Introduction to Supernovae Neutrinos

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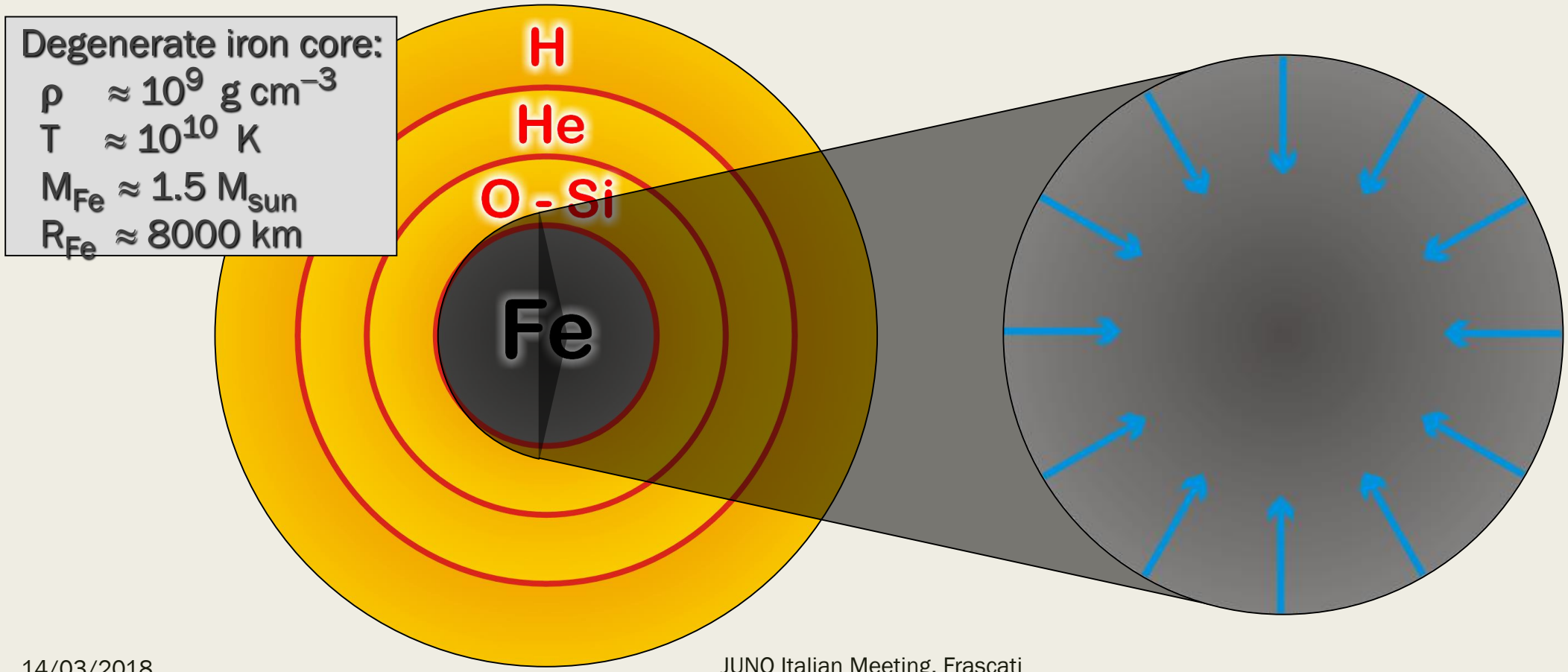
Introduction to Supernova Neutrinos

