The Standard Solar Model

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XII Neutrino Telescopes, Venice

Topics

- Metallicity controversy

- MSW vs VAC

- The Sun as a laboratory

Chemical controversy at the solar surface

Improved measurements of elemental abundances suggest that something might be wrong with our model of the Sun :

the solar surface contains 30-40% less carbon, nitrogen, oxygen, neon and argon than previously believed.

Asplund et al, astro-ph/0410214

Chemical controversy at the solar surface

Wrong predictions for the speed of sound and density at various locations inside the Sun

No-one has identified significant errors

Cautious in our conclusions about more distant less well understood stars

What to do?

Separate analysis of the chemical abundances

Recalculate radiative opacity in the range between 2 and 4.5 MK

Solar neutrino physicists relatively indifferent to the outcome, but neutrino experiments may help to resolve the problem

May take years before we stumble upon the key to resolve the mistery

2006-2007 improvement

S34 (LUNA) new measurements :
- activation studies
- gamma prompt studies

S34(0) = 0.560 (0.016)

LUNA collaboration, next talk

2006-2007 improvement

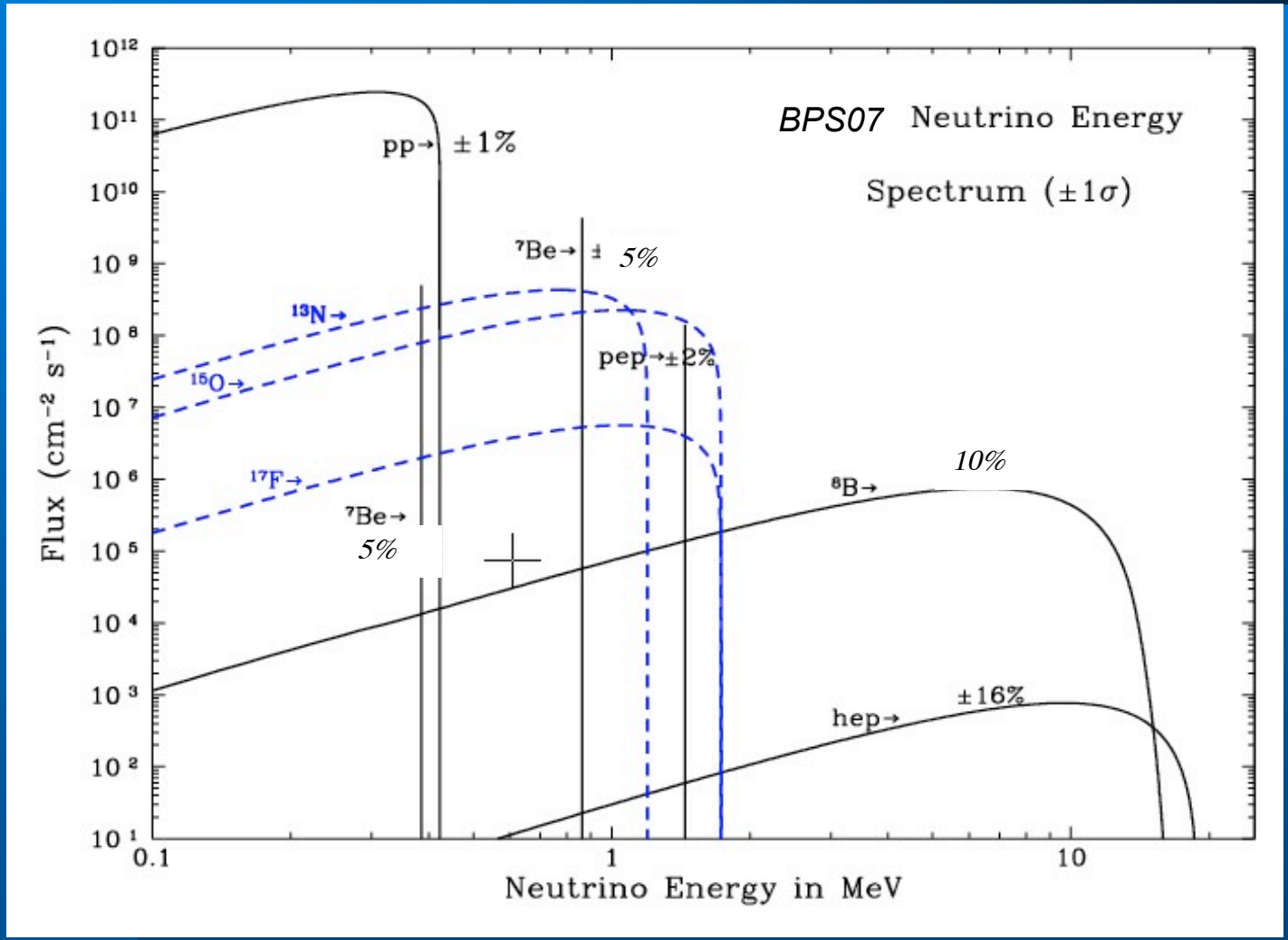
Helioseismology with BiSON (Birmingham Solar-Oscillations Network) data Basu et al, astro-ph/0610052

