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Solar ν results from Super-Kamiokande

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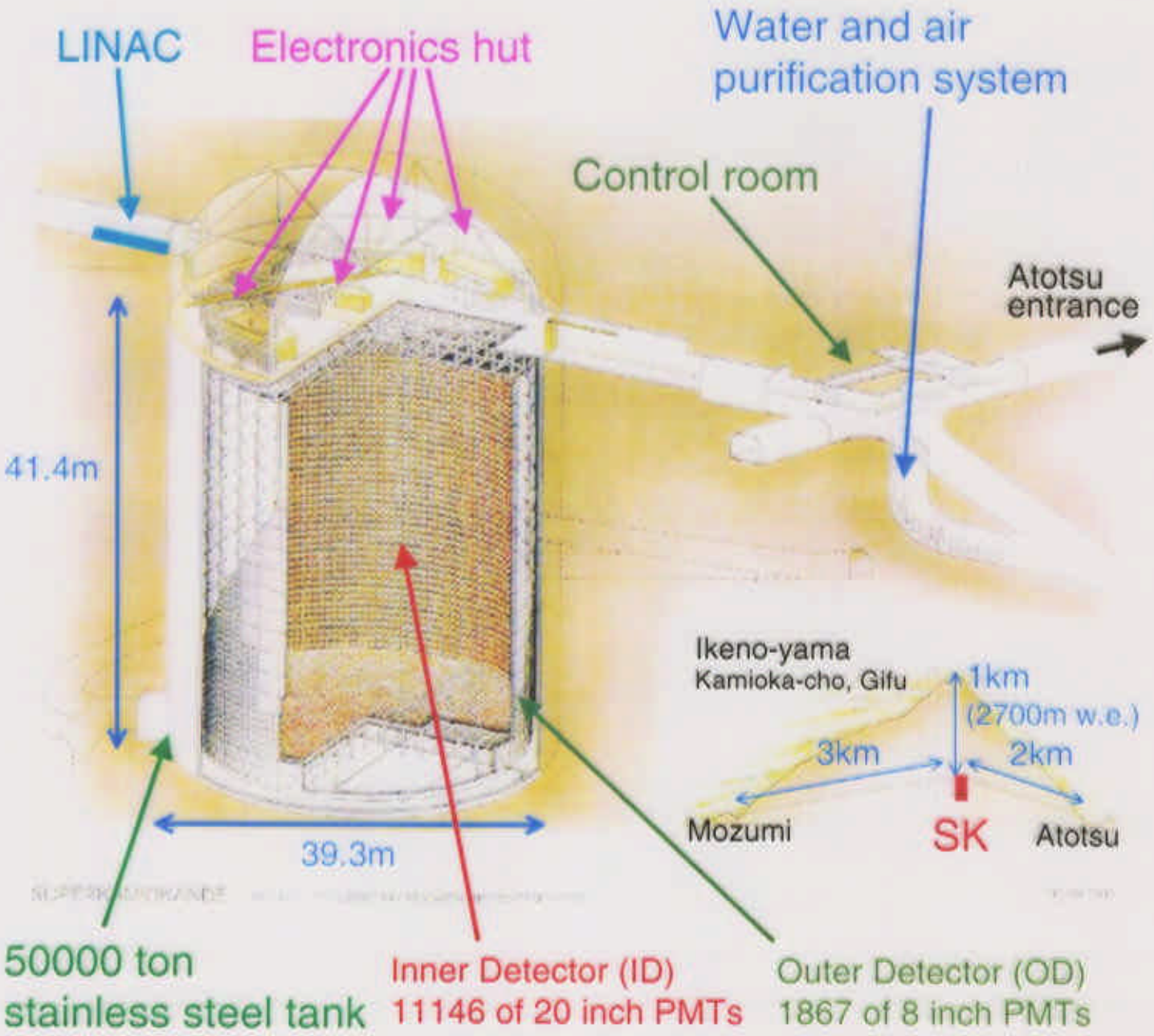
Outline

- What is new
- Results
  - Flux
  - Day / Night
  - Spectrum
  - (Hep)
- Oscillation analysis
  - Active / Sterile (2-flavor)
  - SK only / SK vs. global fit
  - Dark side
- Summary

This presentation is available at
http://www-sk.icrr.u-tokyo.ac.jp/~takeuchi/radon/

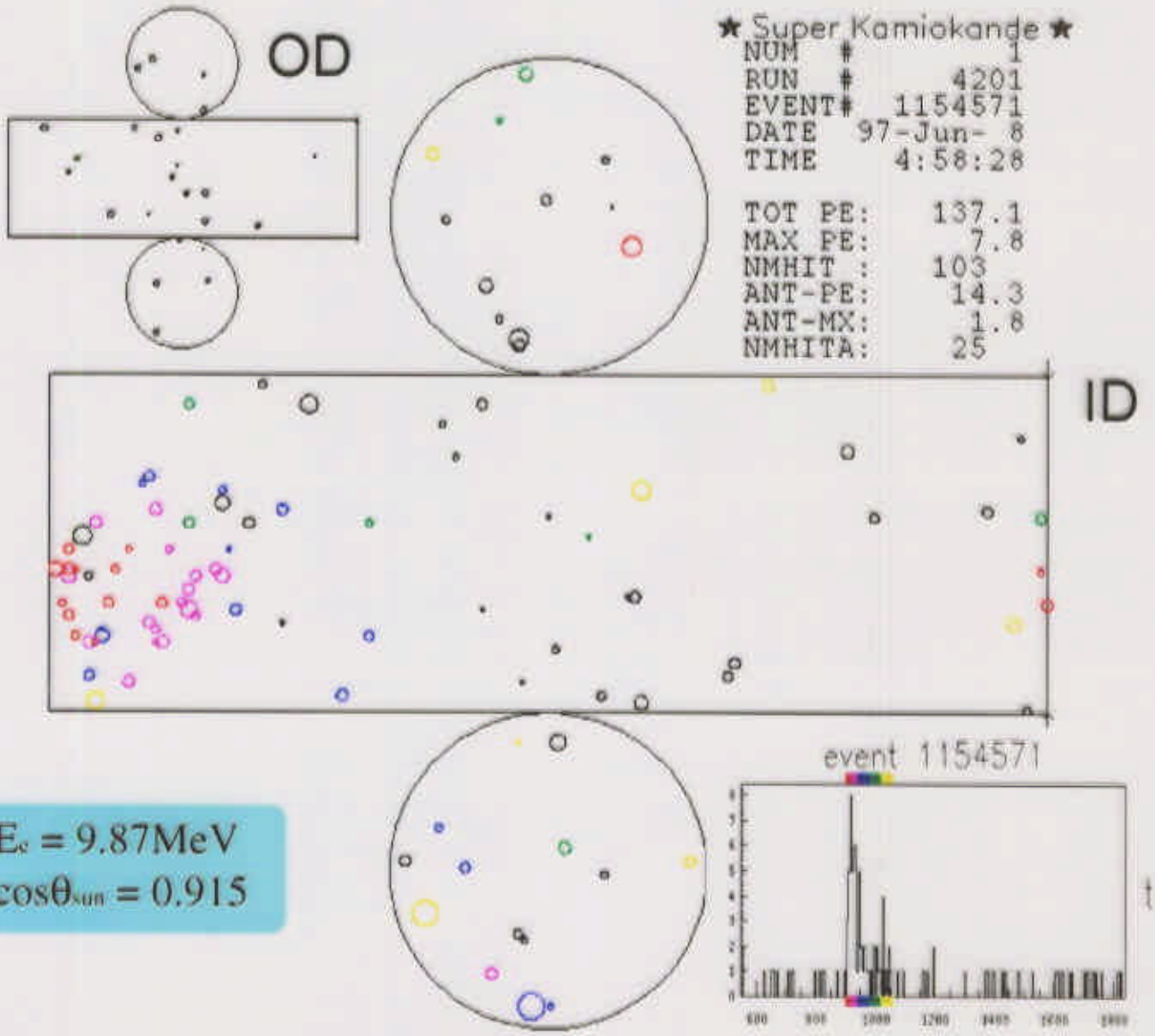
Super-Kamiokande



• photo coverage	40%
• outer detector	2.5m for all surfaces
• fid. vol. for ν_{solar}	22.5kt (2m from ID wall)
• for 10 MeV electron	
vertex resolution	87cm
energy resolution	14%
angular resolution	26°

A Typical low-energy event

- Timing information — vertex position
- Ring pattern — direction
- number of hit PMTs — energy



$E_e = 9.87\text{MeV}$
$\cos\theta_{sun} = 0.915$

Detect solar neutrinos by

$\nu + e \rightarrow \nu + e$ scattering

What's new

- Data update

  Run1742-7200 (SLE524d+LE825d)

  1996/05/31-1999/04/03 **(previous)**

  ↓

  Run1742-8656 (unified analysis 1117day)

  1996/05/31-2000/04/24 **(new)**

- Improve analysis tools

  E<6.5MeV: Super-Low-Energy(SLE) analysis
  E>6.5MeV: Low-Energy(LE) analysis

  → whole energy range: unified analysis

- re-tune M.C. simulation

  energy scale was shifted by 0.27 %
  (within estimated systematic error of 0.64%)