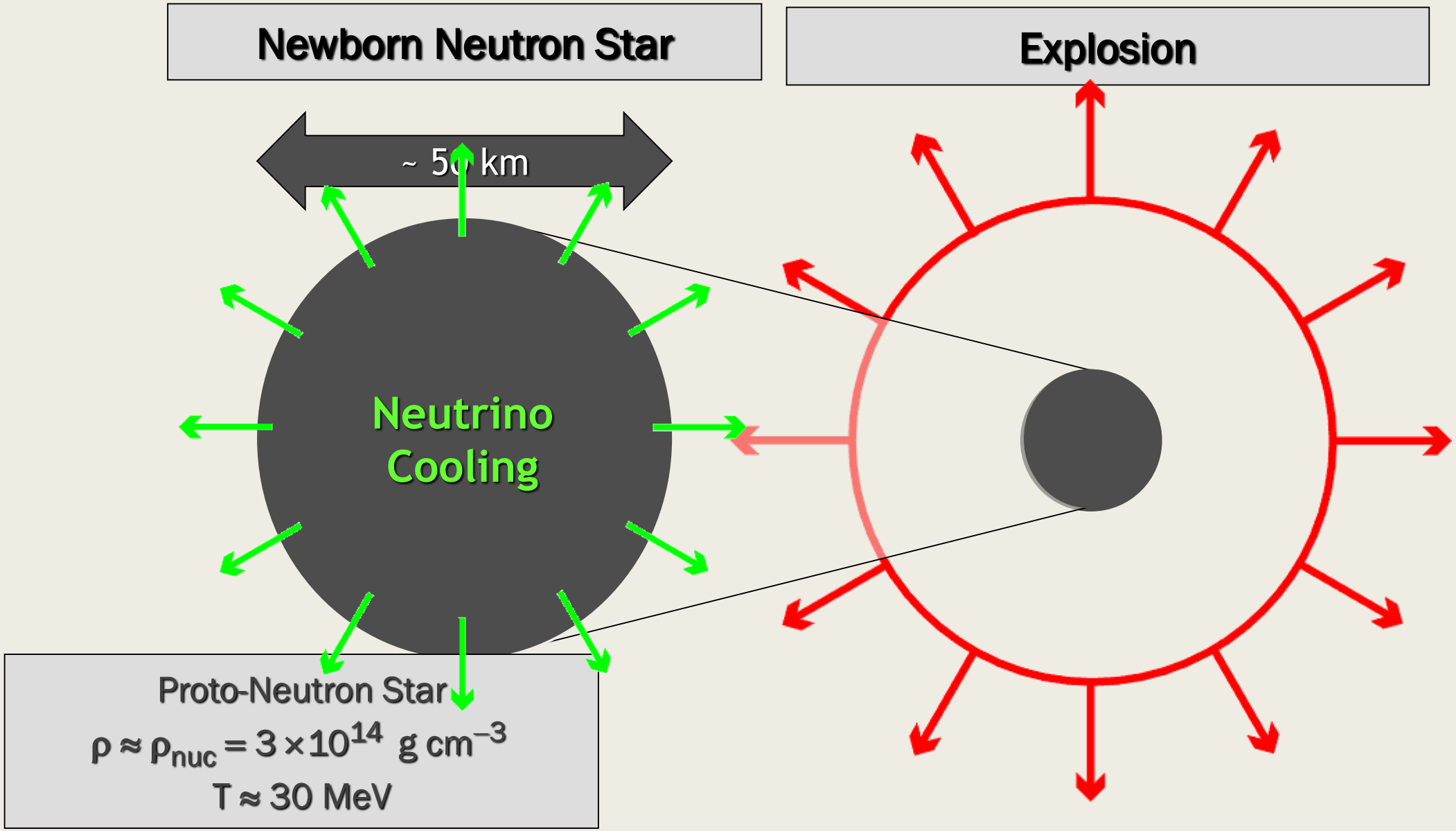
- Core- collapse Supernova explosion : Neutrino driven

Onion structure

Collapse (implosion)

