^{11}C backround in liquid scintillator detectors

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Reference

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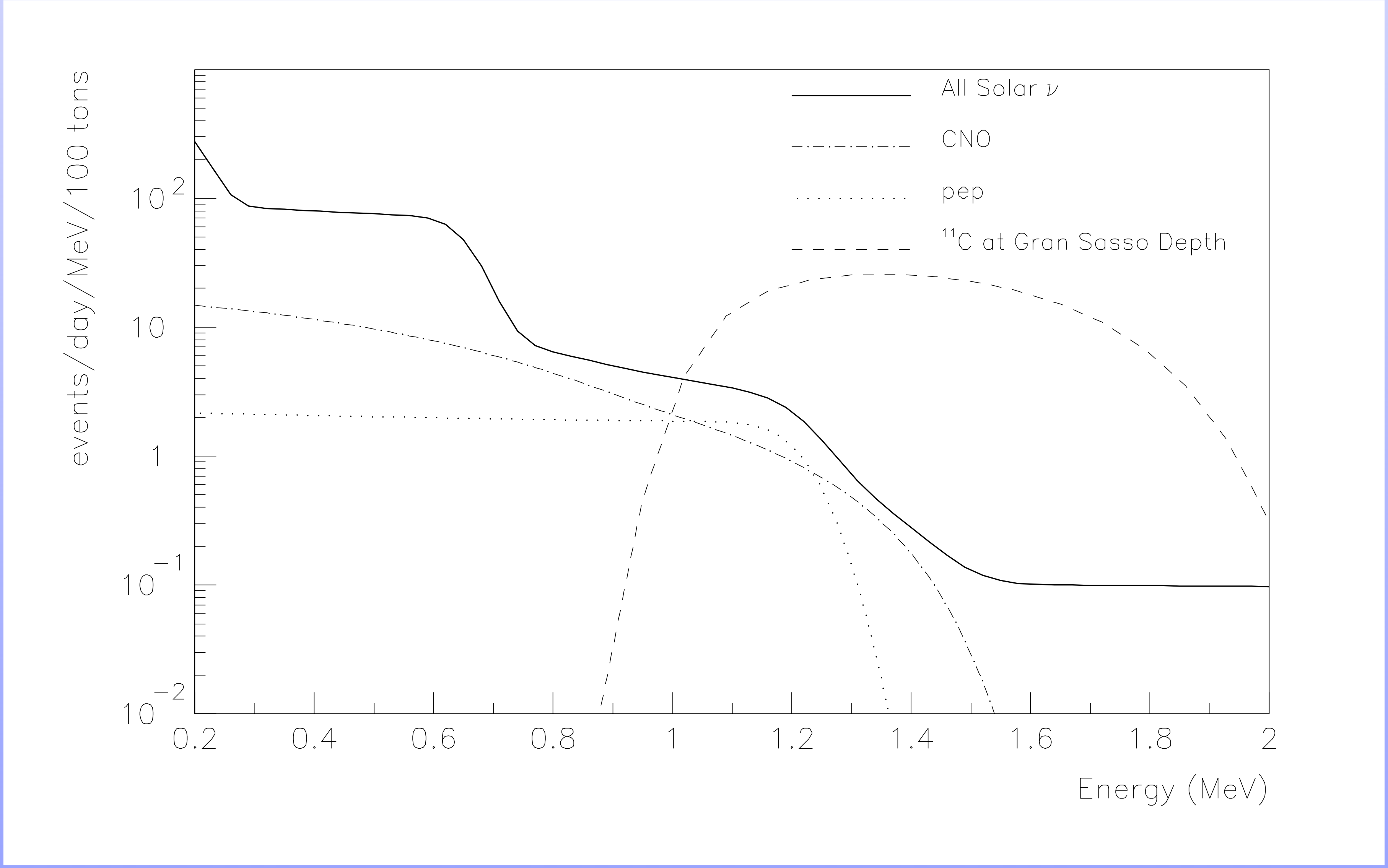
L. Cadonati,
S. Schönert

arXiv:hep-ph/0411002
(submitted to Phys. Rev. C)

