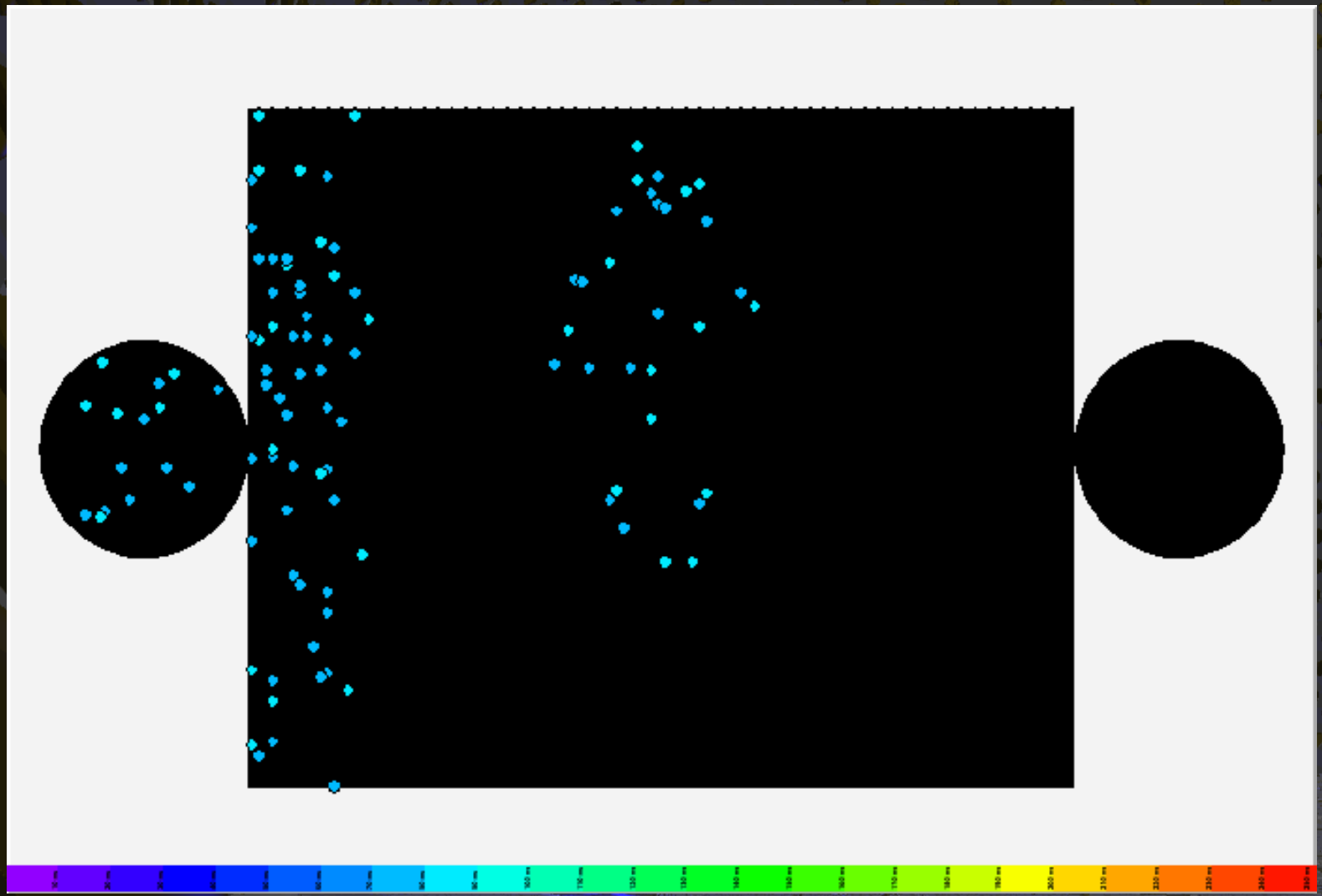

