

Model Independent Analysis of v_0 data

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with

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Model Independent analysis

ν_e experiments

→ SSM independent information

→ If some incompatibility, problem exist

• Super kam vs. ^{37}Cl

Bahcall & Bethe '90

$$R_{\text{ce}}^{\text{obs}}(^8\text{B}) = \phi(^8\text{B})^{\text{obs}} \times \frac{R_{\text{ce}}^{\text{SSM}}(^8\text{B})}{\phi^{\text{SSM}}(^8\text{B})}$$

• No ^8B ν spectrum distortion

• ν cross sections are correct

$$R_{\text{ce}}^{\text{obs}}(^8\text{B}) = (2.44 \pm 0.01) \times \frac{5.9}{5.15}$$

$$= 2.80 \pm 0.01 \text{ SNU}$$

$$R_{\text{ce}}^{\text{obs}} = 2.56 \pm 0.22 \text{ SNU}$$

$$R_{\text{ce}}^{\text{obs}}(X) \equiv R_{\text{ce}}^{\text{obs}} - R_{\text{ce}}^{\text{obs}}(^8\text{B}) = -0.24 \pm 0.22 \text{ SNU}$$

$$X = ^7\text{Be} + \text{CNO}$$

No ^7Be ν !

• ${}^7\text{Ga}$ experiments

SAGE: $66^{+7.8}_{-8.1}$ SNU

GALLEX: 78 ± 8 SNU

$$R_{\text{Ga}}^{\text{SSM}}(\text{pp+pep}) = 72.4 \text{ SNU}$$

No room for ${}^7\text{Be} \rightarrow !$

$$R_{\text{Ga}}^{\text{SSM}}({}^7\text{Be}) = 34.4 \text{ SNU}$$

• Many works on model indep. analysis

S. Bludman et al, PRD 47 (1993) 2220

Hata & Langacker, PRD 49 (1994) 3622

Castellani et al. Astron. Astrophys. 271 (1993) 601

Berezinsky comm. Nucl. Part. Phys. 21 (1994) 249

Kwong & Rosen PRL 73 (1994) 369

Bahcall, PLB 338 (1994) 276

Parke, PRL 74 (1995) 839

Dogl'Innocenti et al. Nucl. Phys. Proc. Supp. 43 (1995) 66

Heeger & Robertson, PRL 77 (1996) 3270

.....

Analysis with Luminosity constraints



$$Q = 26.73 \text{ MeV}$$

$$\frac{L_\odot}{4\pi r^2} = \sum_{i=p, \gamma_{\text{Be}}, \nu_{\text{B}} \dots} \left(\frac{Q}{2} - \langle E_\nu \rangle_i \right) \Phi_i$$

- Sun is in quasiequilibrium.