- re-estimate systematic errors

- Lower trigger and analysis energy threshold

  Previous: 5.5-20MeV
  New: 5.0-20MeV

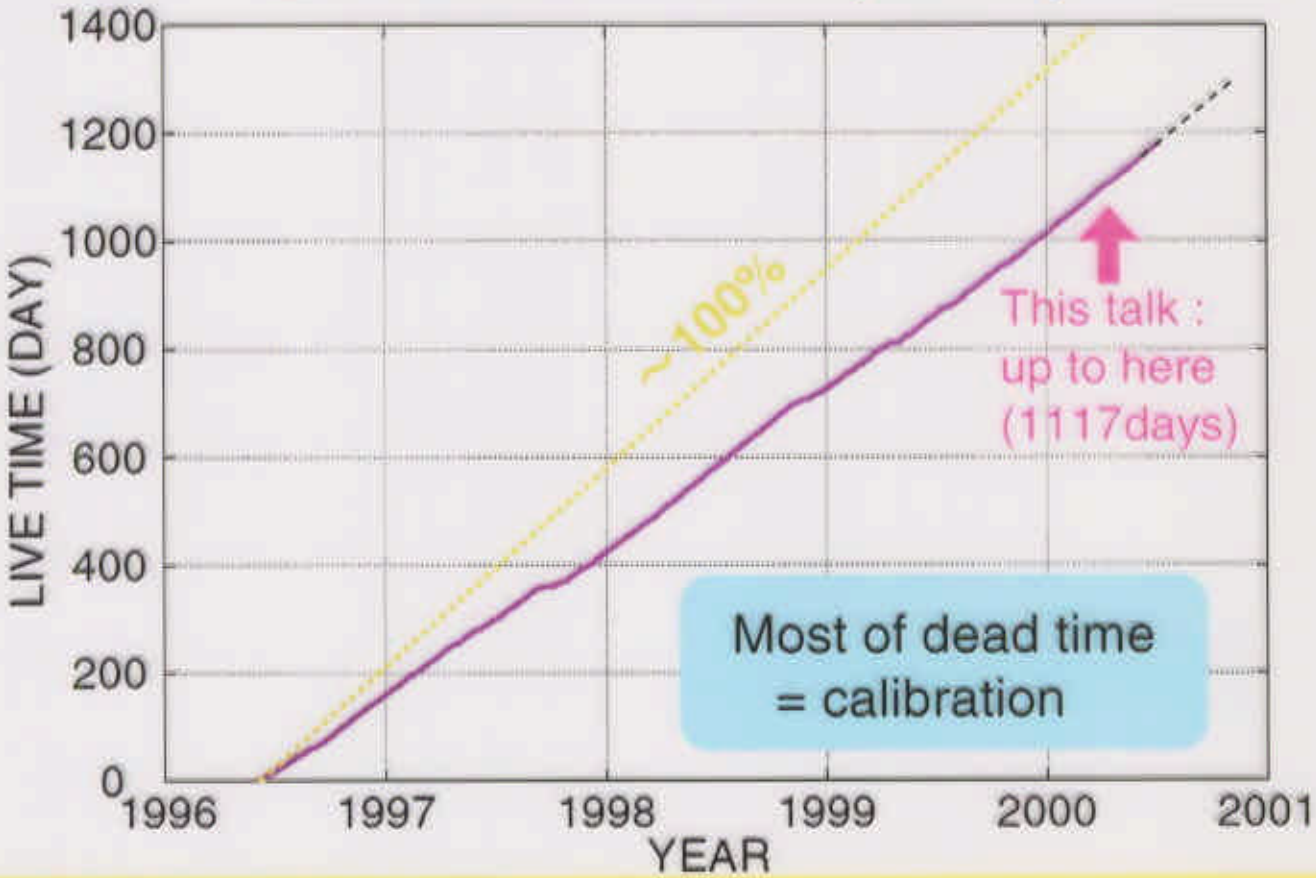
  (But, 5.0-5.5MeV data is not used for results yet)

Trigger threshold

- Low-Energy(LE) trigger (April 1996~)
  ≧29PMT hits / 200nsec (10Hz)
- Super-Low-Energy(SLE) trigger (May 1997~)
  ≧24PMT hits / 200nsec (120Hz)

raw rate ~120Hz (most of them are close to the ID wall)
⟶ on-line fid. vol. cut ⟶ 20Hz

- SLE-version 2 trigger (September 1999~)
  ≧20PMT hits / 200nsec (550Hz)
- SLE-version 3 trigger (July 2000~)
  ≧17PMT hits / 200nsec (1650Hz)



5.7 / 6.5MeV ⟶

4.7 / 5.5MeV ⟶

4.2 / 5.0MeV ⟶

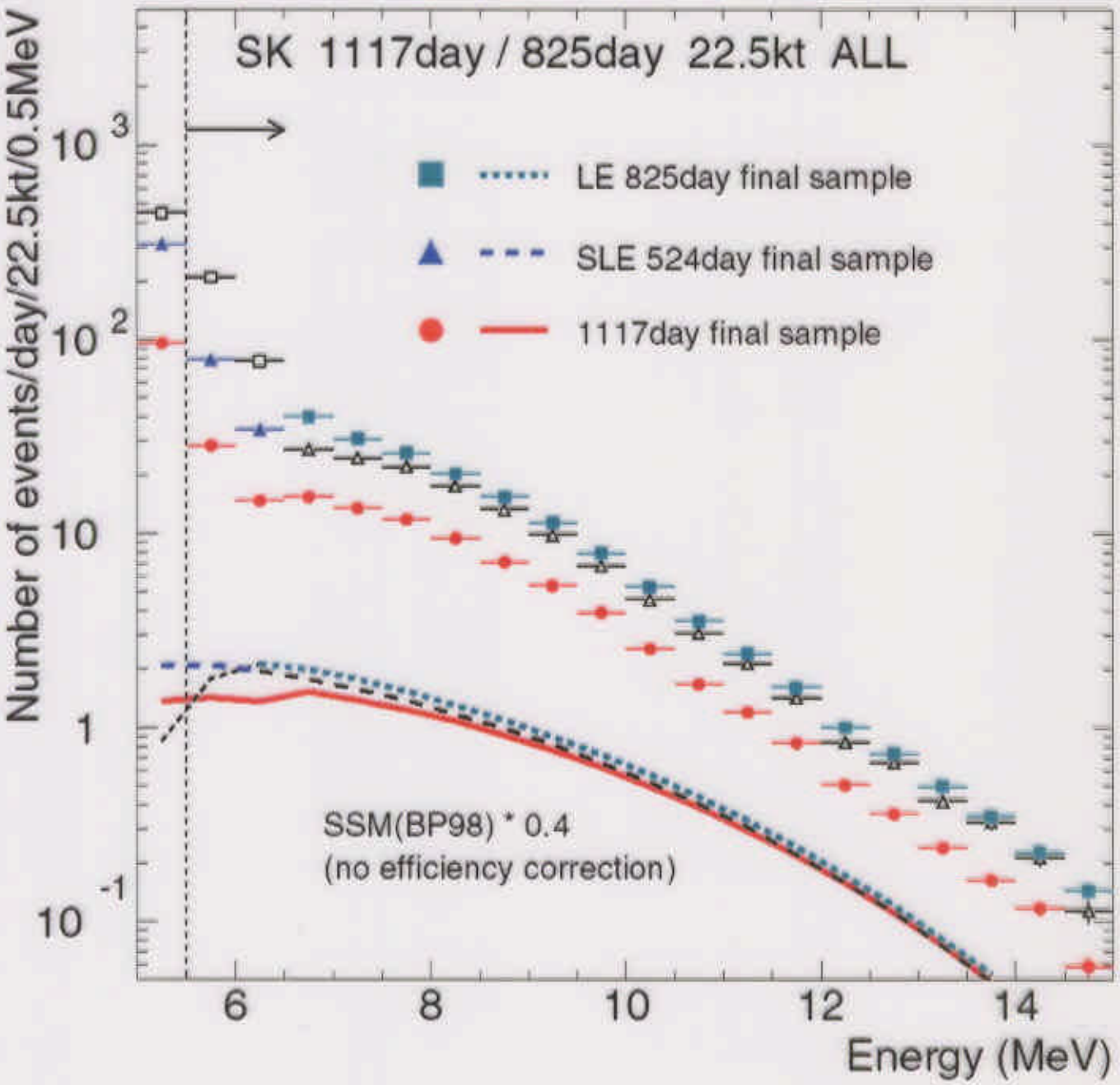
3.7 / 4.5MeV ⟶

@50%/100% trigger ef.