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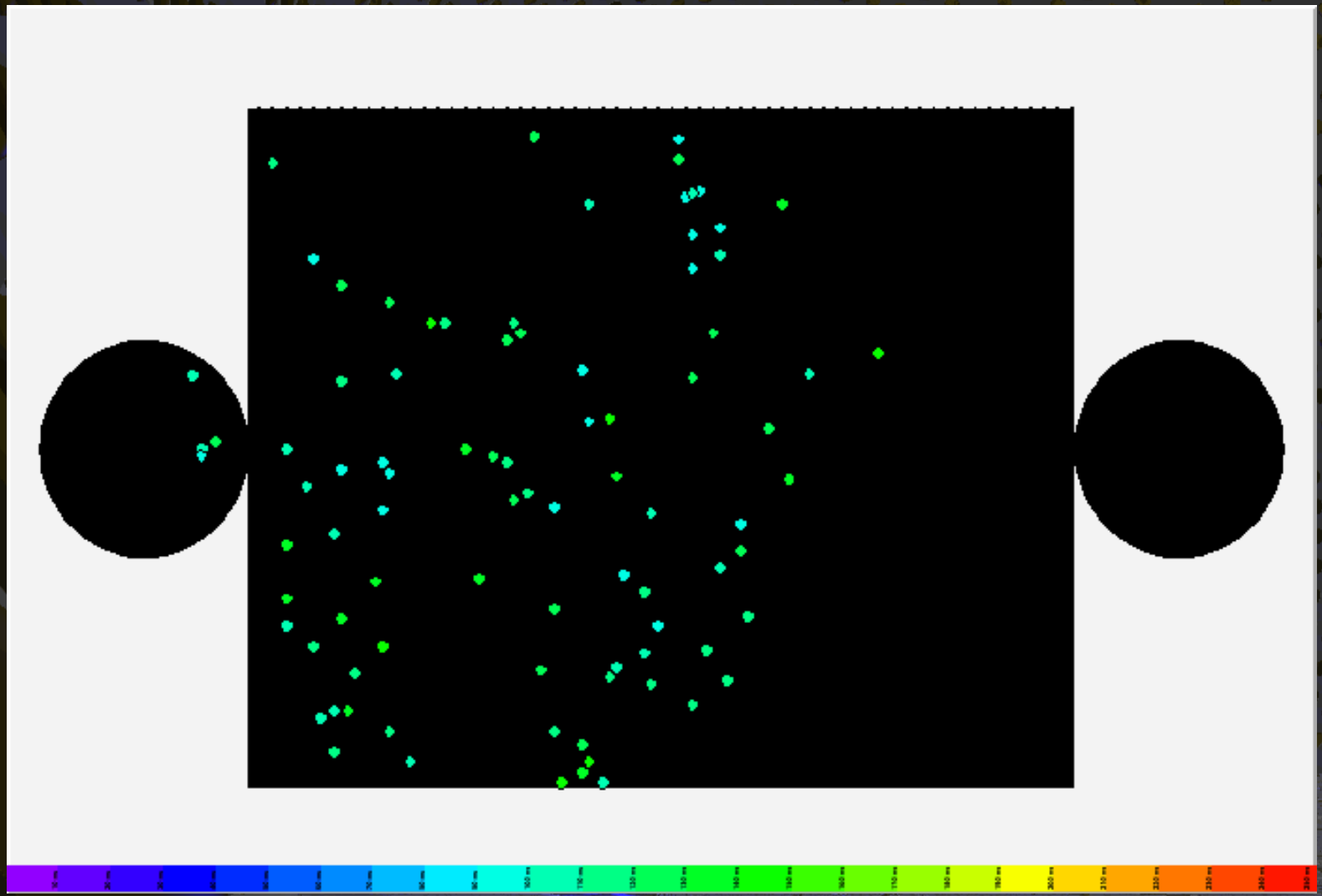