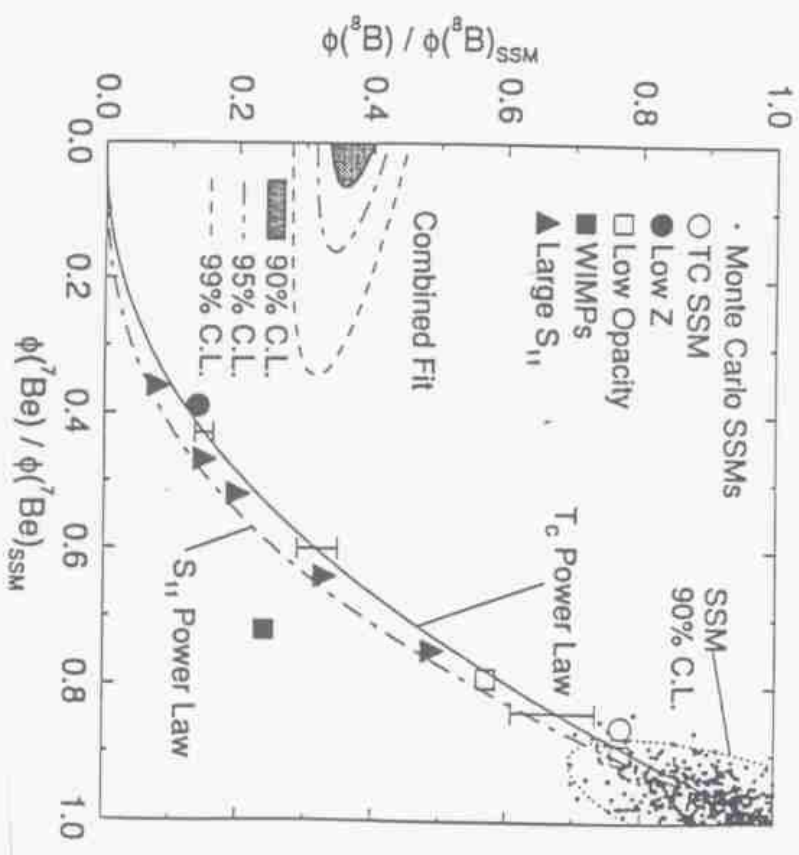
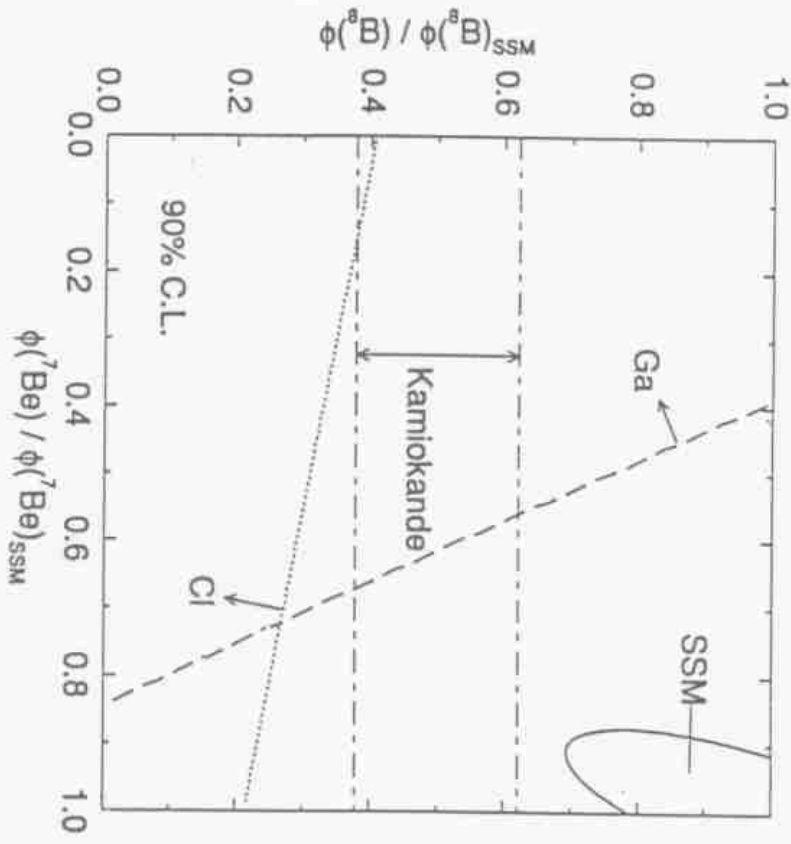
$$\phi^i \equiv \frac{\Phi_i}{\Phi_i^{\text{SSM}}}$$

$$1 = 0.907 \phi_{pp} + 0.0755 \phi_{\gamma_{\text{Be}}} + 4.97 \times 10^{-5} \phi_{\nu_{\text{B}}} + \dots$$

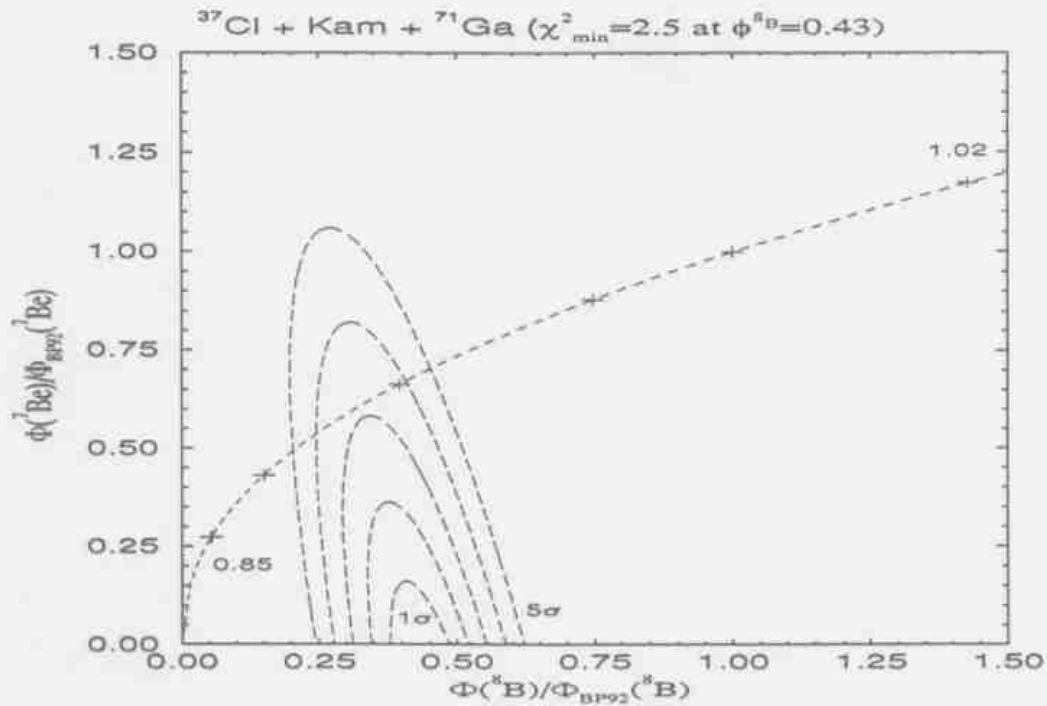
$$\left\{ \begin{array}{l} R_{\text{ce}}^{\text{th}} = 5.9 \phi_{\nu_{\text{B}}} + 1.15 \phi_{\gamma_{\text{Be}}} \quad \text{SNU} \\ R_{\text{ga}}^{\text{th}} = 12.4 \phi_{\nu_{\text{B}}} + 34.4 \phi_{\gamma_{\text{Be}}} + 69.9 \phi_{pp} \quad \text{SNU} \\ \phi_{\text{sk}}^{\text{th}} = \phi_{\nu_{\text{B}}} \end{array} \right.$$