To study the core calculate small frequency spacings ($\nu_{n,l}$-$\nu_{n-1,l+2}$) and frequency separation ratios for the Sun:

- depend sensitively on the metallicity
- affected in a similar way by near-surface effects.

Low metallicity models can be ruled out. Strong support for lowering (conservative to optimistic) the theoretical uncertainties on the neutrino fluxes

Solar Neutrinos : Bahcall model 2007



P-G & Serenelli, BPS07

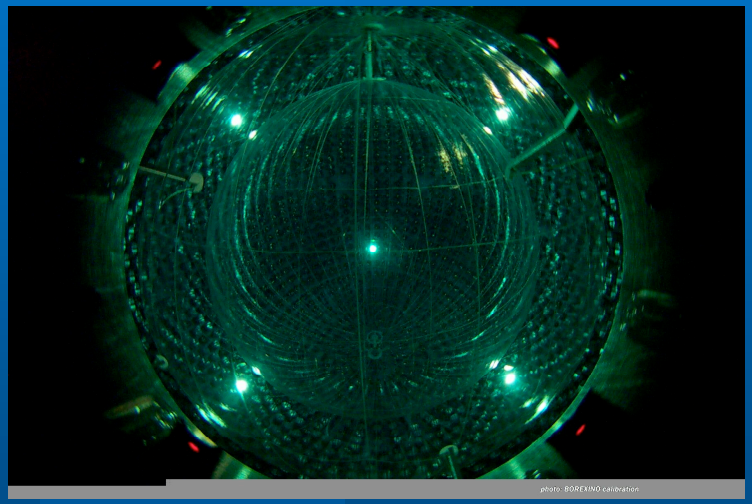
BPS07 : High Z vs Low Z

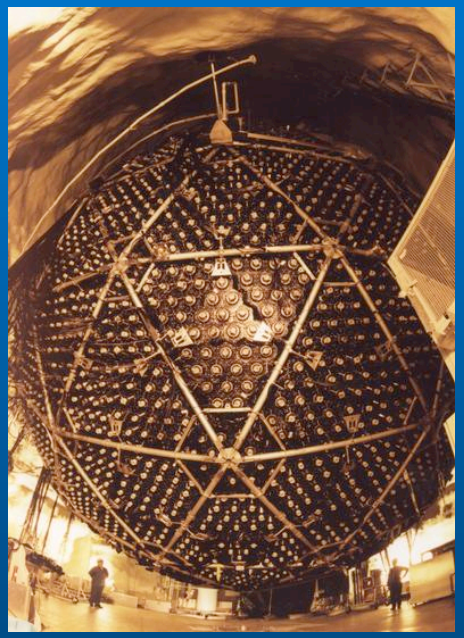
	GS98	AGS05	δ_{TH} % (δ_Z)	EXP
pp	5.97	6.04	0.8 (0.3)	
pep	1.41	1.46	1.3 (0.6)	*
hep	7.90	8.22	15.4 (0.9)	
Be	5.08	4.55	5.0 (2.4)	***
B	5.94	4.72	10.1 (5.3)	4.94 (0.43)
N	2.93	1.93	+20-15 (11)	*
O	2.20	1.37	+23-16 (11)	*
F	5.82	3.24	25 (15)	