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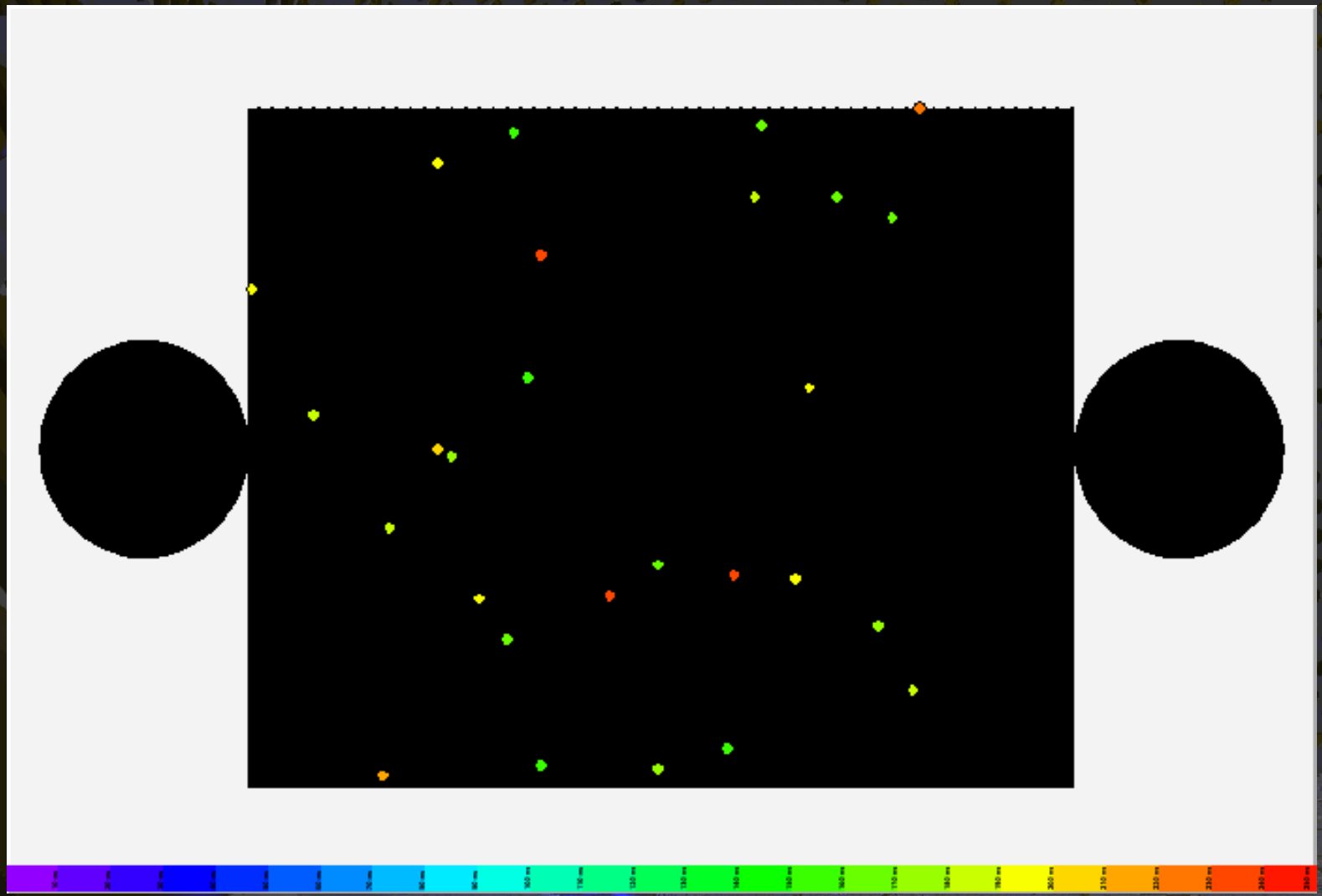