Hata & Langacker PRD 49 (1994) 3622

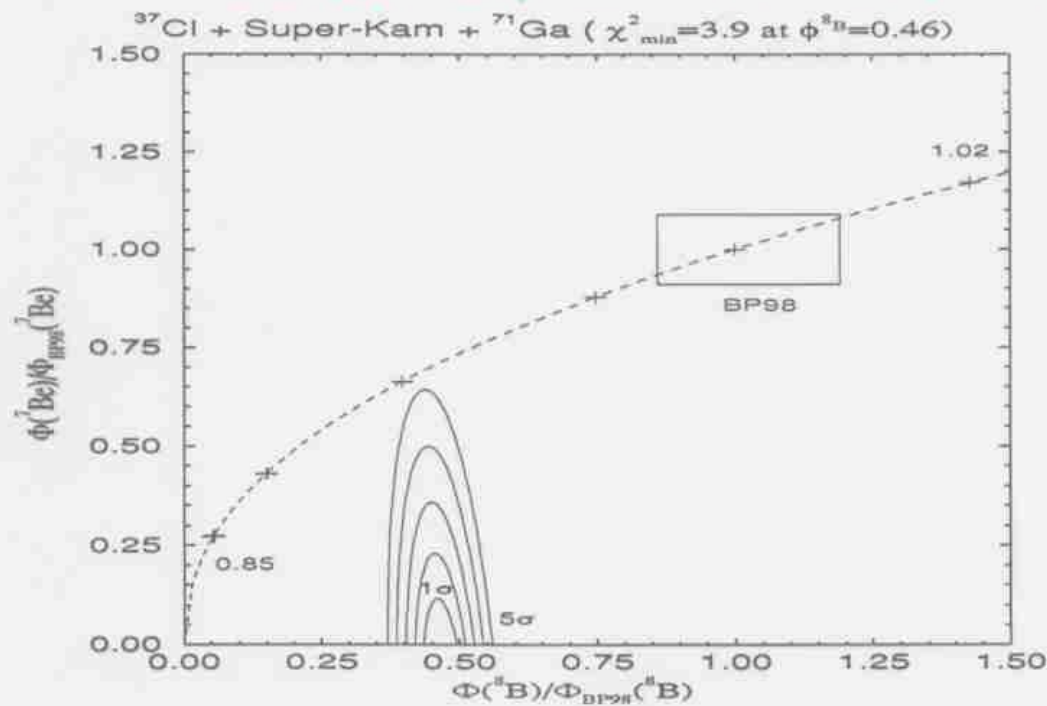
ASTROPHYSICAL SOLUTIONS ARE INCOMPATIBLE WITH ...



Before Superkam ('94)