6.5MeV ← 5.5MeV & 5.0MeV →

current analysis energy threshold

Energy spectrum of final data sample



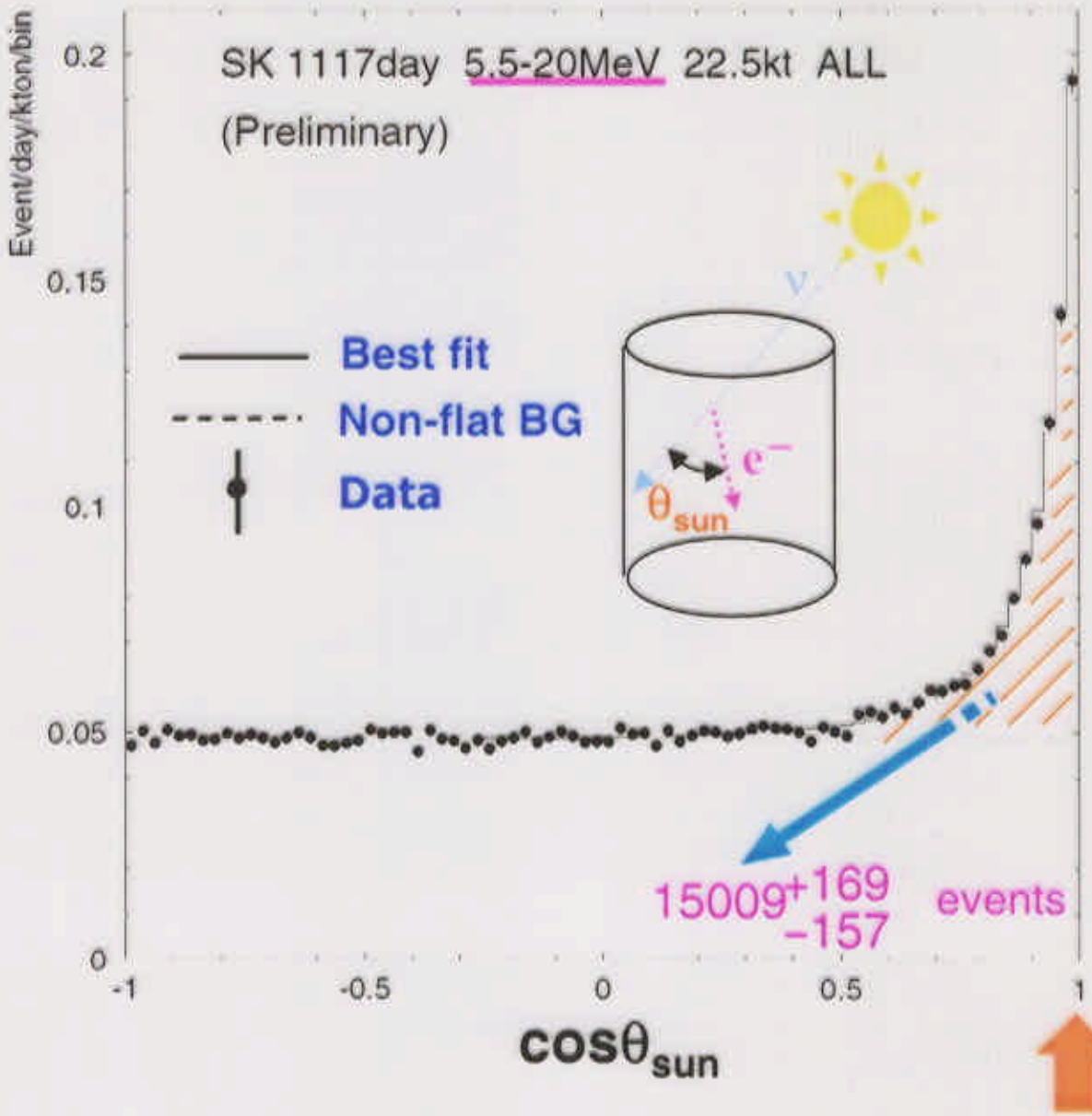
Analysis tools are improved

6.5-20MeV: Background –63%
Signal –20%

^{8}B flux

May 31, 1996 - Apr.24, 2000

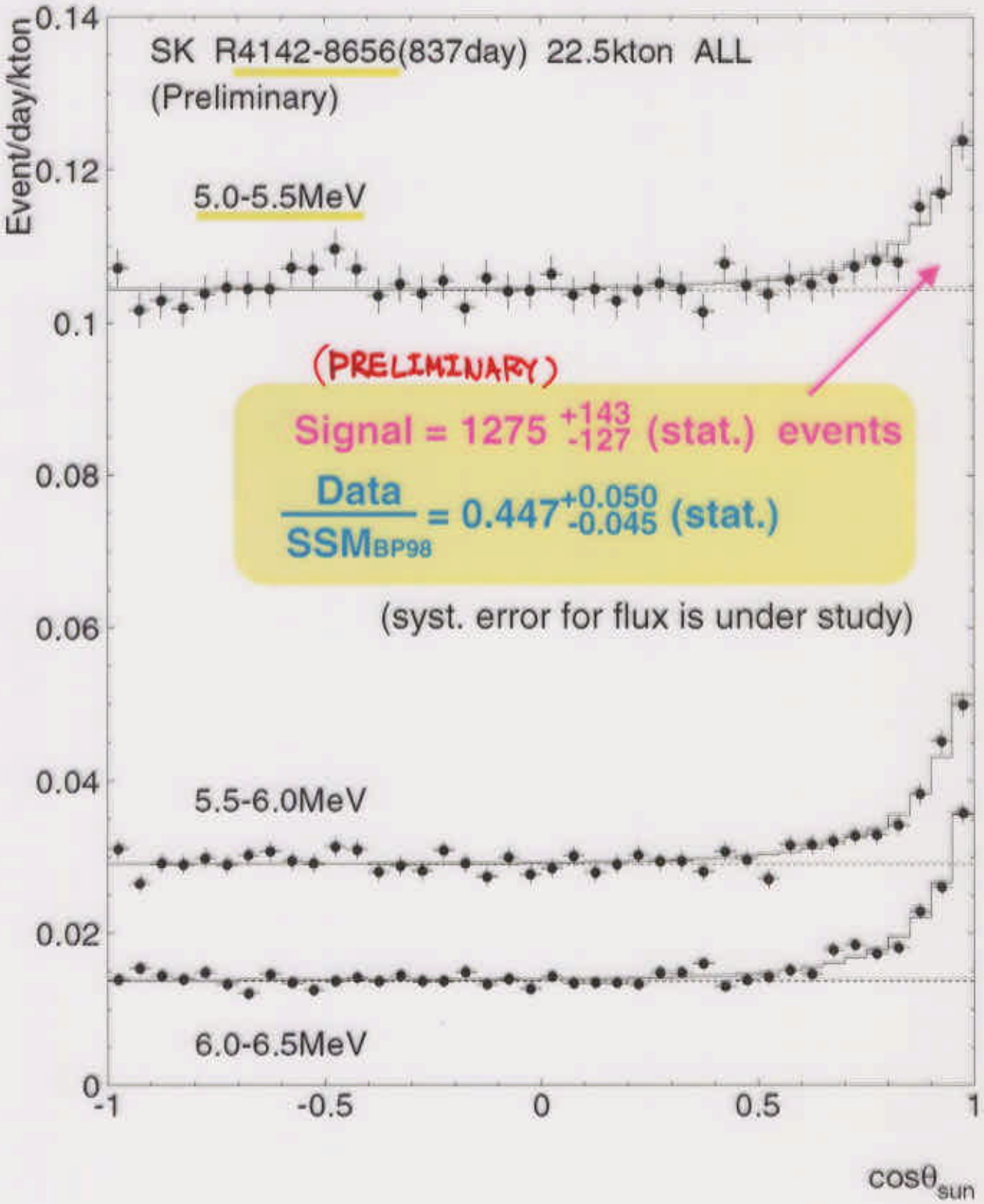
1117 days



^{8}B FLUX= $2.40\ ^{+0.03}_{-0.03}$(stat.) $^{+0.08}_{-0.07}$ (syst.) [x10^6/cm^2/s]

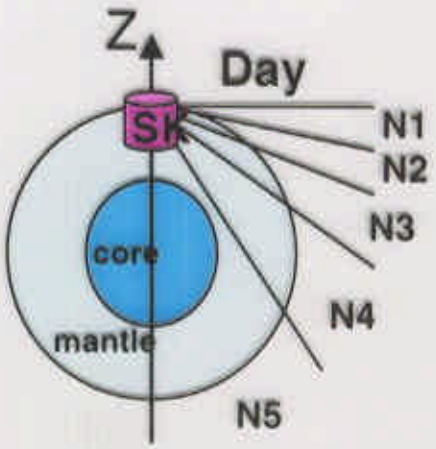
$$\frac{\text{Data}}{\text{SSM(BP98)}} = 0.465\ ^{+0.005}_{-0.005}\text{(stat.)}\ ^{+0.015}_{-0.013}\text{(syst.)}$$