Histograms; Example: e^- *and* e^+

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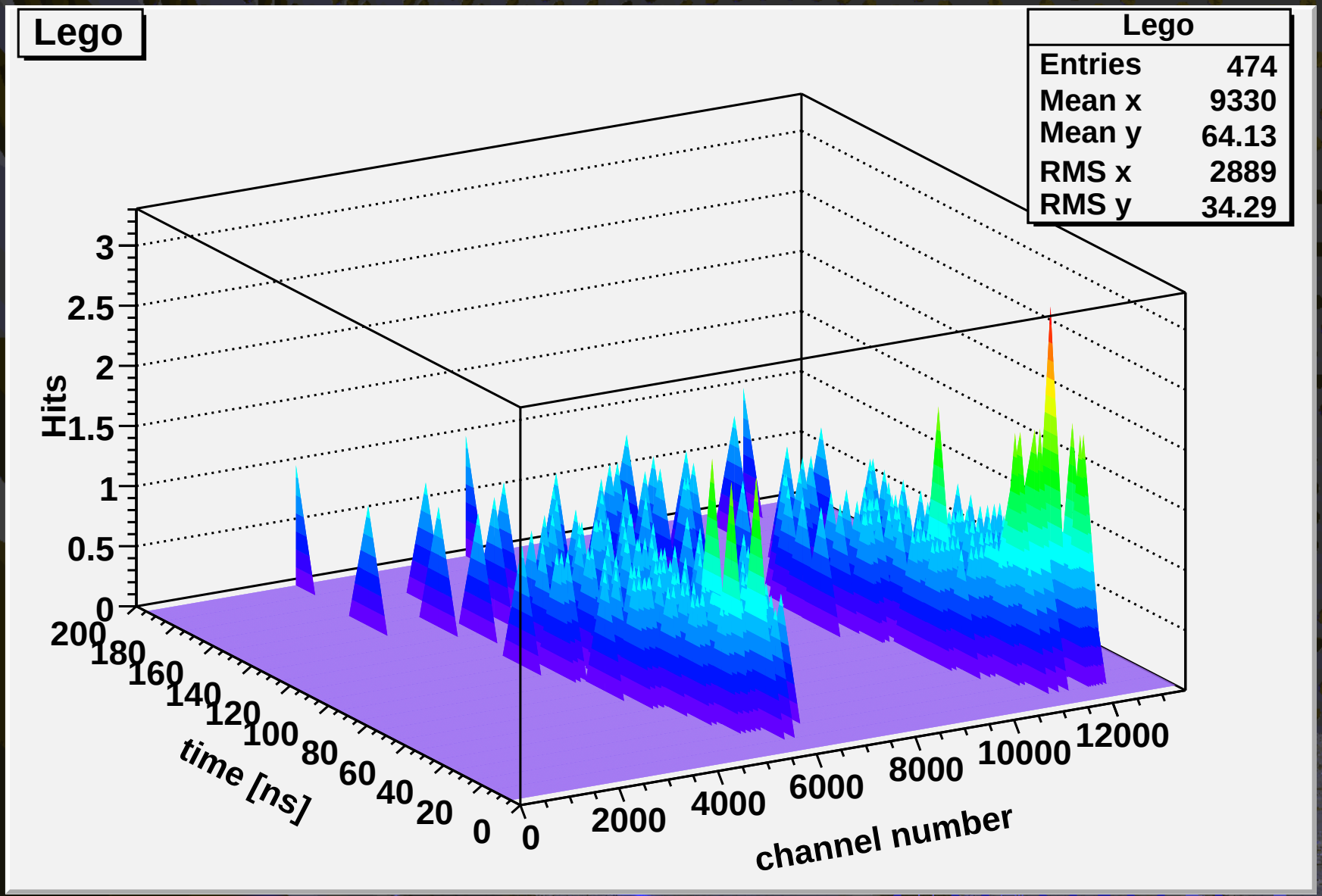