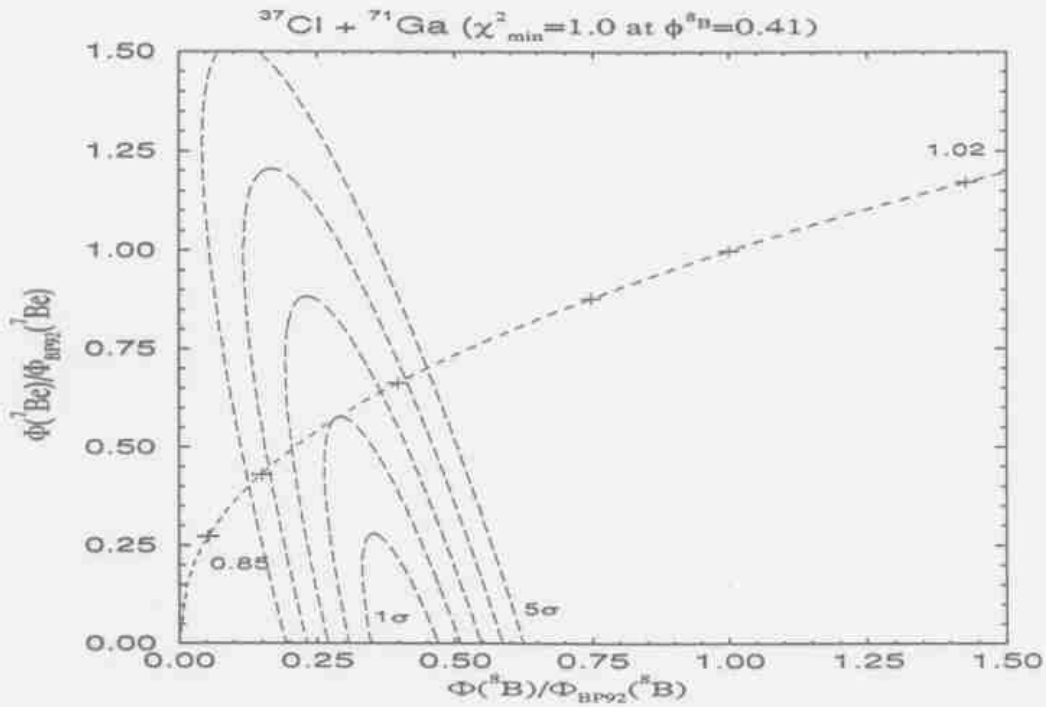
After Superkam ('98) SK504 days



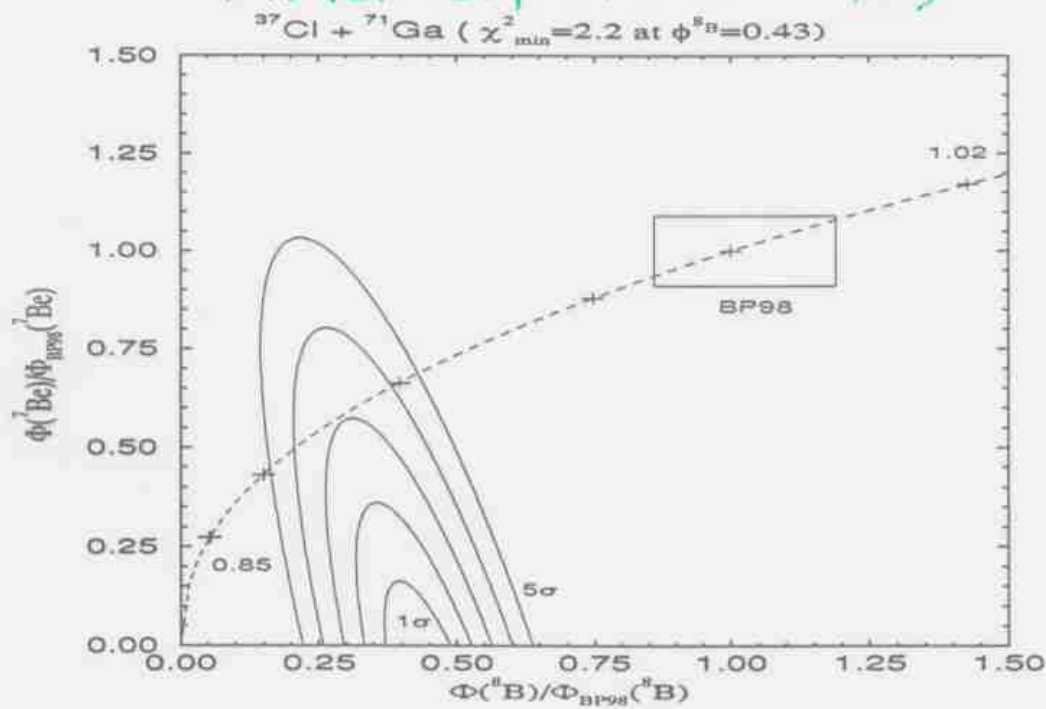
$$\chi^2 = \chi^2_{\text{min}} + \Delta\chi^2$$

$$\Delta\chi^2 = 2.3, 6.2, 11.8, 19.4, 28.7$$

Before Superkam ('94)