Motivation

- ➙ Muon–induced radioactive isotopes can be a background
- ➙ Short–lived isotopes can be vetoed by tagging the muon
- ➙ ^{11}C half life: ~ 20 minutes (positron emitter)
- ➙ ^{11}C is a serious background for pep solar neutrinos (1.44 MeV line); a precision measurement of pep solar neutrinos would be an alternative to measuring the pp flux
  (lower flux, but higher energy)

Spectrum



All Solar ν
CNO
pep
11C at Gran Sasso Depth
events/day/MeV/100 tons
10^2
10
1
10^-1
10^-2
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Energy (MeV)

^{11}C tagging

- ➙ ^{11}C production in scintillator measured with muon beam (Hagner at al., 2000)
- ➙ can tag ^{11}C if a neutron is ejected in the reaction:
  muon + delayed neutron capture (2)
- ➙ veto a volume around the neutron capture site for a given time
- ➙ if muon flux is high enough, dead time is very high
- ➙ is a neutron always emitted?

^{11}C production channels

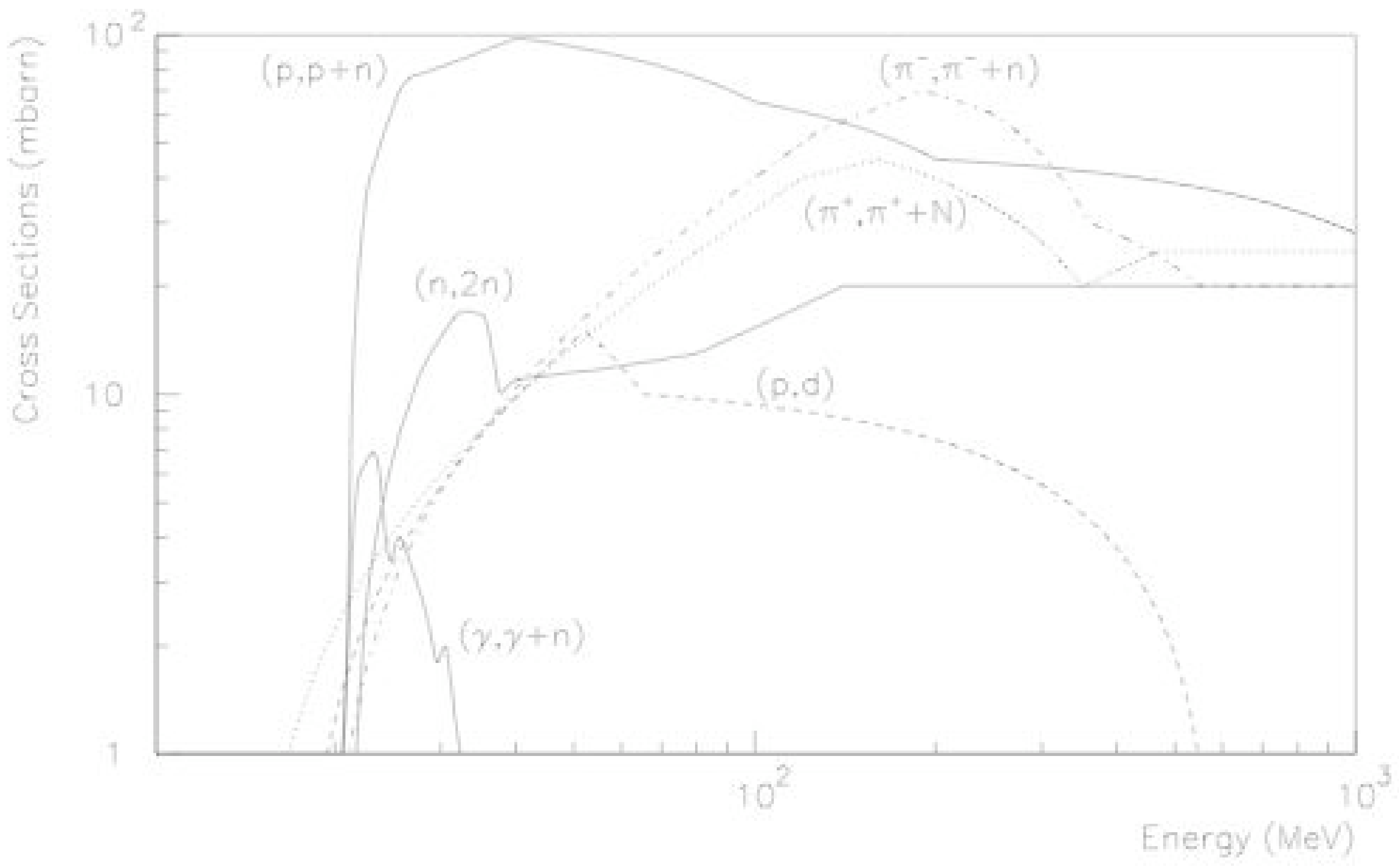
- Calculate amplitudes of each channel
- estimate role of "blind" channels