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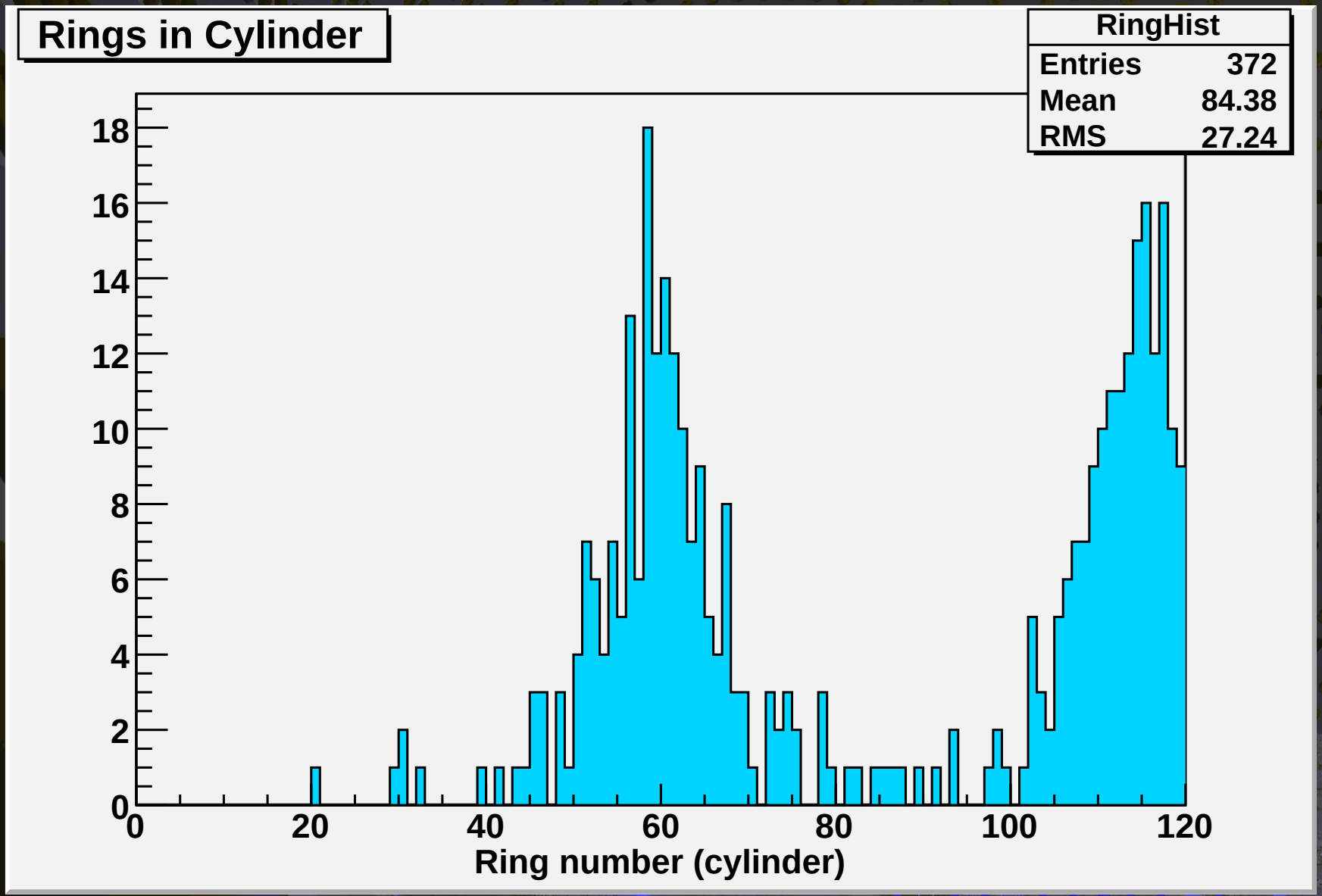
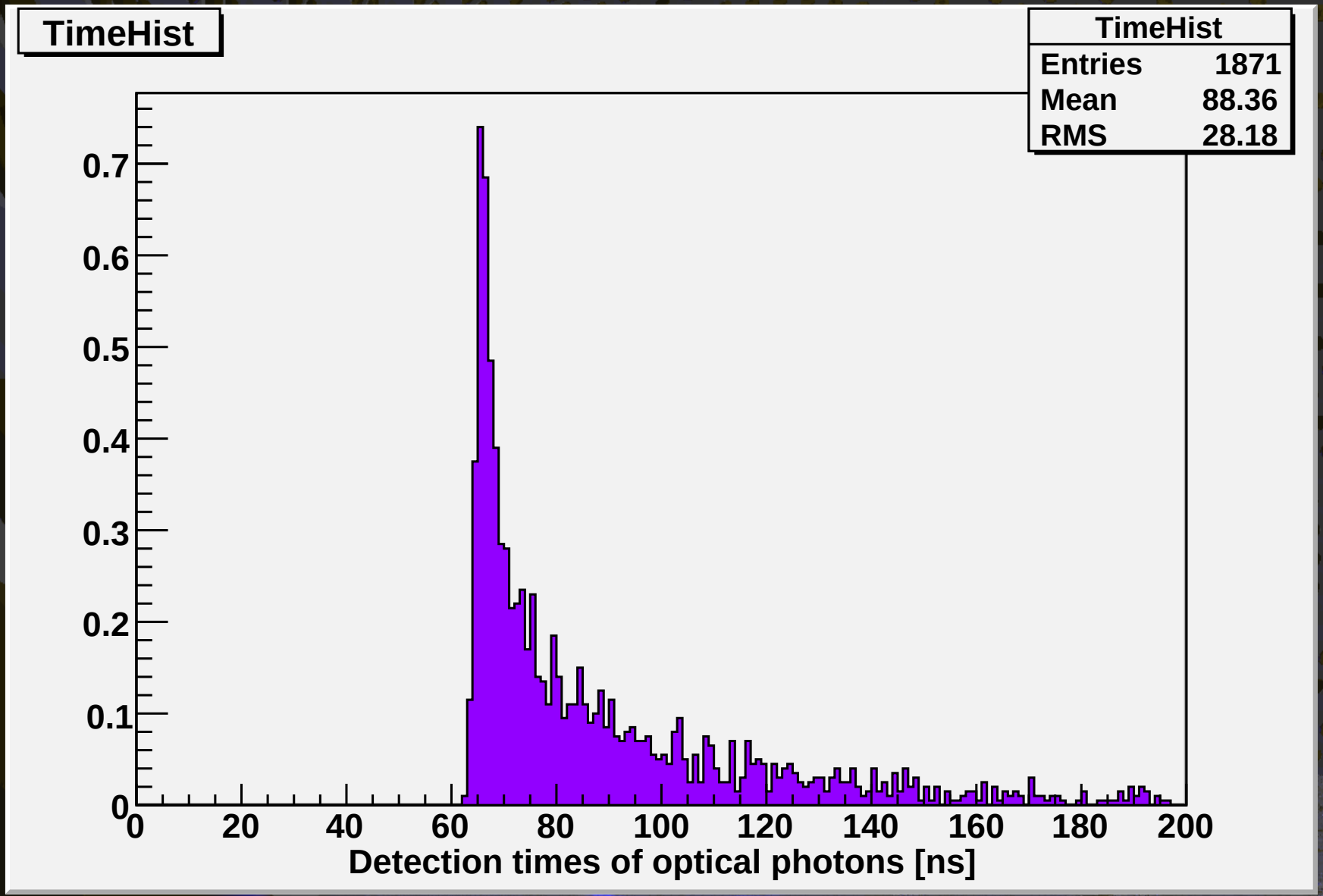


Hit Time


TimeHist
TimeHist
Entries 1871
Mean 88.36
RMS 28.18
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 20 40 60 80 100 120 140 160 180 200
Detection times of optical photons [ns]

Summary and Outlook

Summary

- Capabilities of LENA for SN ν
  - Energy spectrum for ν_e, $\overline{\nu}_e$ and ν_x
  - Separate measurement of F_{ν_e}, $F_{\overline{\nu}_e}$ and F_{ν_x} $x = \mu, \tau$
- Geant4 simulation finished

Outlook

- Development of an Reconstruction Program
  - Maximum Likelihood Method
  - Neural Network
- Optimization of PMT distribution, Light concentrators
- Further studies on LENA potential in SN ν