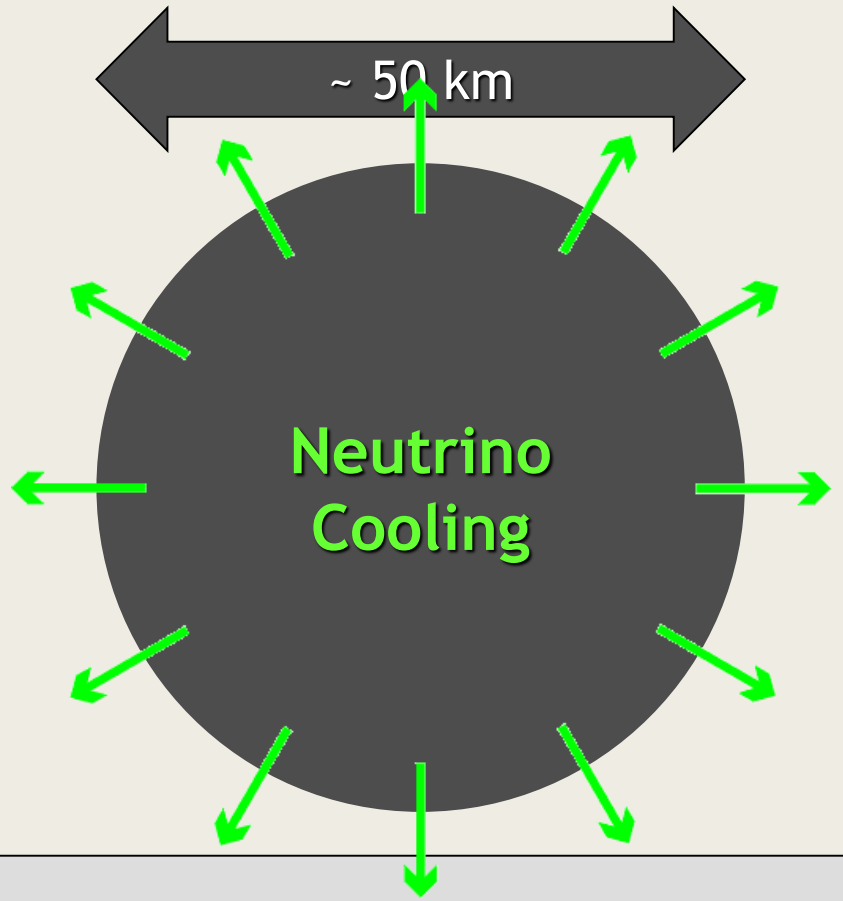


Star collapse and Supernova Explosion



Introduction to Supernova neutrinos

Newborn Neutron Star



Proto-Neutron Star

$\rho \approx \rho_{nuc} = 3 \times 10^{14}$ g cm^{-3}

Gravitational binding energy

$E_b \approx 3 \times 10^{53}$ erg $\approx$ 17% $M_{SUN}\, c^2$

This shows up as
- 99% Neutrinos
- 1% Kinetic energy of explosion (1% of this into cosmic rays)
- 0.01% Photons, outshine host galaxy