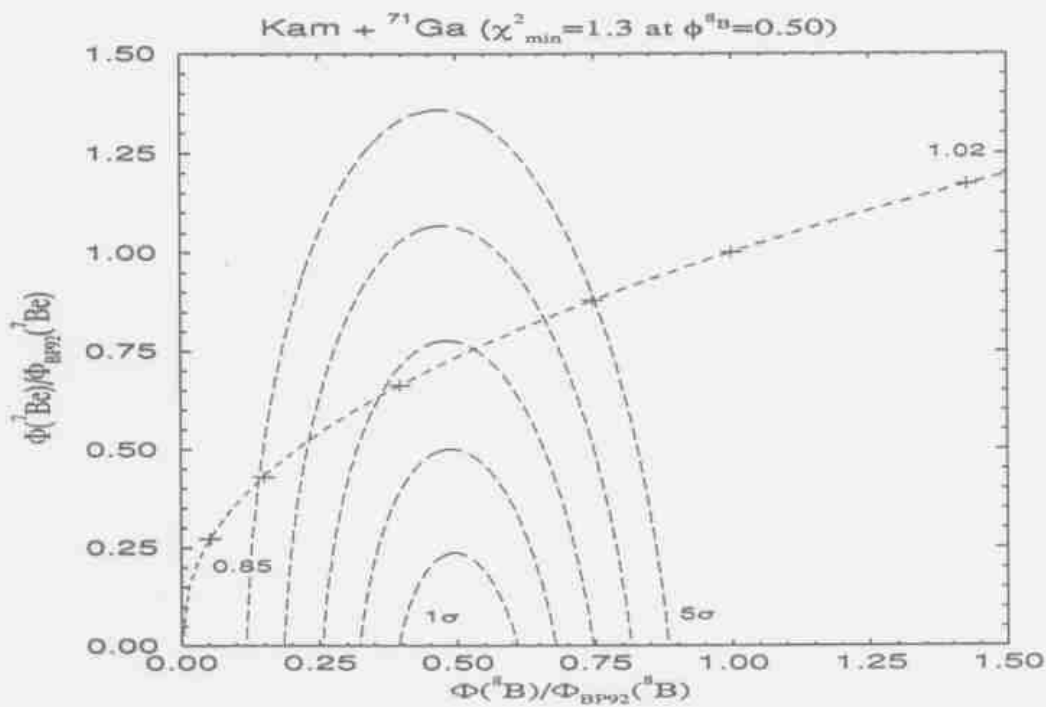
After Superkam ('98) SK504 days



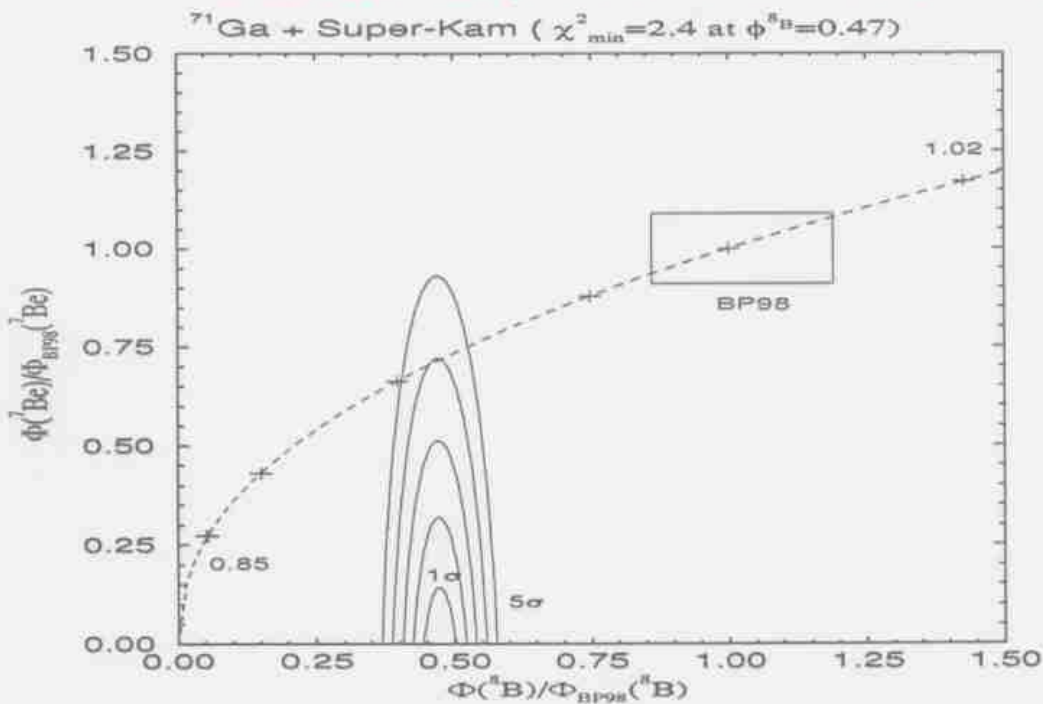
$$\chi^2 = \chi^2_{\min} + \Delta\chi^2$$

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Before Superkam ('94)