Neutrino fluxes can point out high/low Z model

Solar Neutrinos : Experiments

2007: SNO NC (phase III)
2007- : Liquid Scintillator Detectors





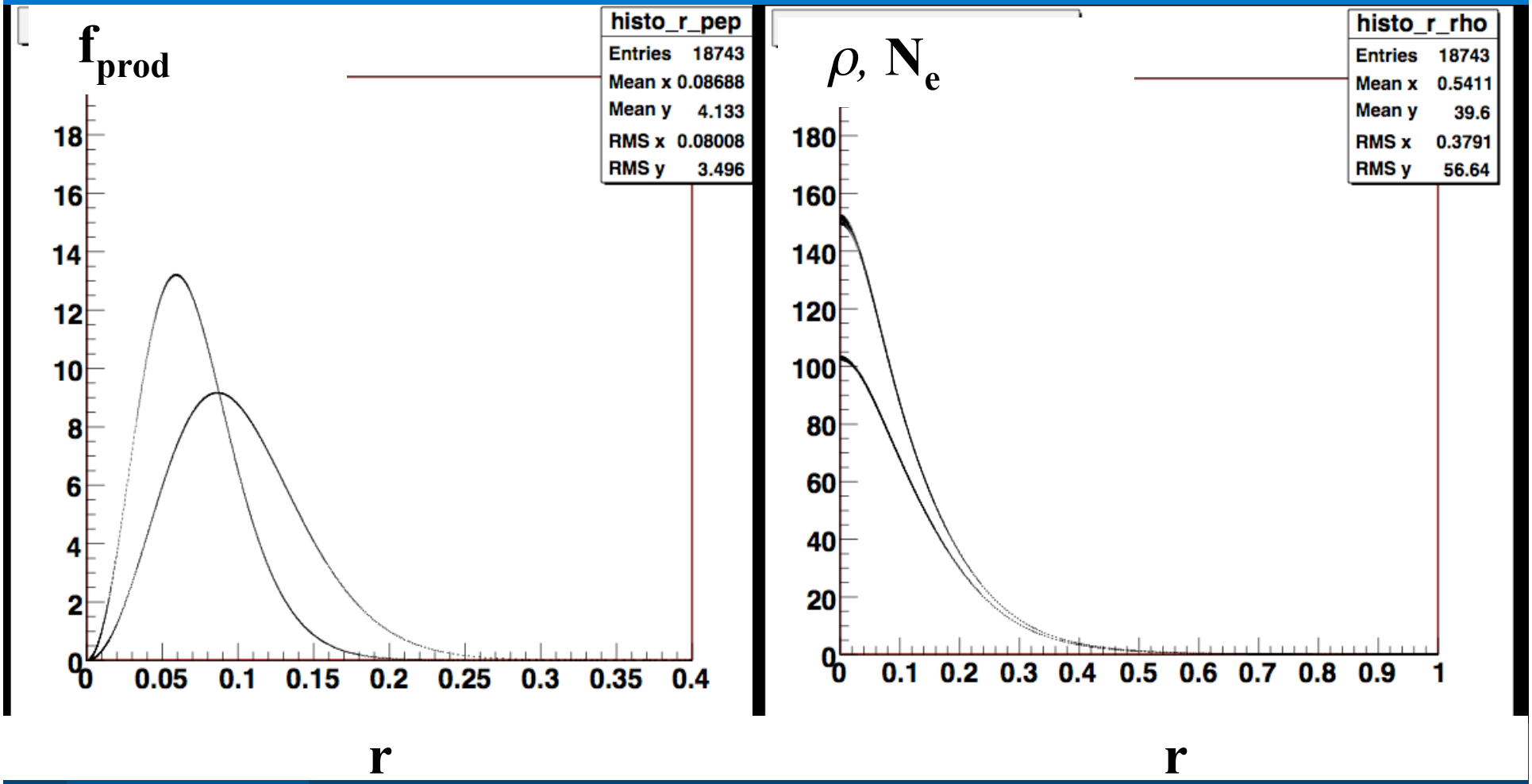
27 Be, 2.2 pep, 1.3+2.0 CNO ν/day in 100 tons fidutial

How well can MSW be identified?