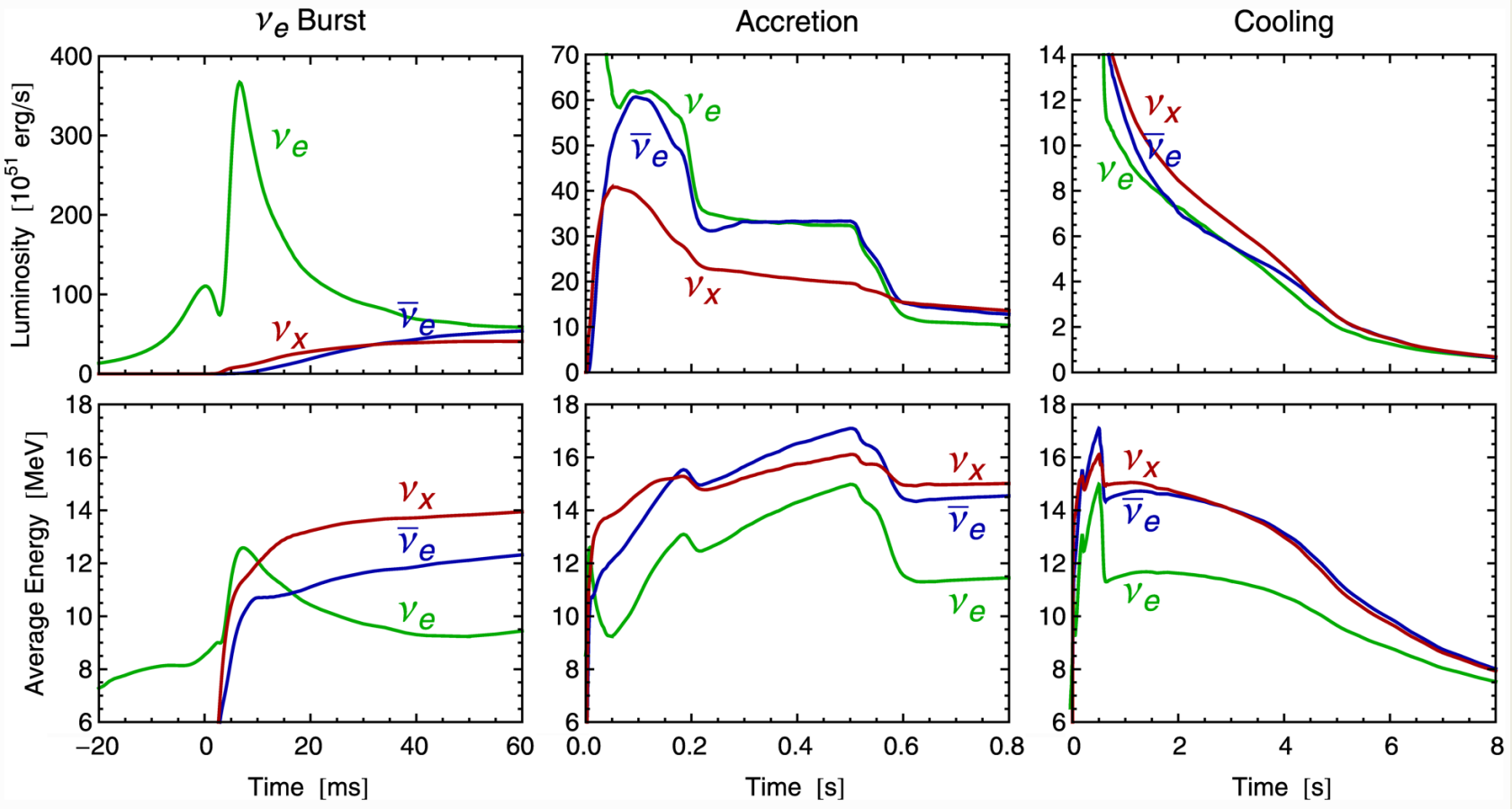
Neutrino luminosity

$L_\nu \approx 3 \times 10^{53}$ erg / 3 sec
$\approx 3 \times 10^{19}\, L_{SUN}$

While it lasts, outshines the entire visible universe

Introduction to Supernova neutrinos

- We have a three-phases of supernova neutrino flux
- ν_e burst phase and cooling phase are quite well understood
- Details of accretion phase are more or less unclear



Channels of Detections

Channel	Type	Events for different $\langle E_\nu \rangle$ values		
		12 MeV	14 MeV	16 MeV
$\overline{\nu}_e + p \rightarrow e^+ + n$	CC	4.3×10^3	5.0×10^3	5.7×10^3
$\nu + p \rightarrow \nu + p$	NC	6.0×10^2	1.2×10^3	2.0×10^3
$\nu + e \rightarrow \nu + e$	ES	3.6×10^2	3.6×10^2	3.6×10^2
$\nu + {}^{12}\mathrm{C} \rightarrow \nu + {}^{12}\mathrm{C}^*$	NC	1.7×10^2	3.2×10^2	5.2×10^2
$\nu_e + {}^{12}\mathrm{C} \rightarrow e^- + {}^{12}\mathrm{N}$	CC	4.7×10^1	9.4×10^1	1.6×10^2
$\overline{\nu}_e + {}^{12}\mathrm{C} \rightarrow e^+ + {}^{12}\mathrm{B}$	CC	6.0×10^1	1.1×10^2	1.6×10^2

Table: Numbers of neutrinos events in JUNO for a SN at a typical distance of about 10 kpc, where ν stands for neutrinos and antineutrinos of all flavours. Three representative values of the average neutrino energy $\langle E_\nu \rangle$= 12 MeV, 14 MeV and 16 MeV are taken for illustration, where in each case the same average energy is assumed for all flavours and neutrino flavour conversions are not considered. For the elastic neutrino-proton scattering , a threshold of 0.2 MeV for the proton recoil energy is chosen.