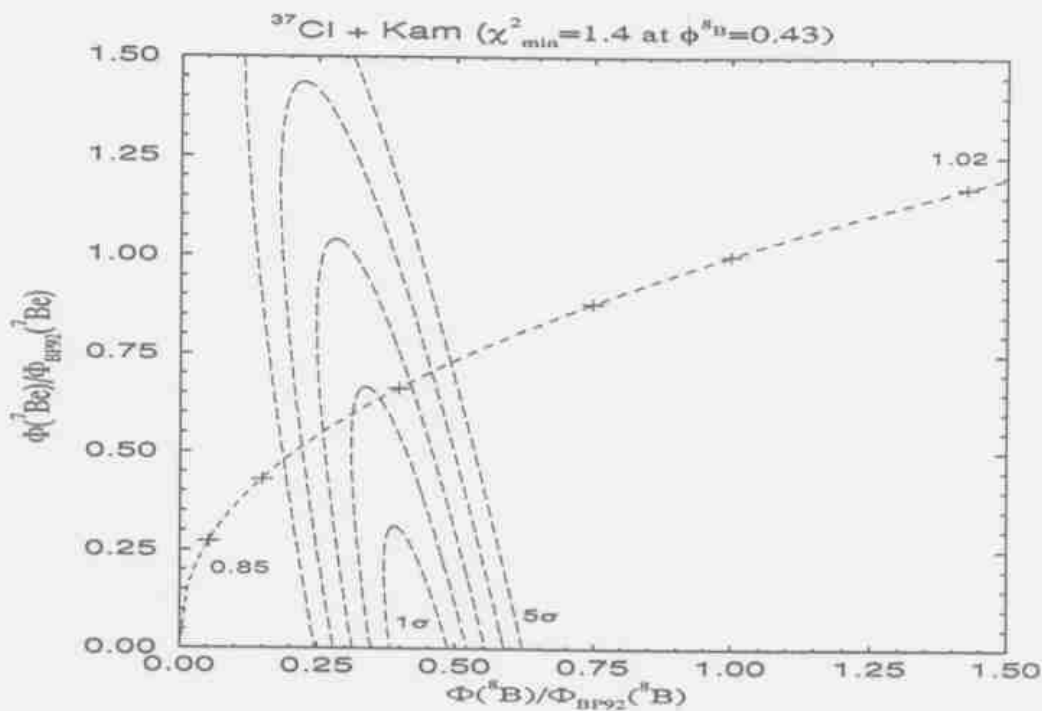
After Superkam ('98) SK504 days



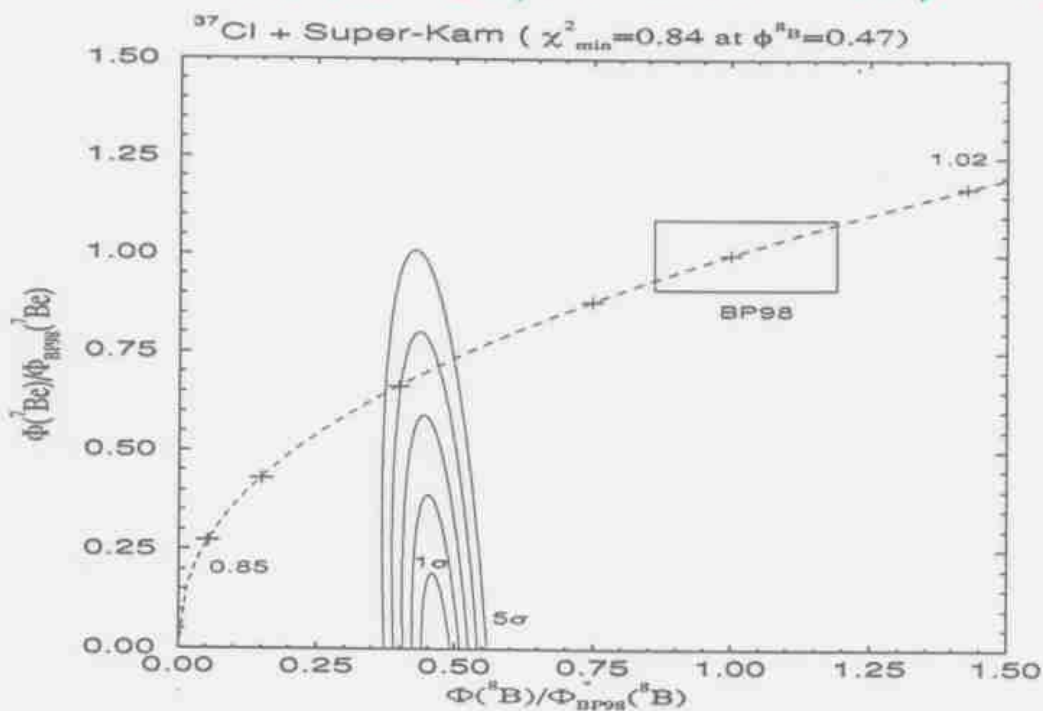
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After Superkam ('98) SK504 days



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Analysis ^{with} ν conversion

$$\langle P_{\nu B}(\nu_e \rightarrow \nu_e) \rangle \equiv \langle P_B \rangle \neq 0$$

$$\Phi_{\nu B}^{SK} \rightarrow \Phi_{\nu B}^{SSM} [\langle P_B \rangle + r(1 - \langle P_B \rangle)]$$

$$r \equiv \frac{\langle \sigma_{\nu pe} \rangle}{\langle \sigma_{\nu eB} \rangle} \sim 0.16$$

$$\langle P_B \rangle = \frac{\Phi_{\nu B}^{SK} / \Phi_{\nu B}^{SSM} - r}{1 - r} \sim 0.37 \quad \text{for BP98}$$

$$R_{ce}^{obs}(\nu B) = 5.9 \times \langle P_B \rangle \sim 2.2 \quad \text{SNU}$$

$$R_{ce}^{obs}(\text{Be} + \text{CNO}) = 0.36 \pm 0.22 \quad \text{SNU}$$

Kwong & Rosen '94

Non negative!