- Consider solar uncertainties
- Relevance of matter effects

Garayoa, P-G, Serenelli

SM : Be vs pep


f_{prod}
histo_r_pep
Entries 18743
Mean x 0.08688
Mean y 4.133
RMS x 0.08008
RMS y 3.496
0 2 4 6 8 10 12 14 16 18
0 0.05 0.1 0.15 0.2 0.25 0.3 0.35 0.4
r
ρ, N_e
histo_r_rho
Entries 18743
Mean x 0.5411
Mean y 39.6
RMS x 0.3791
RMS y 56.64
0 20 40 60 80 100 120 140 160 180
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
r

10000 SMs

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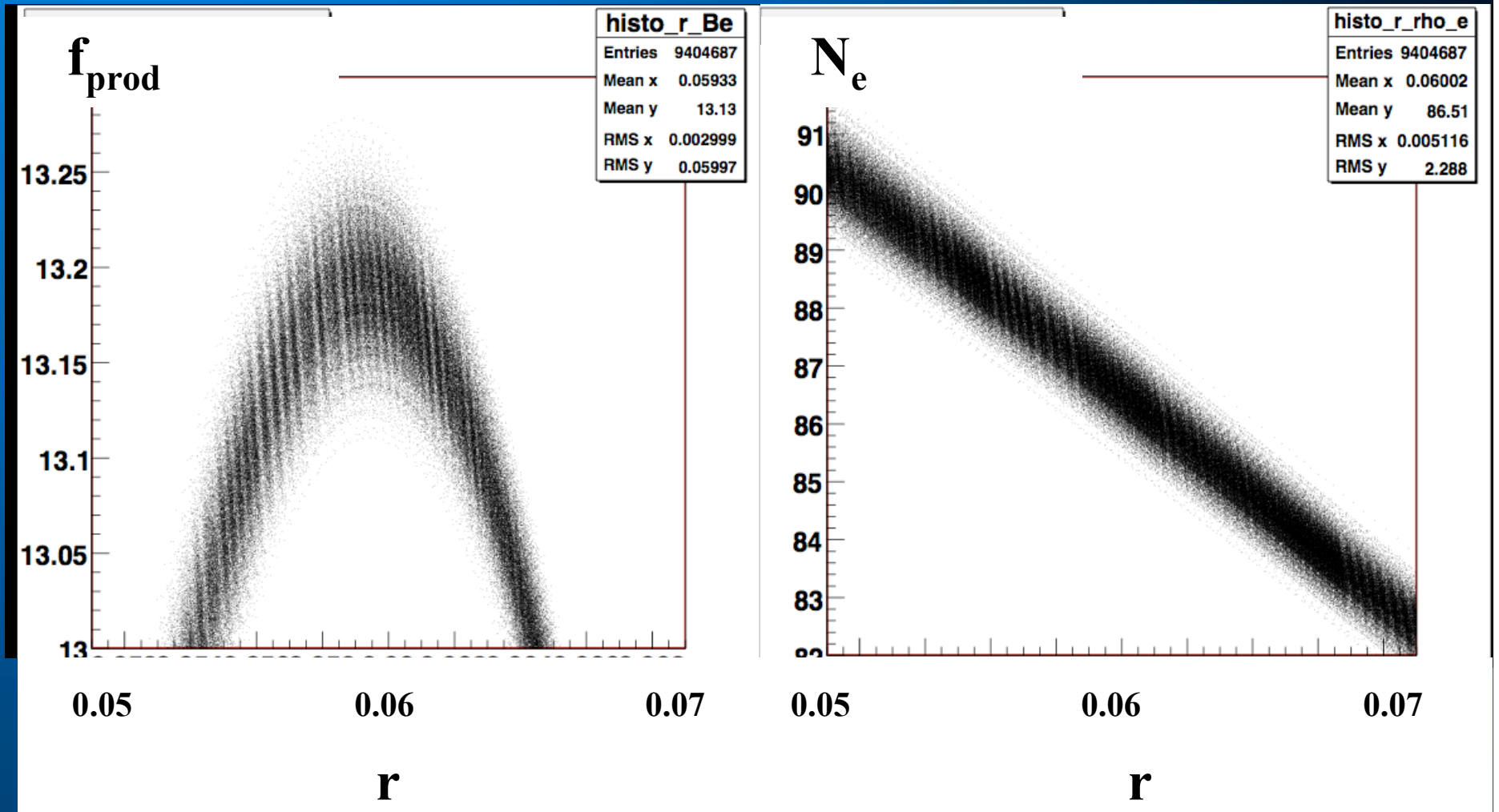
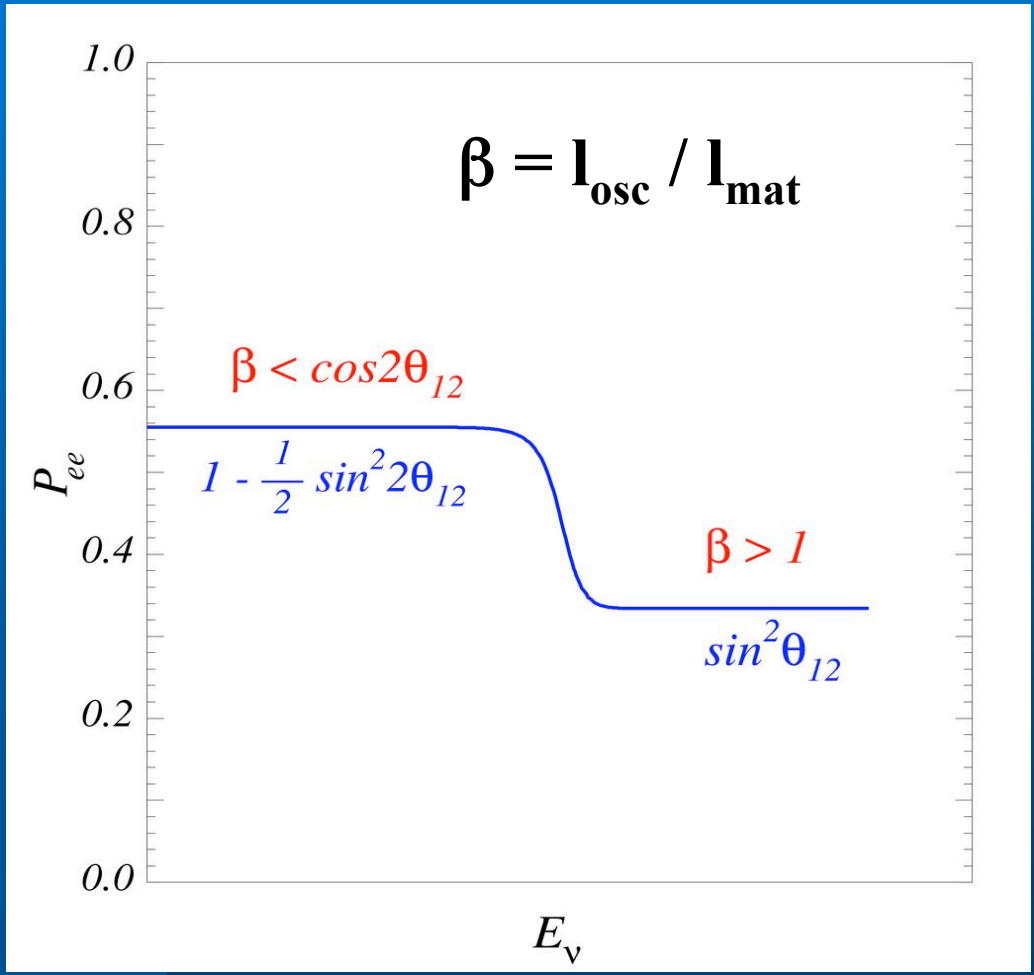