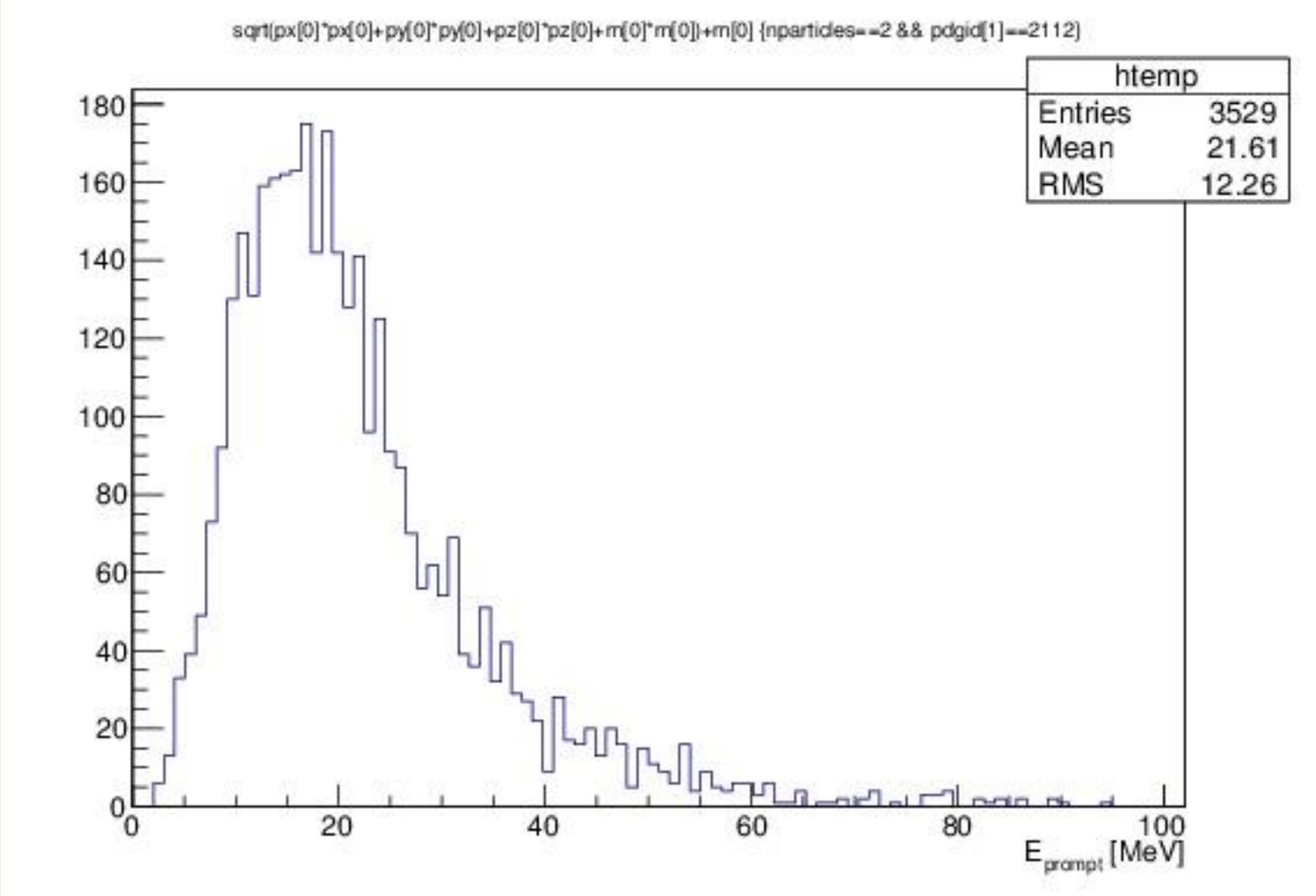
Supernova Neutrino Events in JUNO

- Neutrino Burst in a short period of time $\mathrm{O}(10\ \mathrm{s})$
- The JUNO event rate peak is about $\mathrm{O}(0.1\mathrm{s})$
- For a typical supernova 10 kpc away, the IBD event rate in JUNO will be about 10 kHz