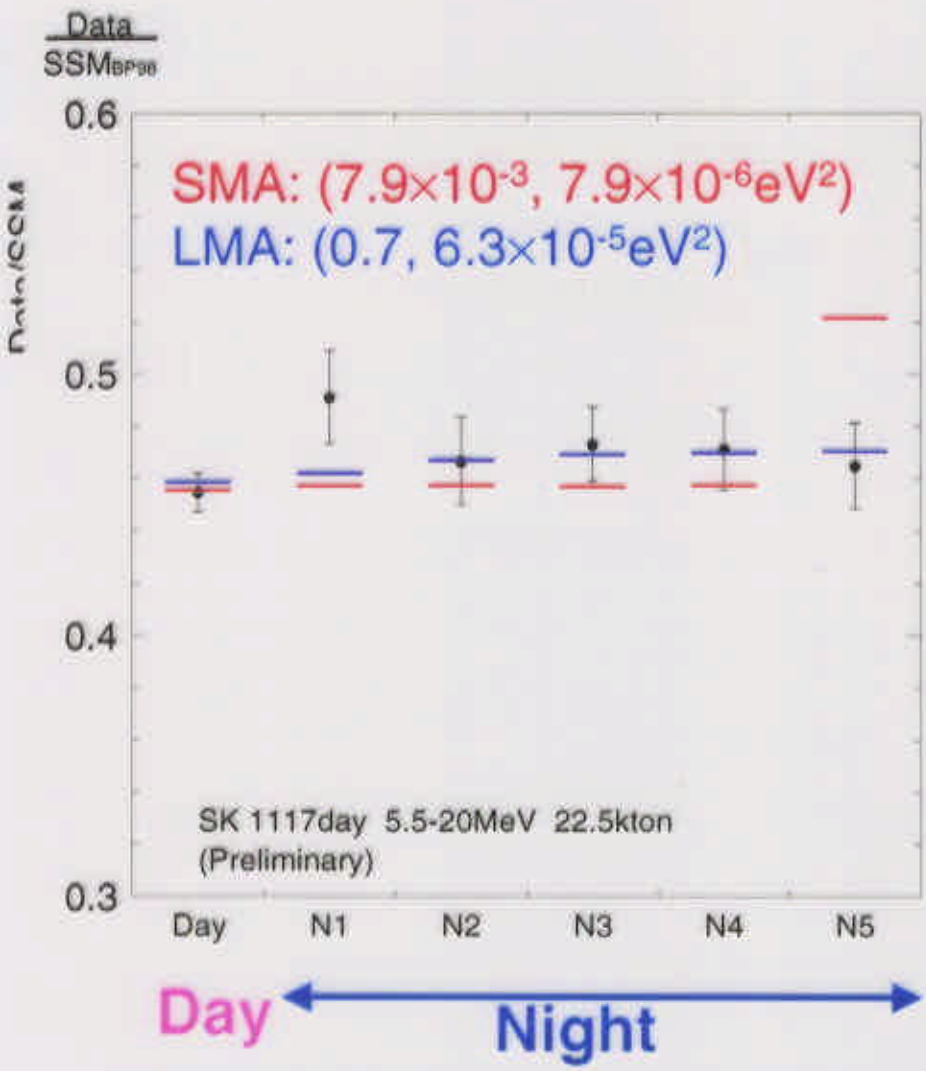
Flux in lower energy regions

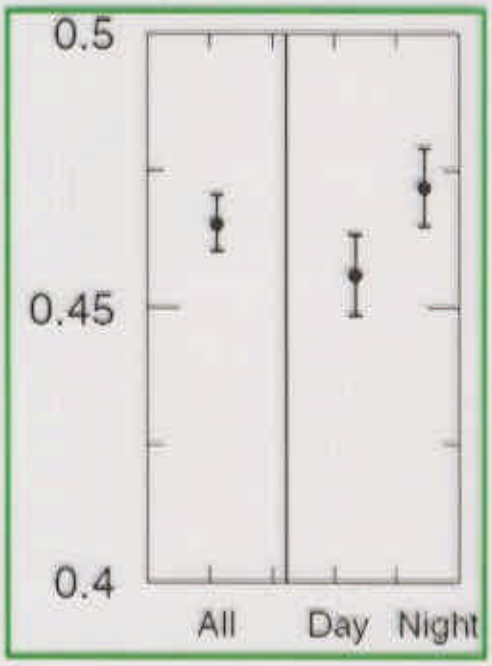


(5.0-5.5MeV data is not used for results yet)

Day/Night analysis







Day: 545days, 5.5-20MeV

$\phi(^8B) = 2.35\ ^{+0.04}_{-0.04}(\text{stat.})\ ^{+0.08}_{-0.07}(\text{syst.})\ [\times 10^6/\text{cm}^2/\text{s}]$

Night: 572days, 5.5-20MeV

$\phi(^8B) = 2.43\ ^{+0.04}_{-0.04}(\text{stat.})\ ^{+0.08}_{-0.07}(\text{syst.})\ [\times 10^6/\text{cm}^2/\text{s}]$

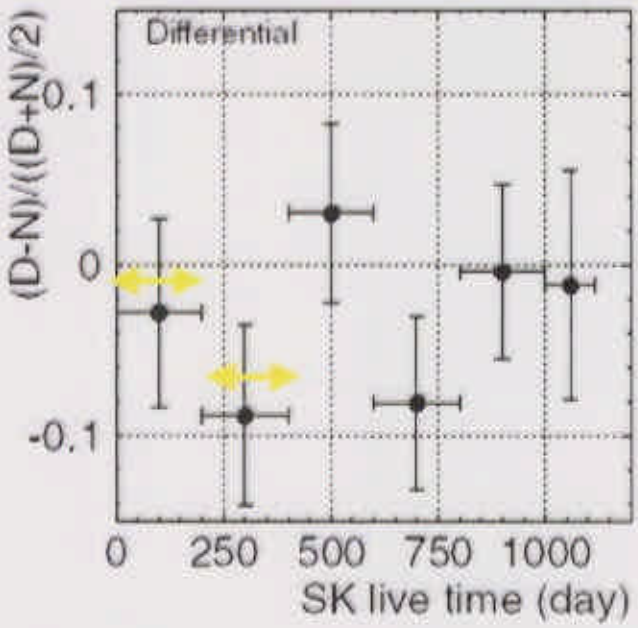
$$\frac{N-D}{(N+D)/2} = -0.034 \pm 0.022(\text{stat.})\ ^{+0.013}_{-0.012}(\text{syst.})$$

(eccentricity is corrected)

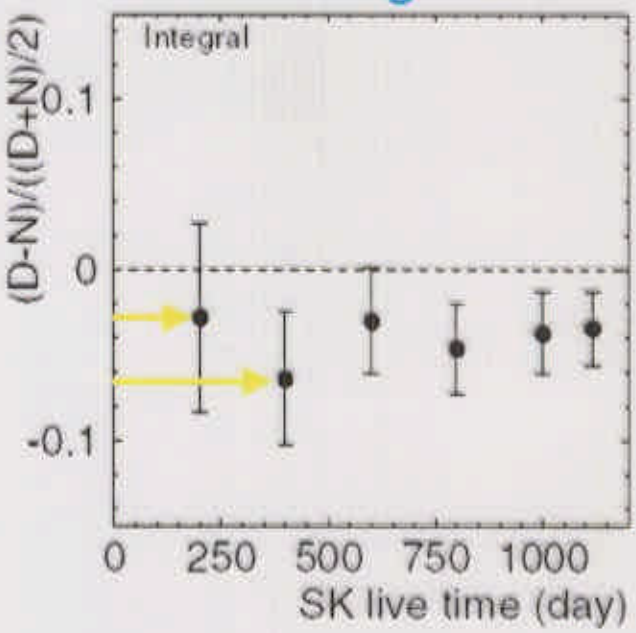
Significance vs. time (day/night)