$\rho(Be) = 81.3\ (0.4)\ \ N_A/cm^3,\ \rho(pep) = 68.0\ (0.3)\ \ N_A/cm^3$

LMA : Very good prediction

$P_{ee} = \cos^4\theta_{13}(\cos^2\theta_{12,m}\cos^2\theta_{12}+\sin^2\theta_{12,m}\sin^2\theta_{12})+\sin^4\theta_{13}$



$P_{ee}(m) - P_{ee}(\nu)$ =

<1σ (Be ν)

~2σ (pep ν)
<1σ
(if θ_{12} not improved)

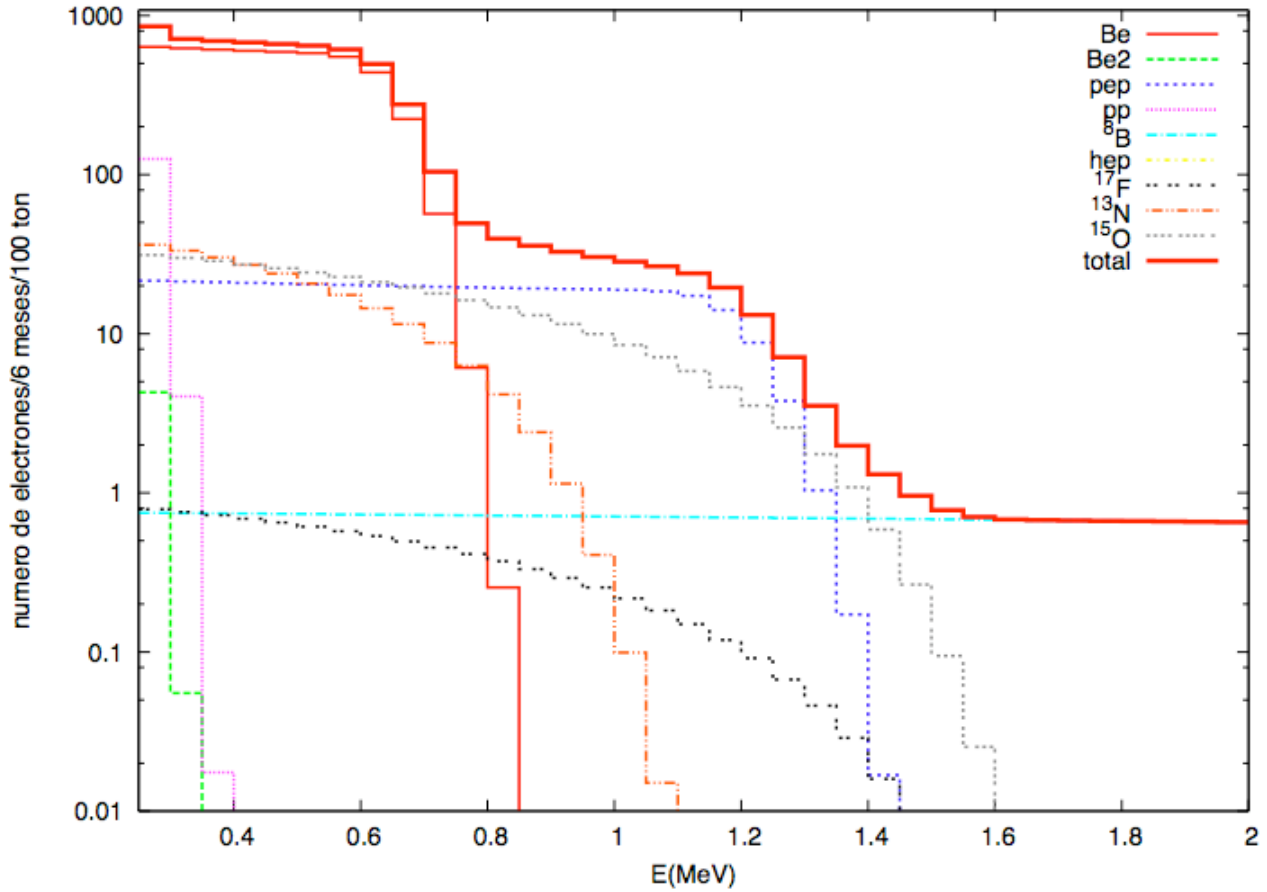
Strong Deviations from vac, will lead to new physics