Strategy:

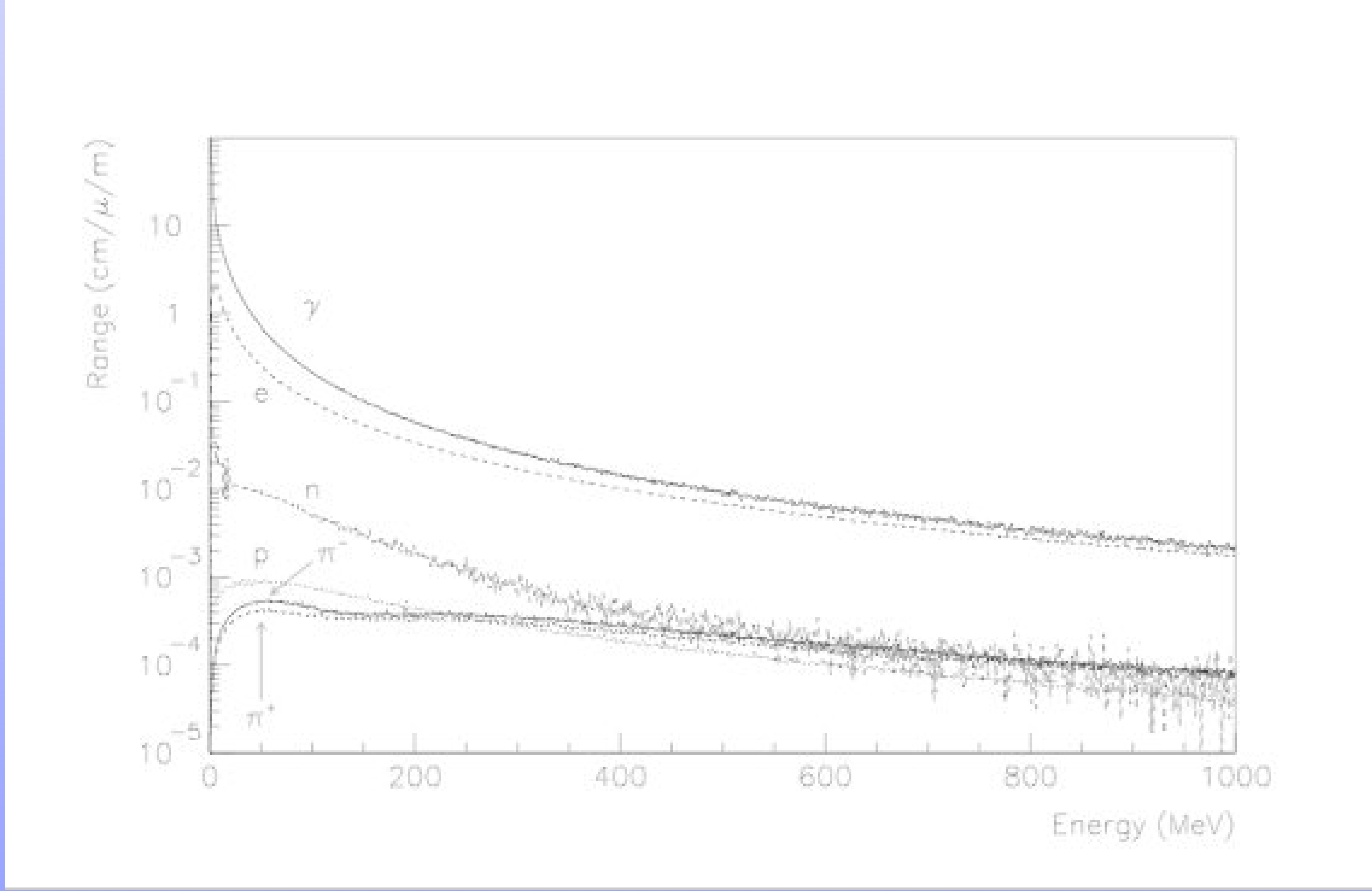
- simulate muon shower, propagate secondaries
- include nuclear cross sections