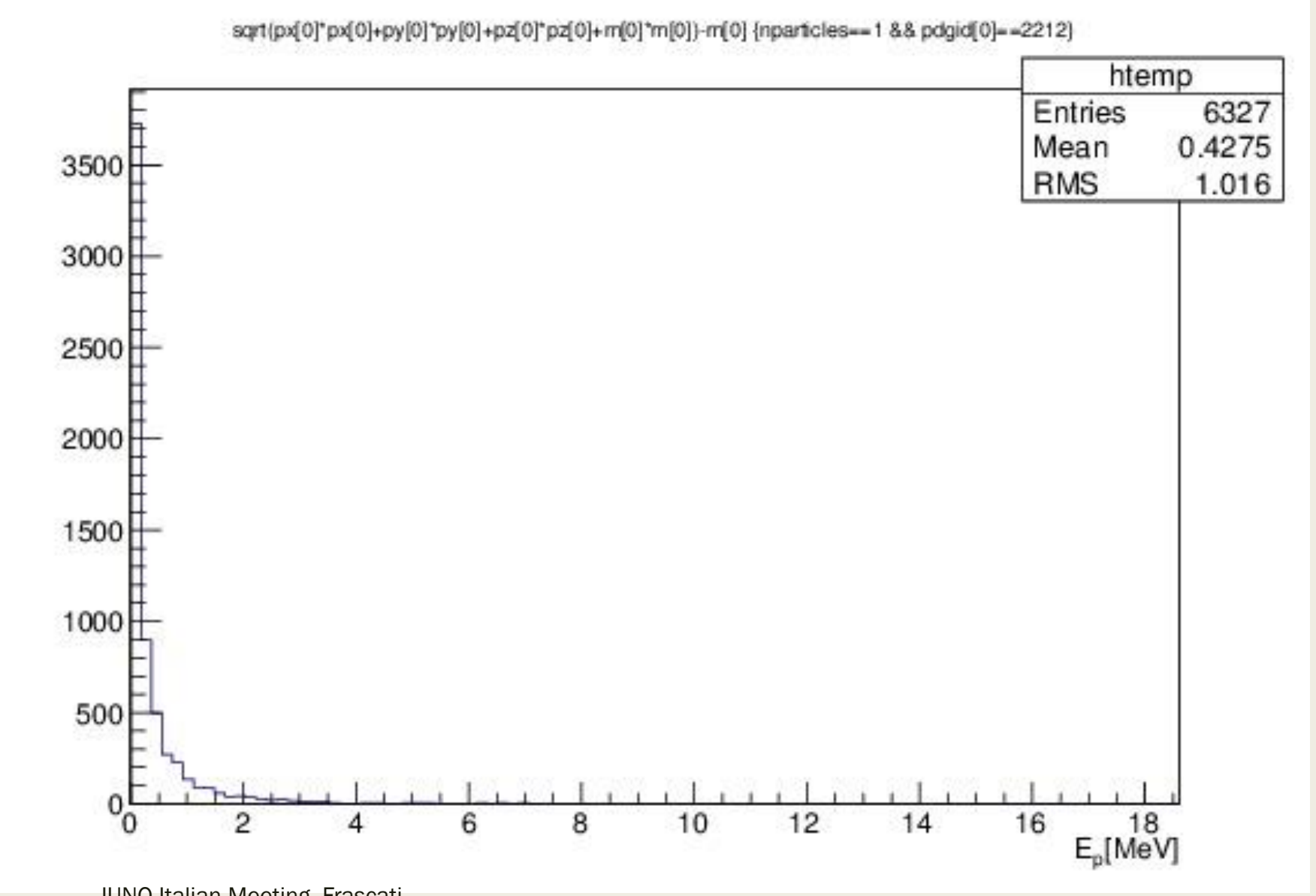
Neutrino Flux Models

- Flux data from -0.05 s to 20 s.
- Different progenitor stellar mass: M = 13, 20, 30, 50 M_{solar}.
- Different progenitor metallicities: Z = 0.02, 0.004.
- Different shock revival time: t_{revive} = 100, 200, 300 ms.
- intp2013.data: M = 20 M_{solar}, Z = 0.004, t_{revive} = 300 ms
- Can be used for general purpose.
- Different progenitor stellar mass: M = 11.2 ~ 40.0 M_{solar}.
- Should be used for studying the ν_e burst phase.