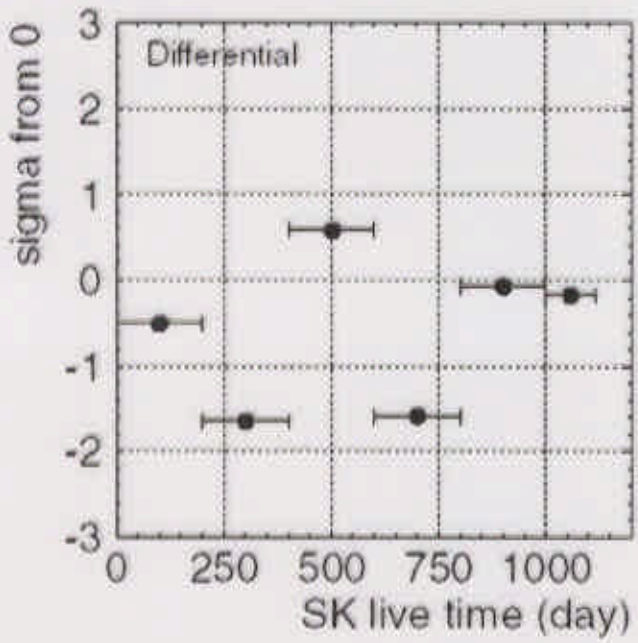
Errors: only statistical

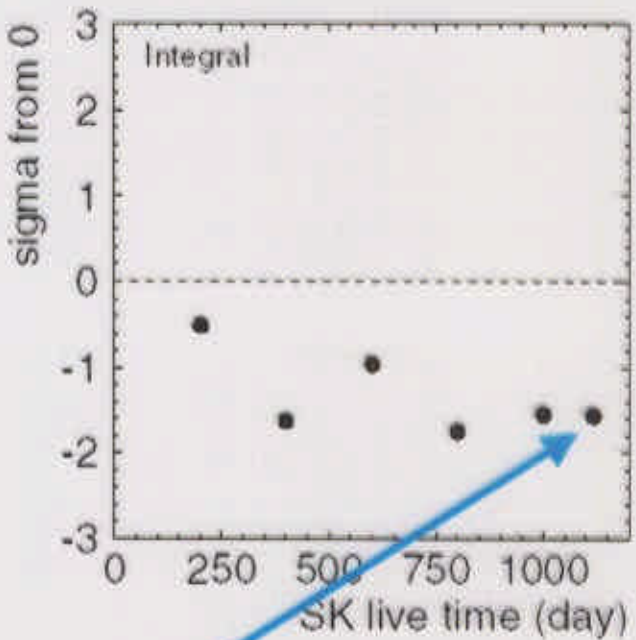
Differential



Integral



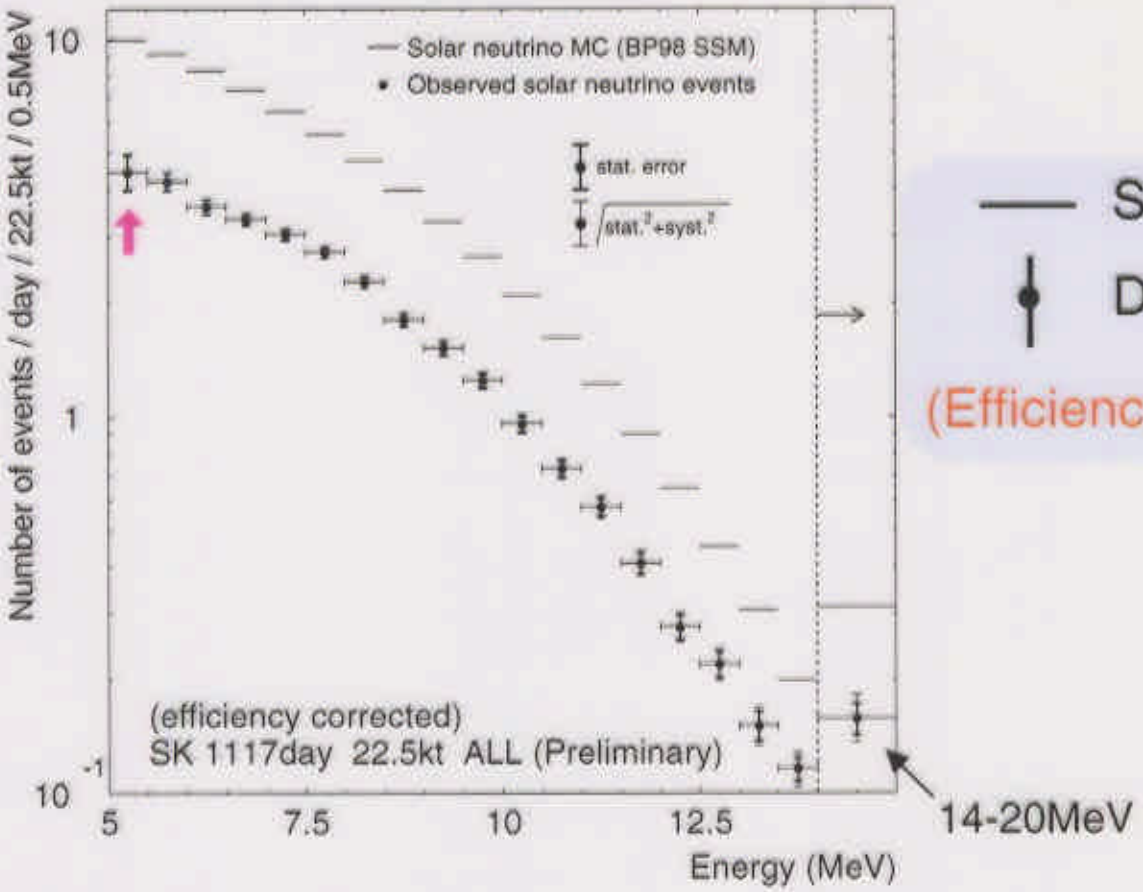




1.6σ (only stat. err.)

1.3σ (including syst. err.)

Energy spectrum

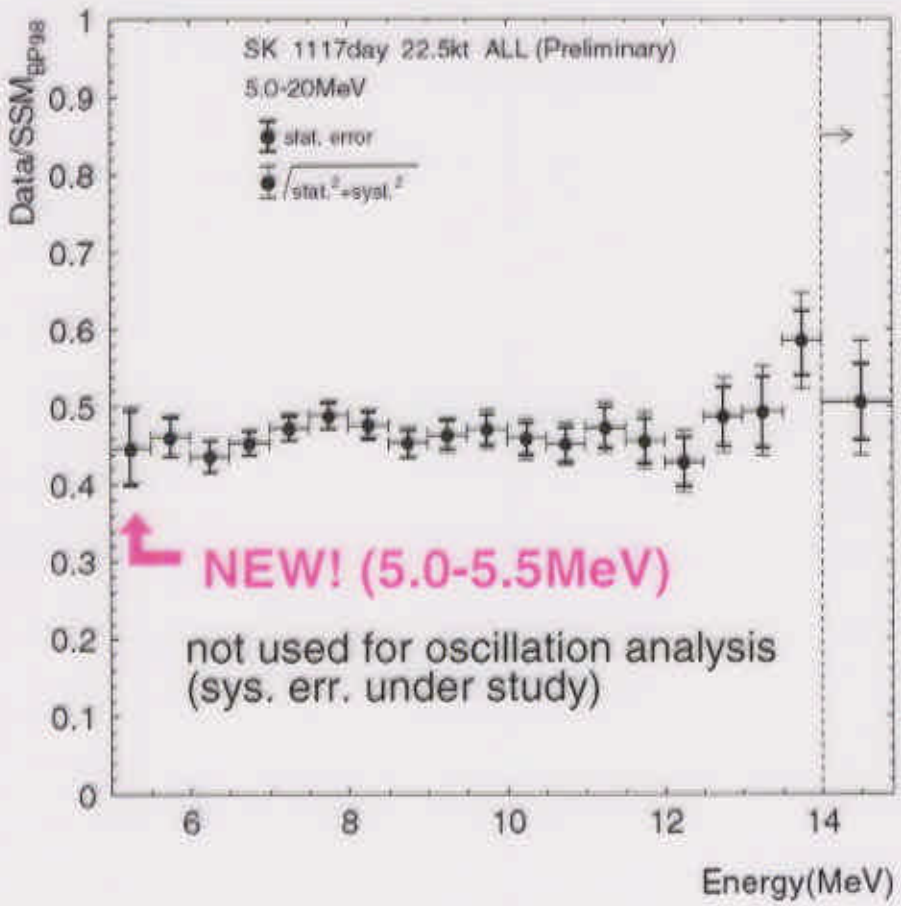


SSM

Data

(Efficiency corrected)

Data/SSM(BP98)



5.5-20MeV:

χ^2 for flat = 13.7/17dof

(including sys. err.)

C.L.= 69 %

consistent with flat

Significance vs. time (spectrum)

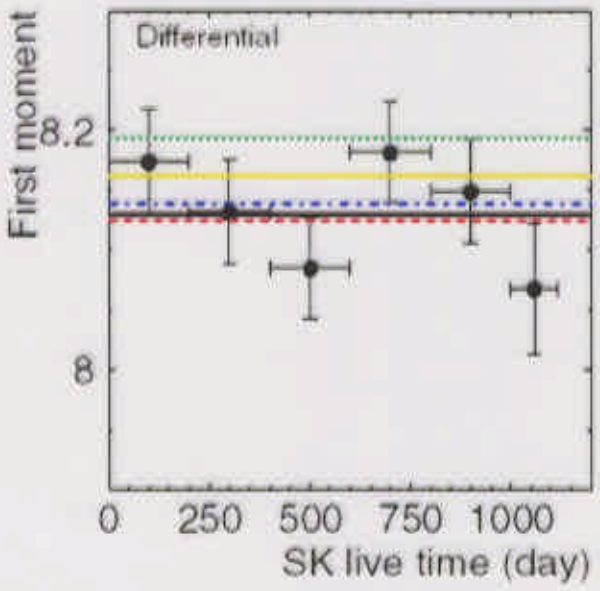
$$\text{First moment} : \langle T \rangle = \frac{\sum \langle T \rangle_i \, N_i}{\sum N_i}$$

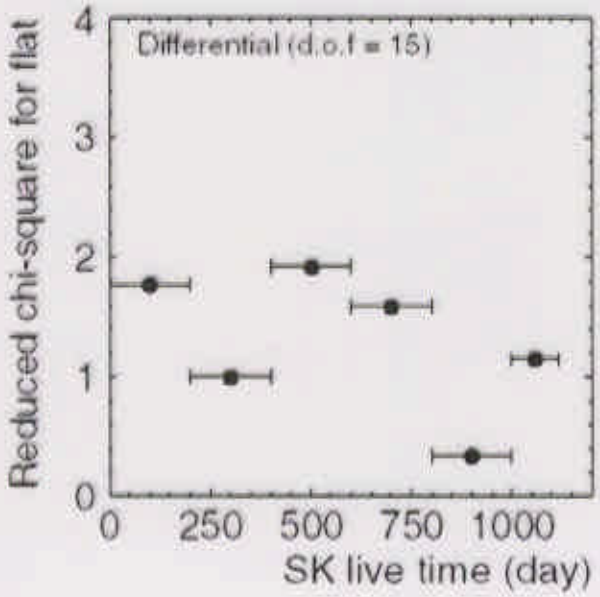
cf. J.N.Bahcall and P.I.Krastev, PRC 56(1997)p2839

> 6.5 MeV data (stat. error only)