$$^{12}\mathrm{C}(\mathrm{p},\mathrm{p}+\mathrm{n})^{11}\mathrm{C}$$
$$^{12}\mathrm{C}(\mathrm{p},\mathrm{d})^{11}\mathrm{C}$$
$$^{12}\mathrm{C}(\gamma,\mathrm{n})^{11}\mathrm{C}$$
$$^{12}\mathrm{C}(\mathrm{n},2\mathrm{n})^{11}\mathrm{C}$$
$$^{12}\mathrm{C}(\pi^+,\pi^+ +\mathrm{N})^{11}\mathrm{C}$$
$$^{12}\mathrm{C}(\pi^-,\pi^- +\mathrm{n})^{11}\mathrm{C}$$
$$^{12}\mathrm{C}(\mathrm{e},\mathrm{e}+\mathrm{n})^{11}\mathrm{C}$$
$$^{12}\mathrm{C}(\mu,\mu+\mathrm{n})^{11}\mathrm{C}$$

^{11}C production cross sections



Path of secondaries (FLUKA)

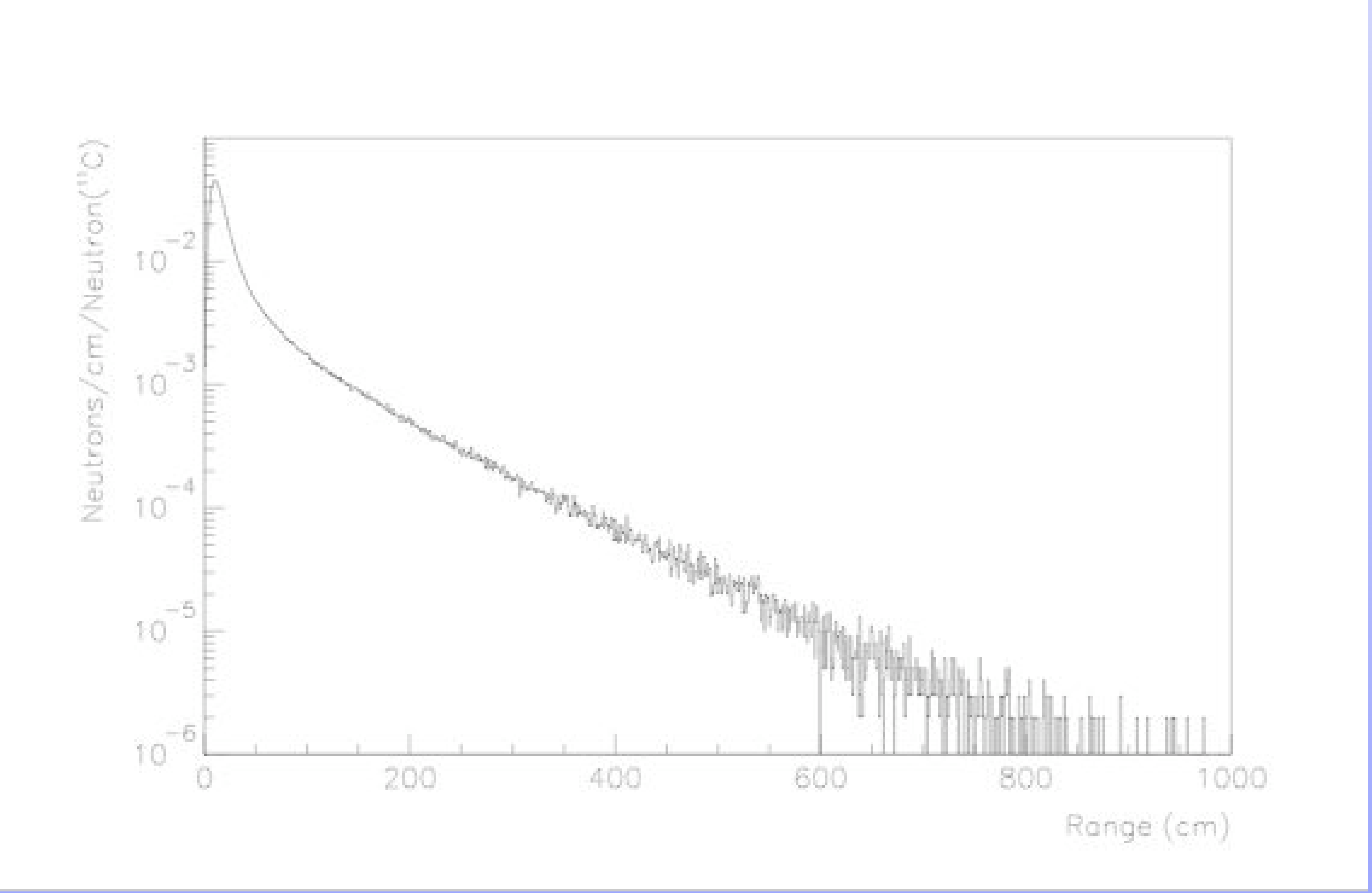


Convolute

E_μ [GeV]	100	190	285	320	350
Process	Rate $[10^{-4}/\mu/\mathrm{m}]$				
$^{12}C(p,p+n)^{11}C$	1.8	3.2	4.9	5.5	5.6
$^{12}C(p,d)^{11}C$	0.2	0.4	0.5	0.6	0.6
$^{12}C(\gamma,n)^{11}C$	19.3	26.3	33.3	35.6	37.4
$^{12}C(n,2n)^{11}C$	2.6	4.7	7.0	8.0	8.2