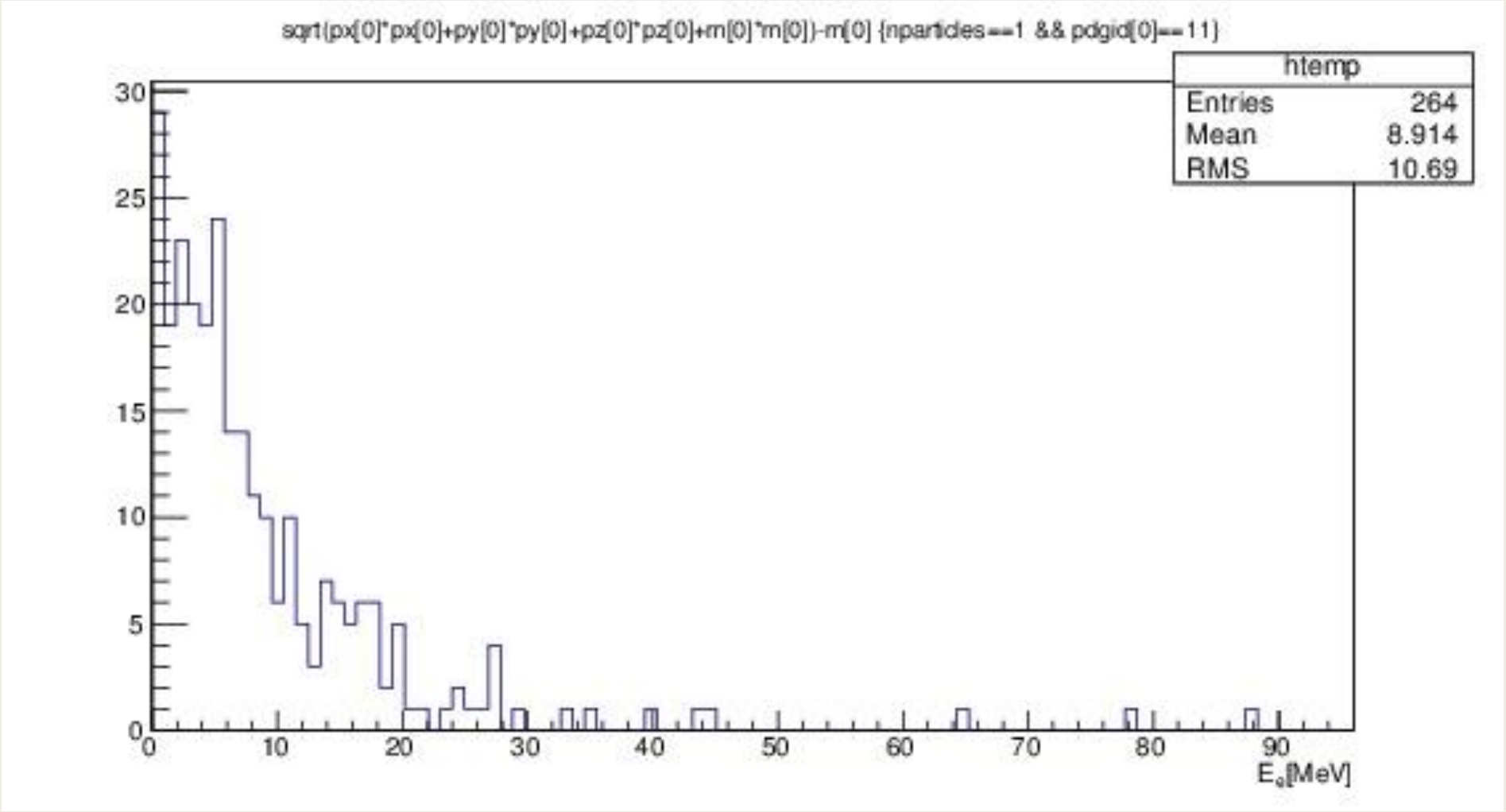
IBD e^+ spectrum



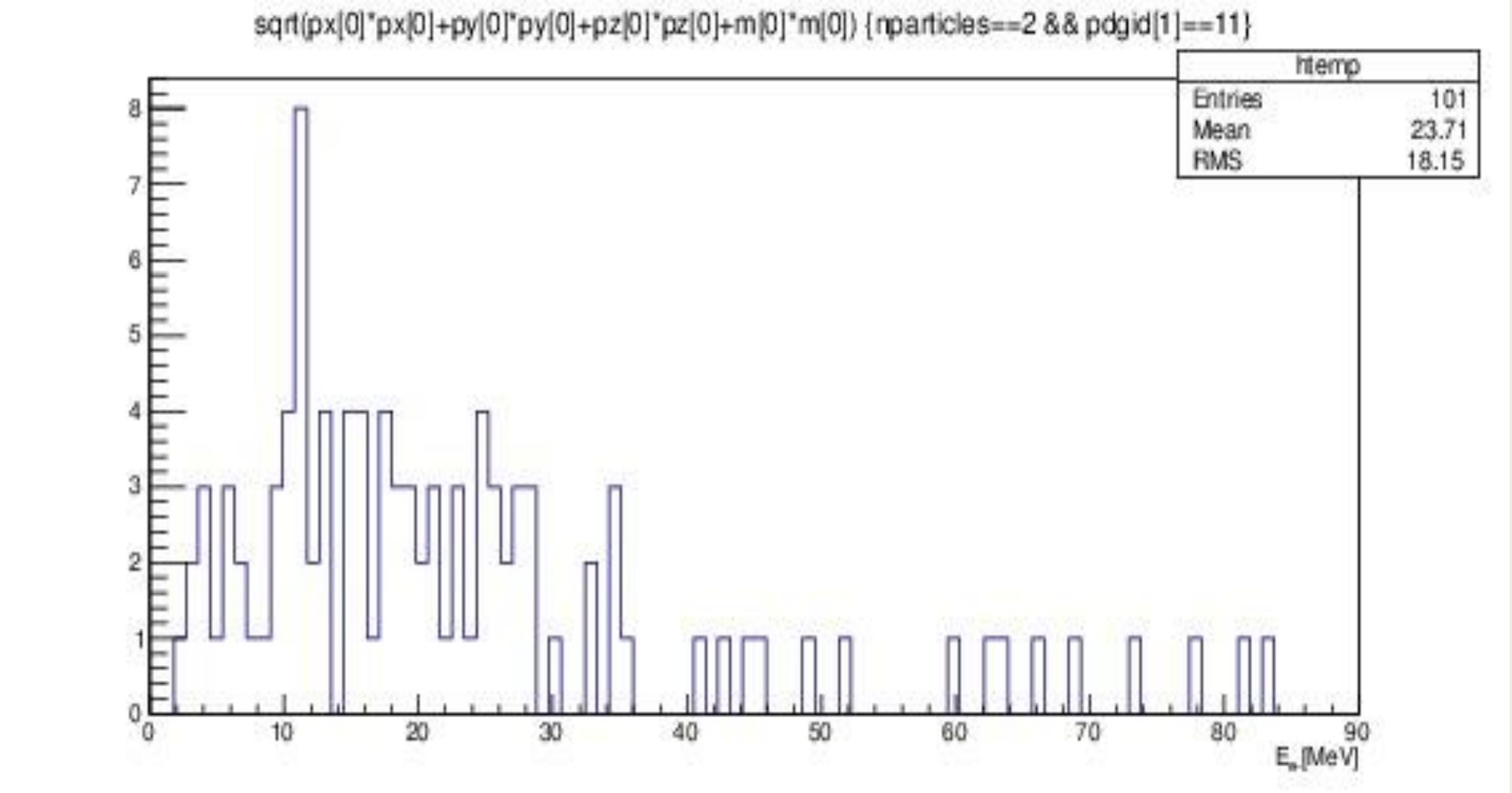
$\nu - p$ ES spectrum



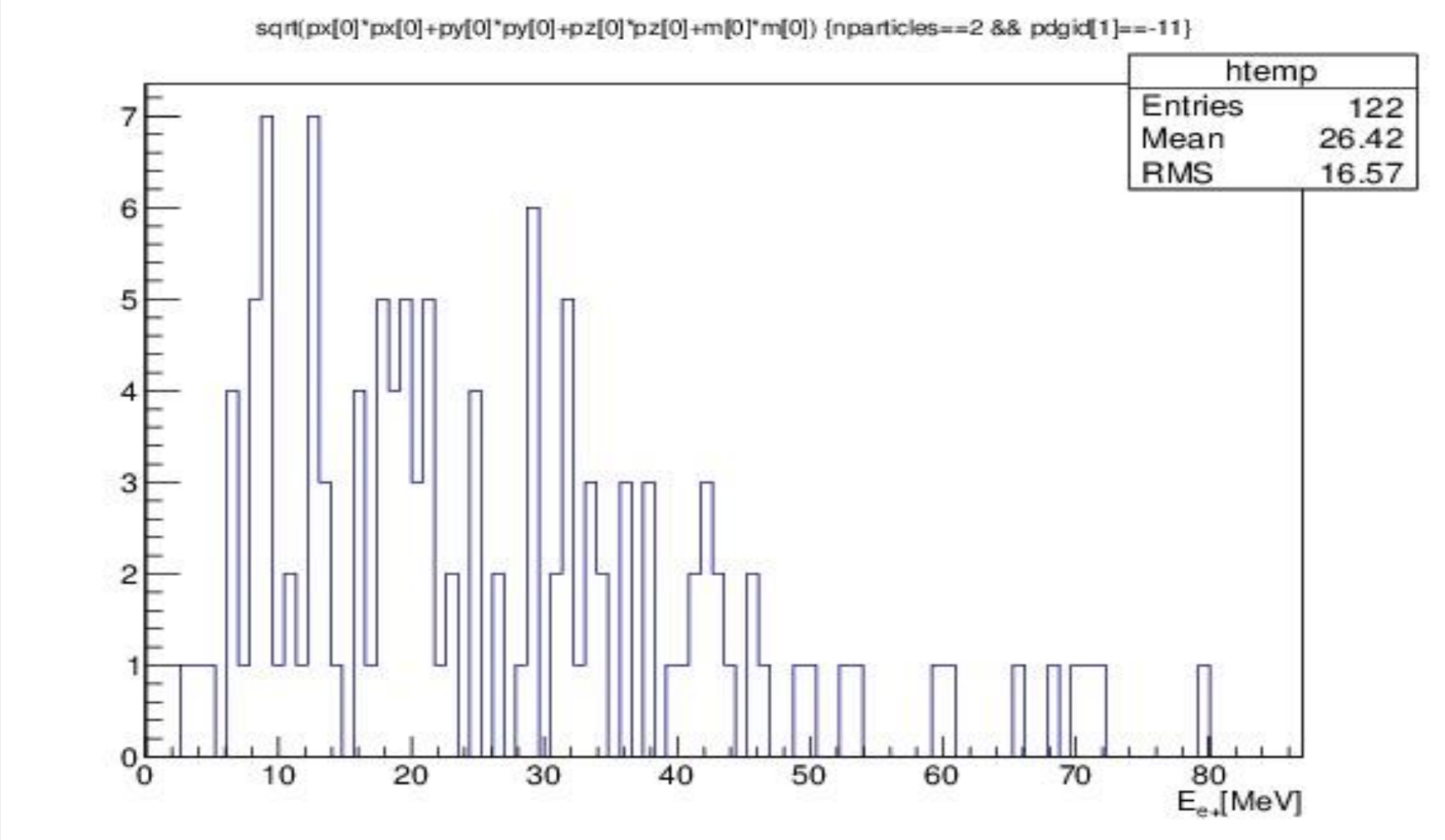
ν-e ES spectrum



ν_e-^{12}C CC e^- spectrum



$\bar{\nu}_{e^-} - {}^{12}C\ CC\ e^+$ spectrum



Summary and Future

- The generator for JUNO now implements one set of numerical flux models
- More will be implemented later
- In parallel with the definition of the Trigger System, the aim is to think and elaborate a software trigger for SN events in the JUNO detector


Thank you
For the Attention