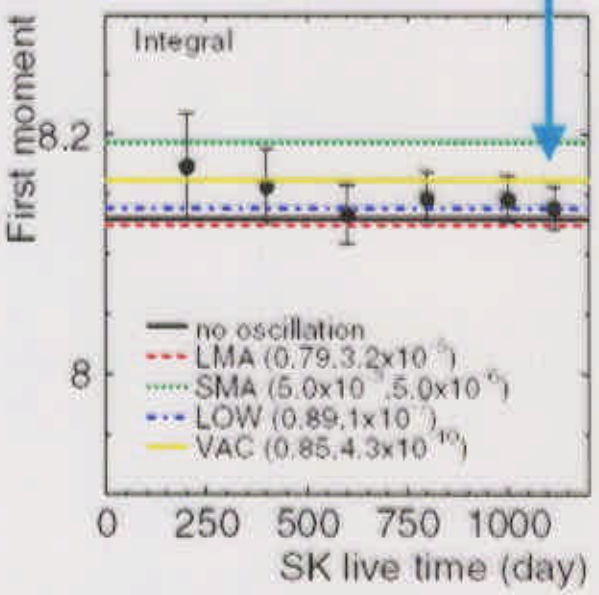
Data: 8.14±0.02 MeV

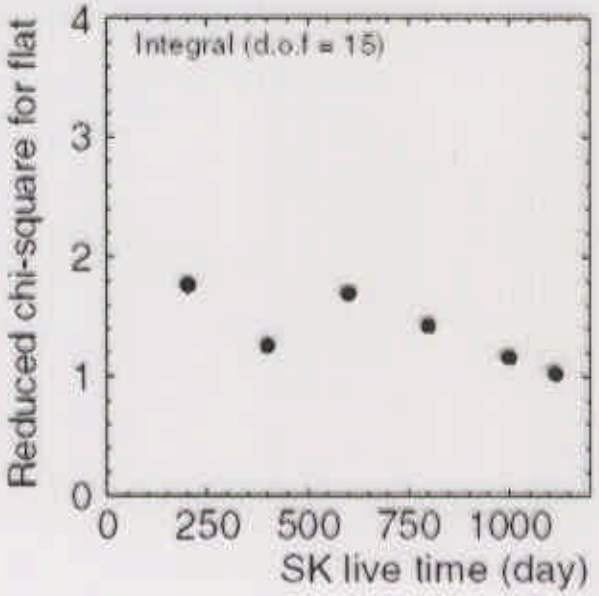
Differential



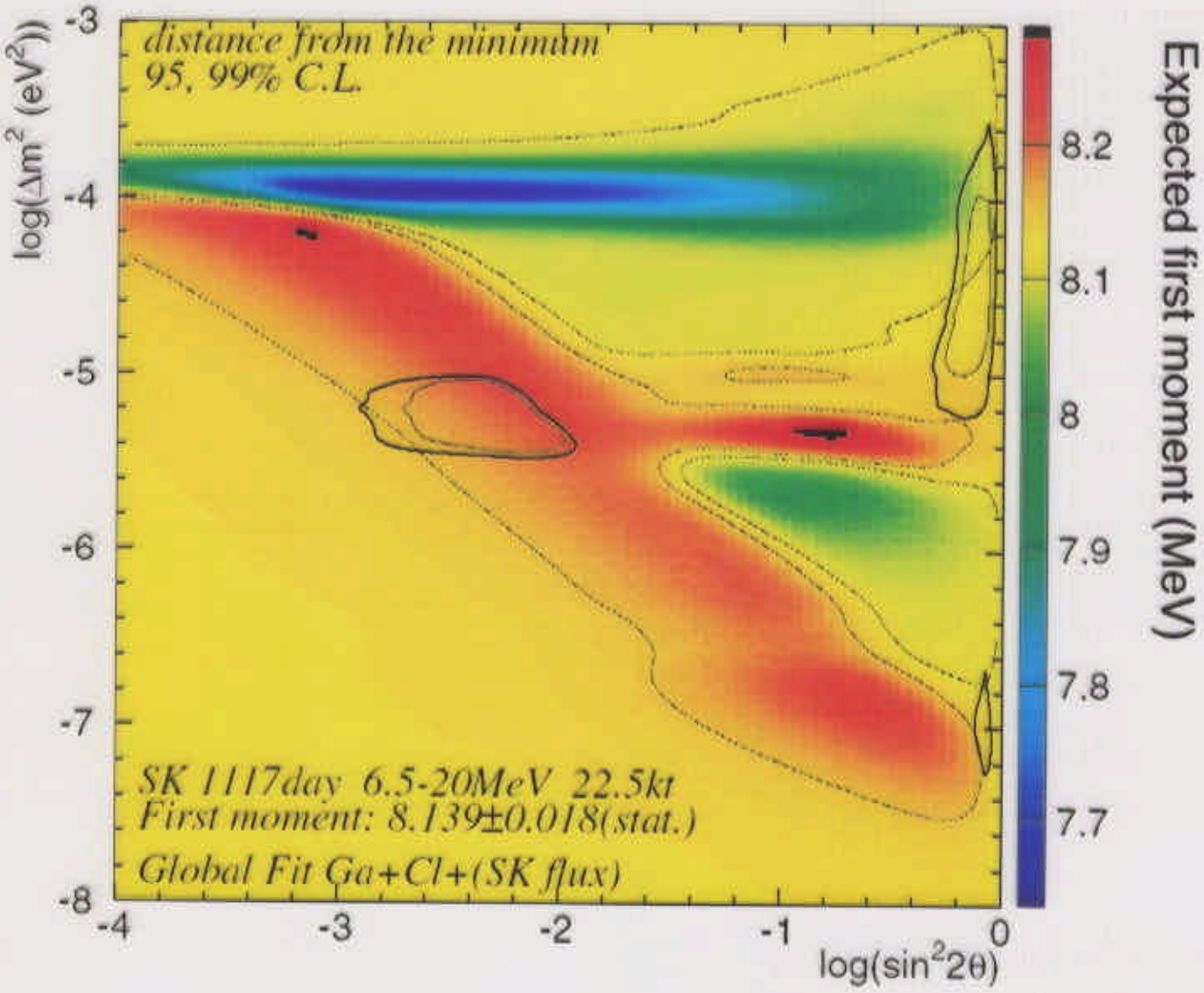


Integral





First moment map (MSW region)



..... Observed first moment ±1σ (stat.)

——— Global fit (99%C.L.)

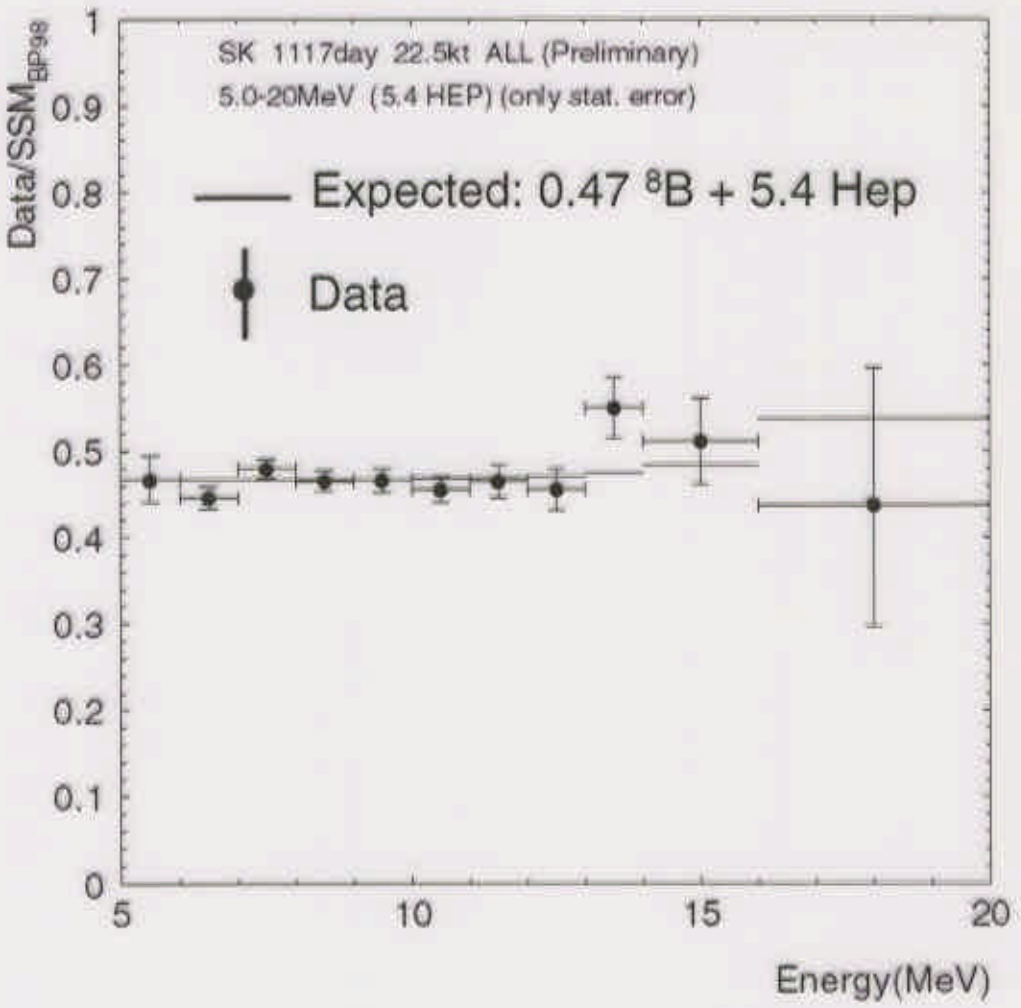
——— Global fit (95%C.L.)