$^{12}C(\pi^+,\pi+N)^{11}C$	1.0	1.8	2.8	3.2	3.3
$^{12}C(\pi^-,\pi^-+n)^{11}C$	1.3	2.3	3.6	4.1	4.2
$^{12}C(e,e+n)^{11}C$	0.2	0.3	0.4	0.4	0.4
$^{12}C(\mu,\mu+n)^{11}C$	2.0	2.3	2.4	2.4	2.4
Invisible channels	0.9	1.6	2.4	2.7	2.8
Total	28.3	41.3	54.8	59.9	62.2
1σ systematic	1.9	3.1	4.4	5.0	5.2
Measured	22.9	36.0			
1σ experimental	1.8	2.3			
Extrapolated			47.8	51.8	55.1

Hagner at al.

Neutron range



needed to set spatial cut

What could be done

- Each experiment (Borexino, KamLAND) can set an efficiency for ^{11}C rejection (must pay dead time price!)
- With $(^{238}U, ^{232}Th) \sim 10^{-17}$ g/g
  $^{nat}K \sim 10^{-15}$ g/g
  Borexino could make 3% measurement in 3 years

Looking beyond

- ➙ An experiment at SNOLab depth could neglect ^{11}C background altogether
- ➙ This analysis technique can be (is being) applied to other target materials