LS event number / 100 ton /6 months

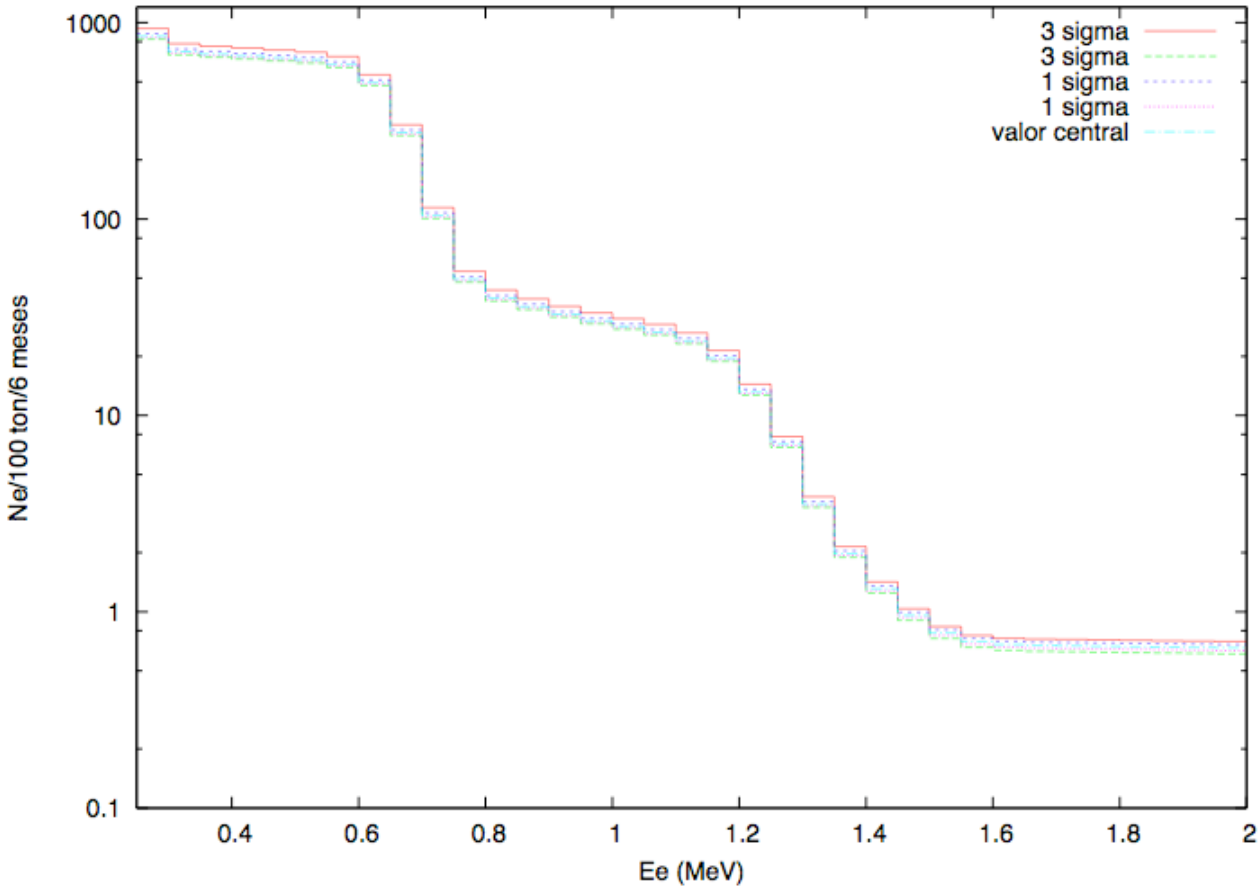
Be
4860

pep
396

CNO
234
+
360



LS event number / 100 ton /6 months



The Sun as a lab for particle physics

Infer solar inputs from neutrino data by modeling the solar neutrino fluxes with power laws of the input parameters with fixed power

Bandyopadhyay et al, hep-ph/0608323

Infer solar inputs from neutrino data and Montecarlo generated 10000 Solar Models Bahcall et al, astro-ph/0511337

We could test astrophysical factors S(0) at the level of precision we obtain from extrapolations.
In particular, 7Be neutrinos can improve S34 precision if ~7Be precision if better than 7 %.

Neutrino fluxes w/o luminosity constraint

LS 100 tons, 6 months data, 5% systematics

With luminosity constraint :

7Be (5%), CNO (20%), pep (1%)

Without luminosity constraint :

7Be (6%), CNO (28%), pep (18%), Luminosity (17%)

Fluxes determined from neutrino data with better precision than differences between high/low Z models.

Conclusions

Chemical controversy at the solar surface likely to stay some years

Measured neutrino might point to high/low Z model: seems the largest theoretical systematic

If new physics, pattern of deviations might be needed

First measurement of Be, pep, CNO neutrinos needed