(preparing a letter paper)

Hep flux

Method 1: fit ^{8}B and Hep flux simultaneously

Hep flux = 5.4±4.6 x SSM(BP98)



But, this results highly depend on possible distortion of the ^{8}B spectrum in the lower energy region

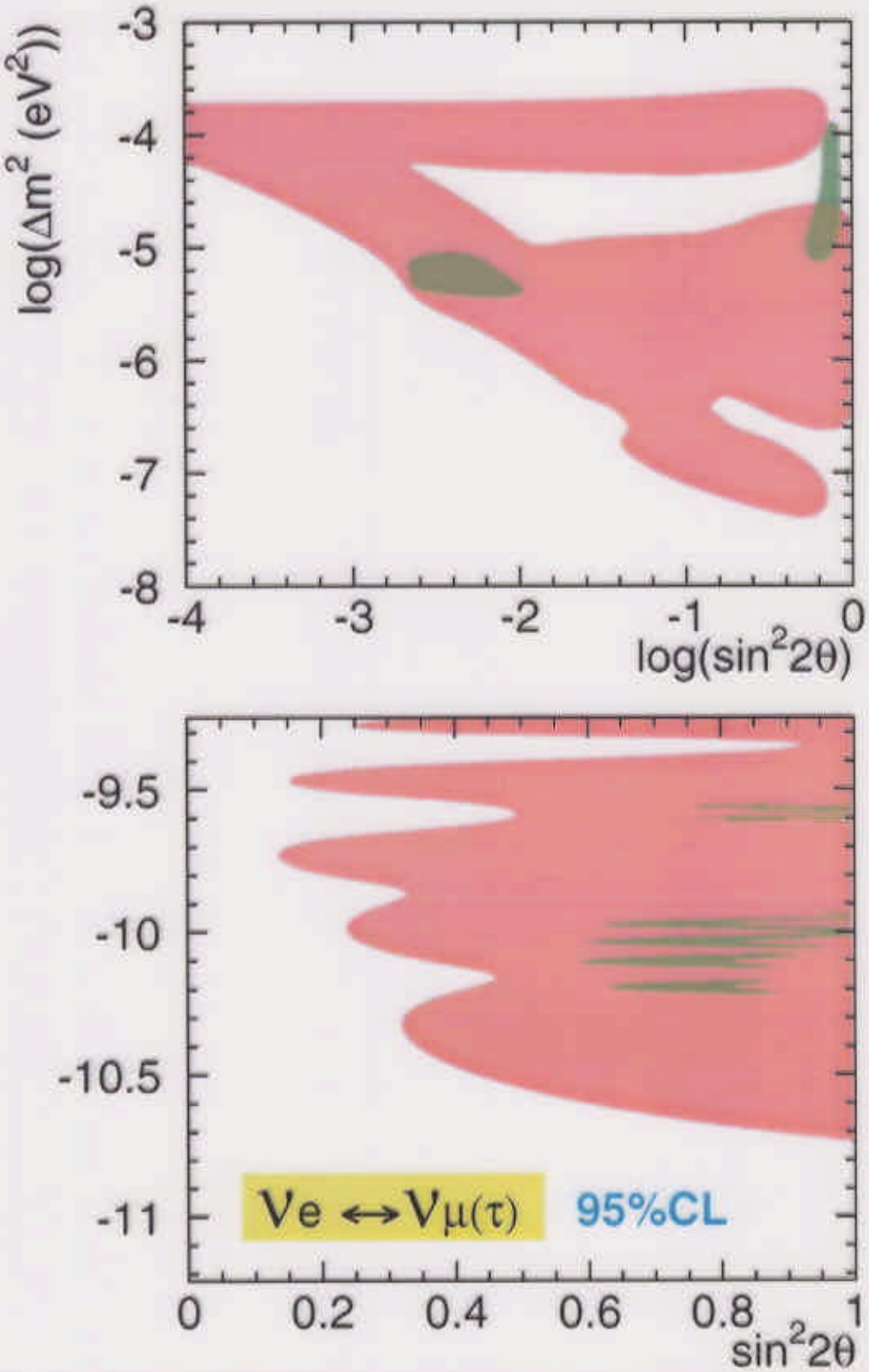
Method 2: assume all signals coming from Hep in higher energy region (18-25MeV)

Hep flux < 13 x SSM(BP98) 90%C.L.
(quote this number)

0 event observed (expected=0.2events)

Oscillation analysis (SK vs. global, active)

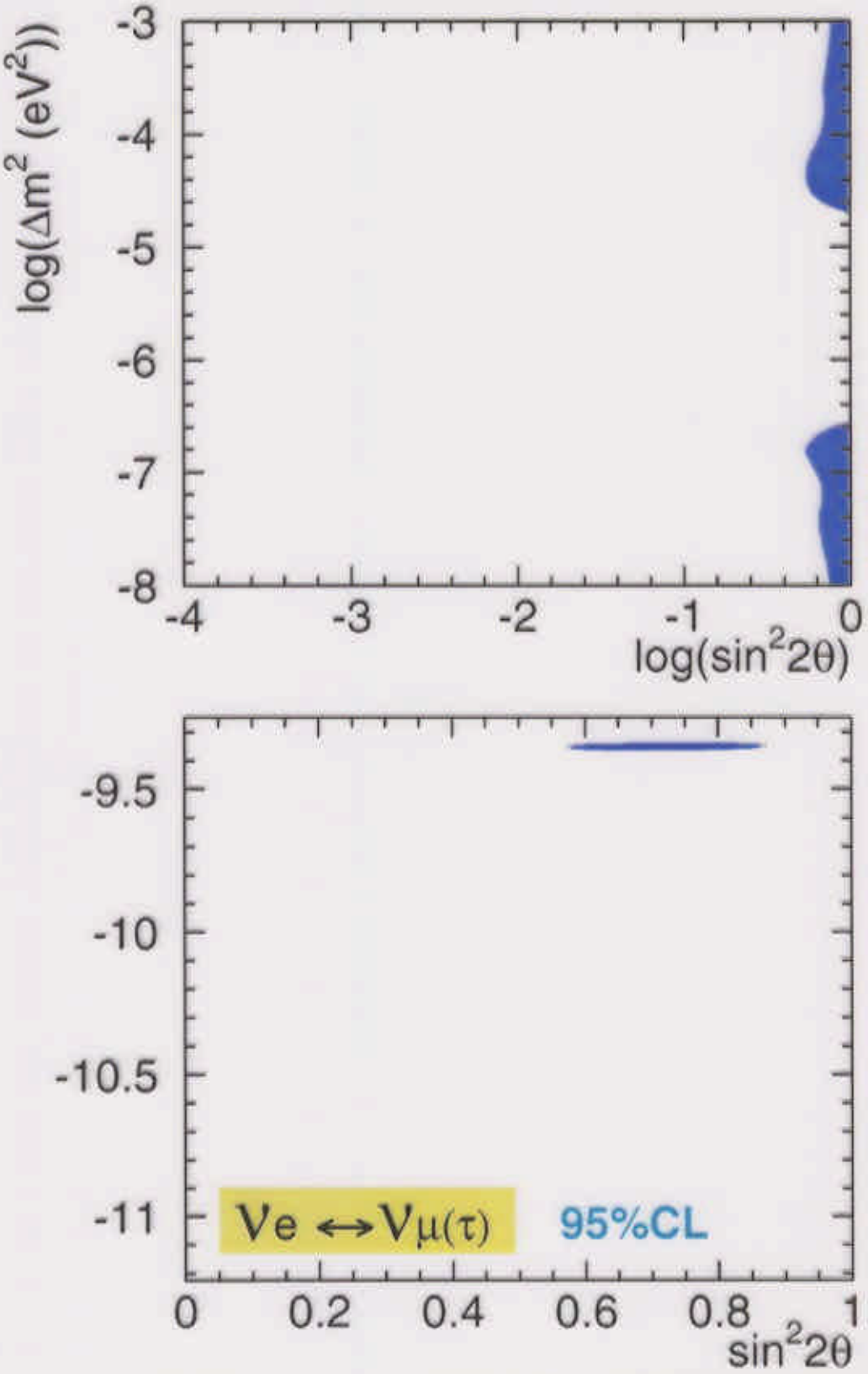
Excluded by SK day spectrum & night spectrum at 95%C.L.
Allowed by global fit (Cl + Ga + SK flux) at 95%C.L.