No νB ν spectrum distortion is assumed

$$\sigma_{ce}(E) \sim \int dE' dE'' \frac{d\sigma_{ce}(E, E', E'')}{dE'} K(E, E', E'')$$

For ^{71}Ge ^{71}Ga

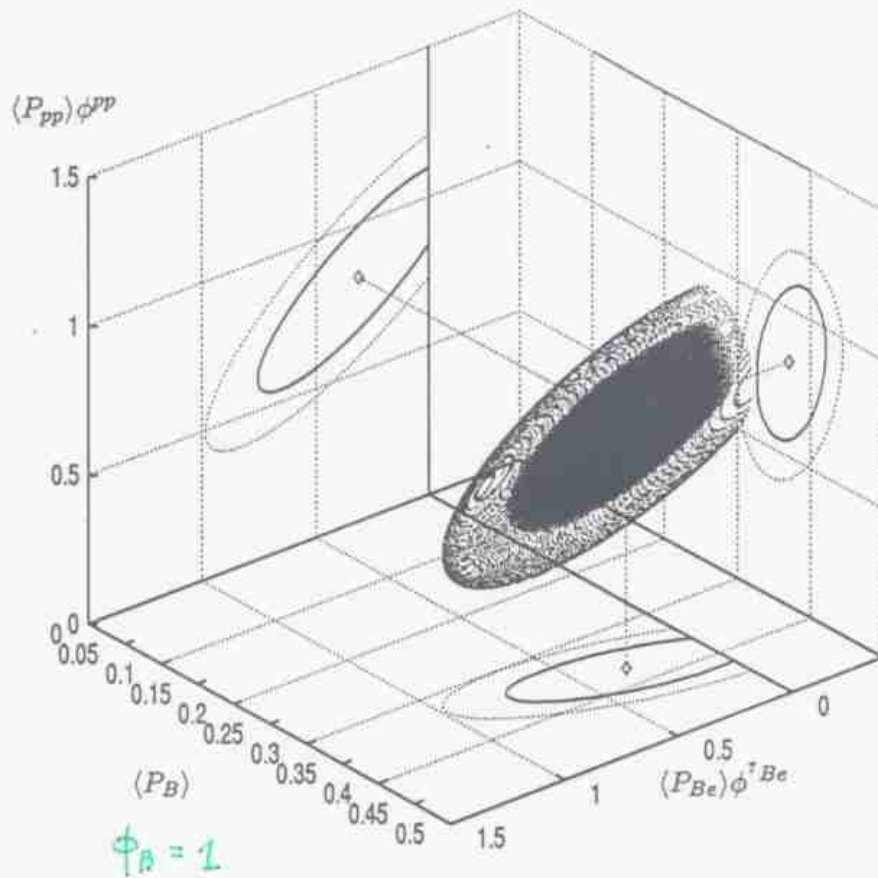
$$\Phi_{Be} \langle P_{Be} \rangle$$

$$\Phi_{pp} \langle P_{pp} \rangle$$

↑
energy resolution
+
efficiency

Active conversion: $\nu_e \rightarrow \nu_{\mu, \tau}$

SK 504 days
BP 98

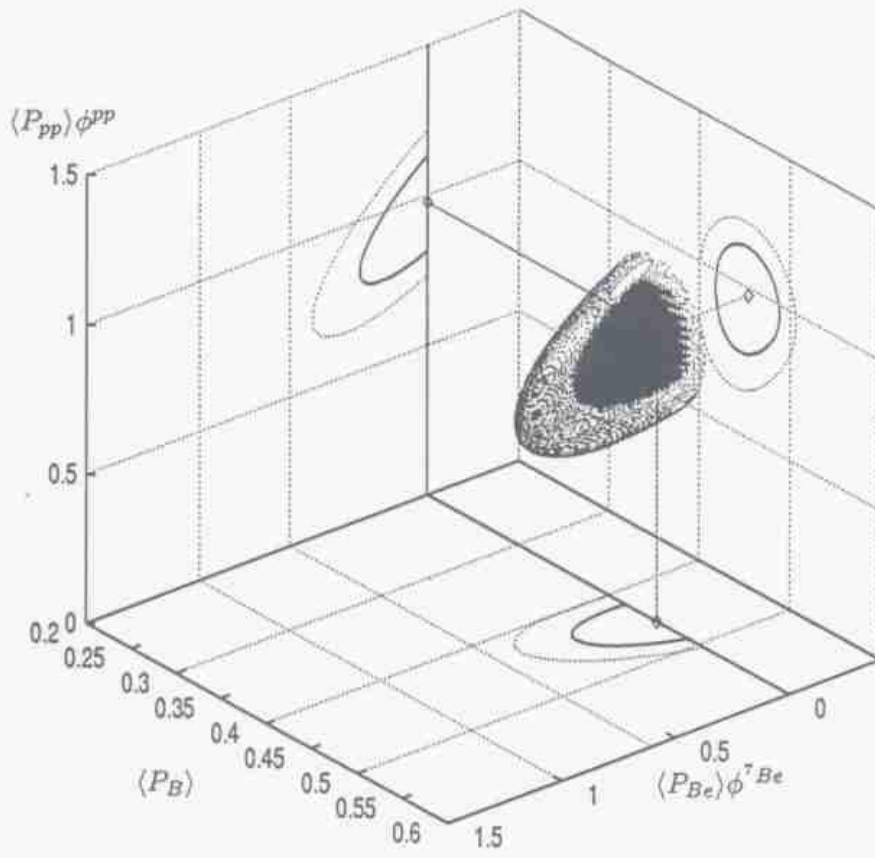


$$\chi^2 = \chi^2_{\min} + \Delta\chi^2$$

$$\Delta\chi^2 = 3.5, 8.0$$

$$\left\{ \begin{array}{l} \langle P_B \rangle \sim 0.37 \\ \langle P_{PP} \rangle \phi_{PP} \sim 0.8 \\ \langle P_{Be} \rangle \phi_{Be} \sim 0.3 \end{array} \right.$$

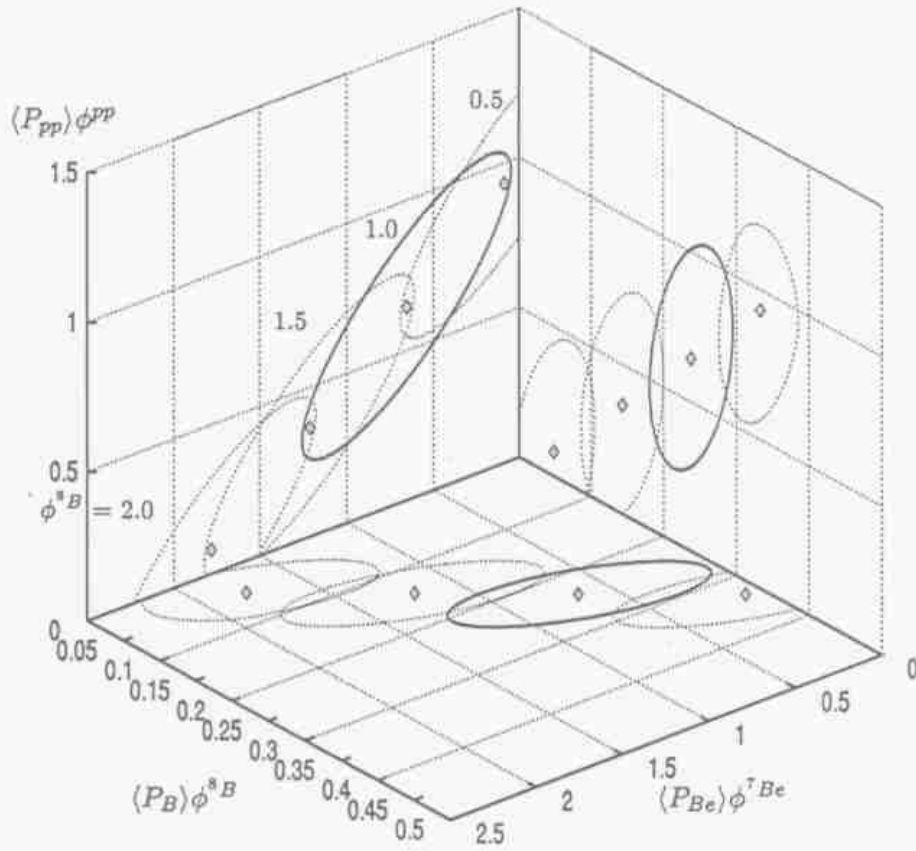
sterile conversion: $\nu_e \rightarrow \nu_s$



SK400days
BP98

Active conversion: $\nu_e \rightarrow \nu_{\mu, \tau}$

Dependence on ϕ_{eB}



SK400 days

BP95

Summary

- We have reconfirmed that SNP can not be explained by astrophysics
- One can generalize the usual (SSM) independent analysis to the where ν conversion exist to some extent
- We tried to determine ν flux ($\langle \phi \rangle$) without specifying any conversion mechanism
- Current ν data suggest

$$\langle P_B \rangle \sim 40\% \quad \phi_B = 1$$

$$\langle P_{PP} \rangle \phi_{PP} \sim 80\%$$

$$\langle P_I \rangle \phi_I \sim 10-30\%$$

} \rightarrow MSW, Just so
or RSFP

$$\Phi_I \equiv \Phi_{\text{osc}} + \Phi_{\text{CKM}} + \Phi_{\text{pep}}, \quad \phi_I \equiv \Phi_I / \Phi_I^{\text{SSM}}$$

$$\phi_B \uparrow \quad \langle P_B \rangle \downarrow \quad \langle P_{PP} \rangle \phi_{PP} \downarrow \quad \langle P_I \rangle \phi_I \uparrow$$

$$\phi_B \downarrow \quad \langle P_B \rangle \uparrow \quad \langle P_{PP} \rangle \phi_{PP} \uparrow \quad \langle P_I \rangle \phi_I \downarrow$$