SMA & VAC solutions are disfavored at 95% C.L. by comparing global fit and SK d/n spectrum

Oscillation analysis (flux constraint, active)

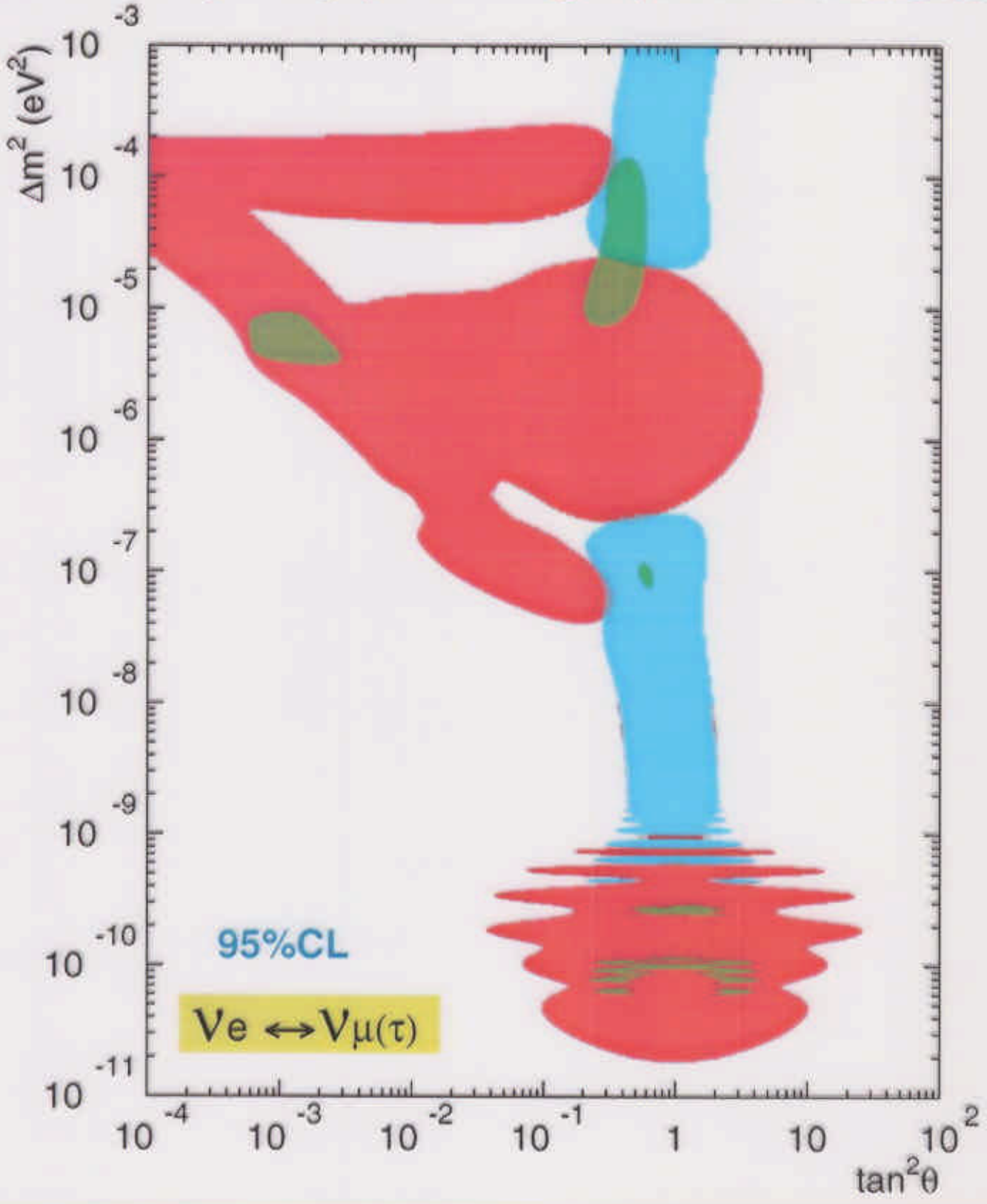
Allowed by SK day spectrum & night spectrum & flux at 95%C.L.



Large mixing is favored by SK d/n spectrum with flux constraint (SK data only)

Oscillation analysis (dark side, active)

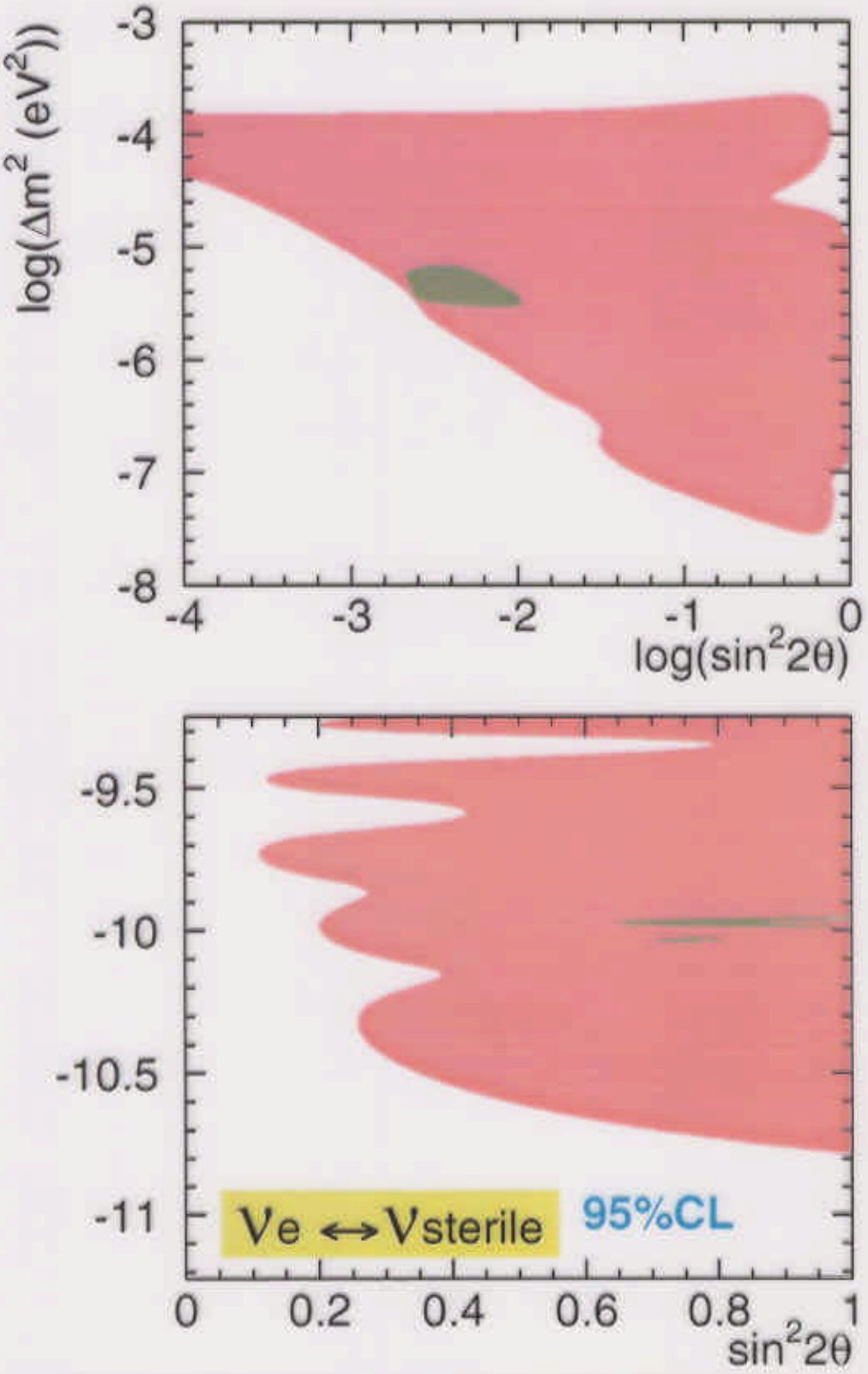
Excluded by SK day spectrum & night spectrum at 95%C.L.
Allowed by global fit (Cl + Ga + SK flux) at 95%C.L.
Allowed by SK day spectrum & night spectrum & flux at 95%C.L.



SMA & VAC solutions are disfavored at 95% C.L. by comparing global fit and SK d/n spectrum

Oscillation analysis (SK vs. global, sterile)

Excluded by SK day spectrum & night spectrum at 95%C.L.
Allowed by global fit (Cl + Ga + SK flux) at 95%C.L.



2-flavor sterile solutions are disfavored at 95% C.L. by comparing global fit and SK d/n spectrum

Summary

PRELIMINARY

- 1117day results (1996/05/31-2000/04/24)

  ^{8}B Flux (5.5-20MeV)

$$\text{Flux} = 2.40 \pm 0.03\ (\text{stat.})\ ^{+0.08}_{-0.07}\ (\text{syst.}) \quad (\times 10^6/\text{cm}^2/\text{s})$$

$$\frac{\text{Data}}{\text{SSM}_{\text{BP98}}} = 0.465 \pm 0.005\ (\text{stat.})\ ^{+0.015}_{-0.013}\ (\text{syst.})$$

  Day / Night (5.5-20MeV)

$$\frac{\text{D-N}}{\text{(D+N)/2}} = -0.034 \pm 0.022(\text{stat.})\ ^{+0.013}_{-0.012}\ (\text{syst.})$$

  - Sigma to 0 = 1.3 (including systematic error)

  Spectrum

  - χ^2 for flat = 13.7 (17d.o.f.) C.L.=69%
    (5.5-20MeV, consider systematic error)

- 5.0-5.5MeV ^{8}B flux is obtained

- Hep flux limit
  - <13 SSM (90%C.L.)

- Oscillation analysis

•SMA & VAC solutions are disfavored at 95% C.L. by comparing global fit and SK day & night spectrum

•2-flavor sterile solutions are disfavored at 95% C.L. by comparing global fit and SK day & night spectrum

•Large mixing is favored by SK d/n spectrum with flux constraint (SK data only)