Borexino and status of the project

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on behalf of the Borexino collaboration

Outline

- ❑Borexino: Italian-Russian cooperation
- ❑Borexino: The Physics Case
- ❑Borexino: Status and Schedule

Borexino Collaboration

- **Italy** (INFN & Universiy of Milano and Genova, Perugia Univ., LNGS)
- **USA** (Princeton Univ., Virginia Tech.)
- **Russia** (RRC KI, JINR, INP MSU, INP St. Petersburg)
- **Germany** (Hiedelberg MPI, Munich Technical University)
- **France** (College de France)
- **Hungary** (Research Institute for Particle & Nuclear Physics)
- **Poland** (Institute of Physics, Jaegollian University, Cracow)

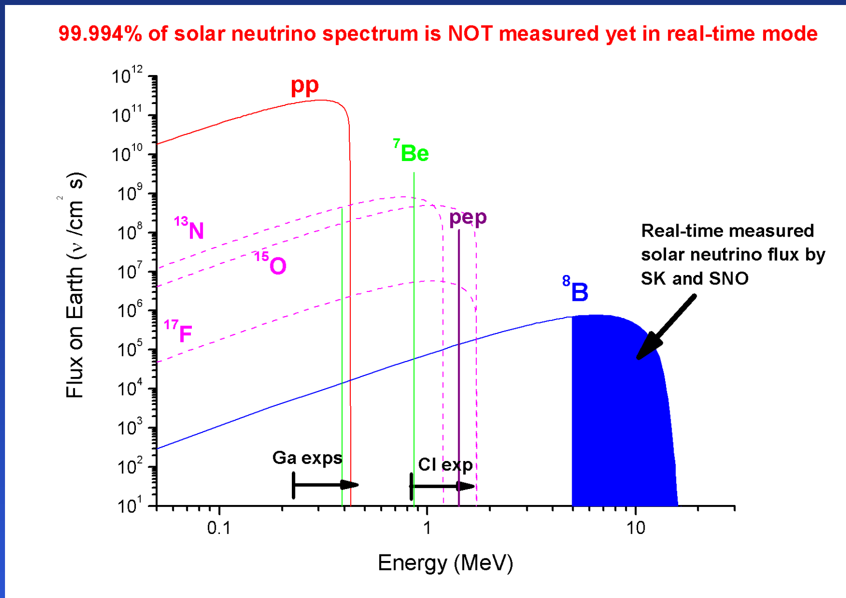
Italian-Russian Cooperation on Borexino

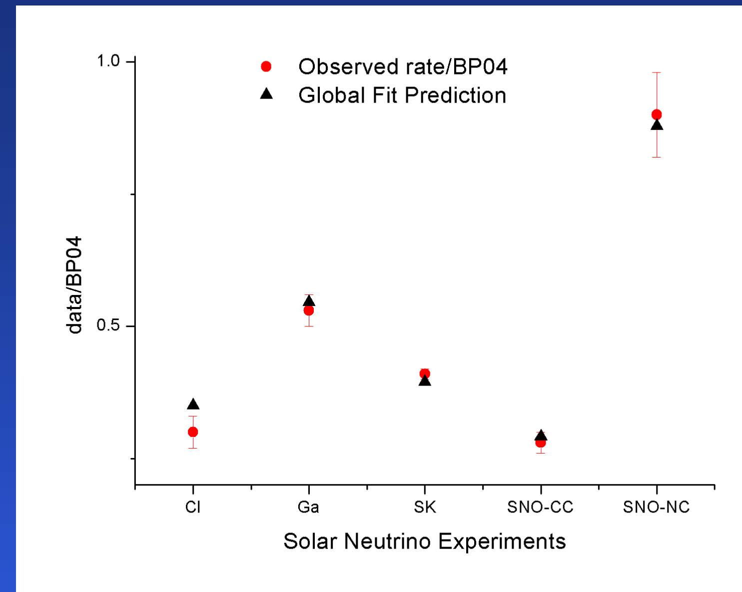
- **From Russia: ~ 20 collaborators**
  - ✓ 60% from RRC KI (M. Skorokhvatov is responsible on the Russian side)
  - ✓ JINR (O. Zaimidoroga)
  - ✓ INP of Moscow State University (A. Chepurnov)
  - ✓ INP of St. Petersburg (A. Derbin)
- **Research Activities carried out by Russian colleagues**:
  - ✓simulations (RRC KI + Dubna + INP St. Petersburg)
  - ✓on-line software development (A. Sabelnikov, RRC KI)
  - ✓development of electronics (INP of MSU + RRC KI)
  - ✓PMT tests and parameters data-base (O. Smirnov, Dubna)
  - ✓Analysis (at present of CTF data – RRC KI + Dubna + St. Petersburg)
  - ✓Contribution on installations, commissioning and filling of detector (shifts – all groups)

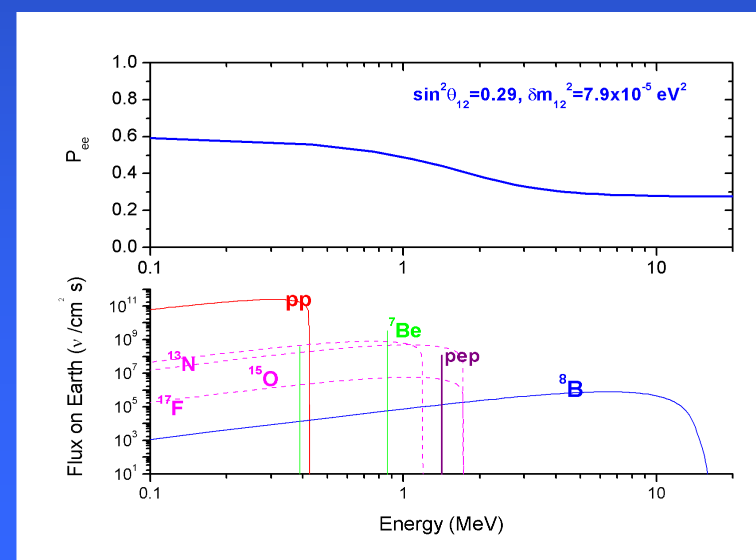
The Physics Case

- Solar Neurinos
- Geo-Neutrinos
- Supernova Neutrinos
- Non standard neutrino interactions, neutrino from reactors

Solar Neutrinos





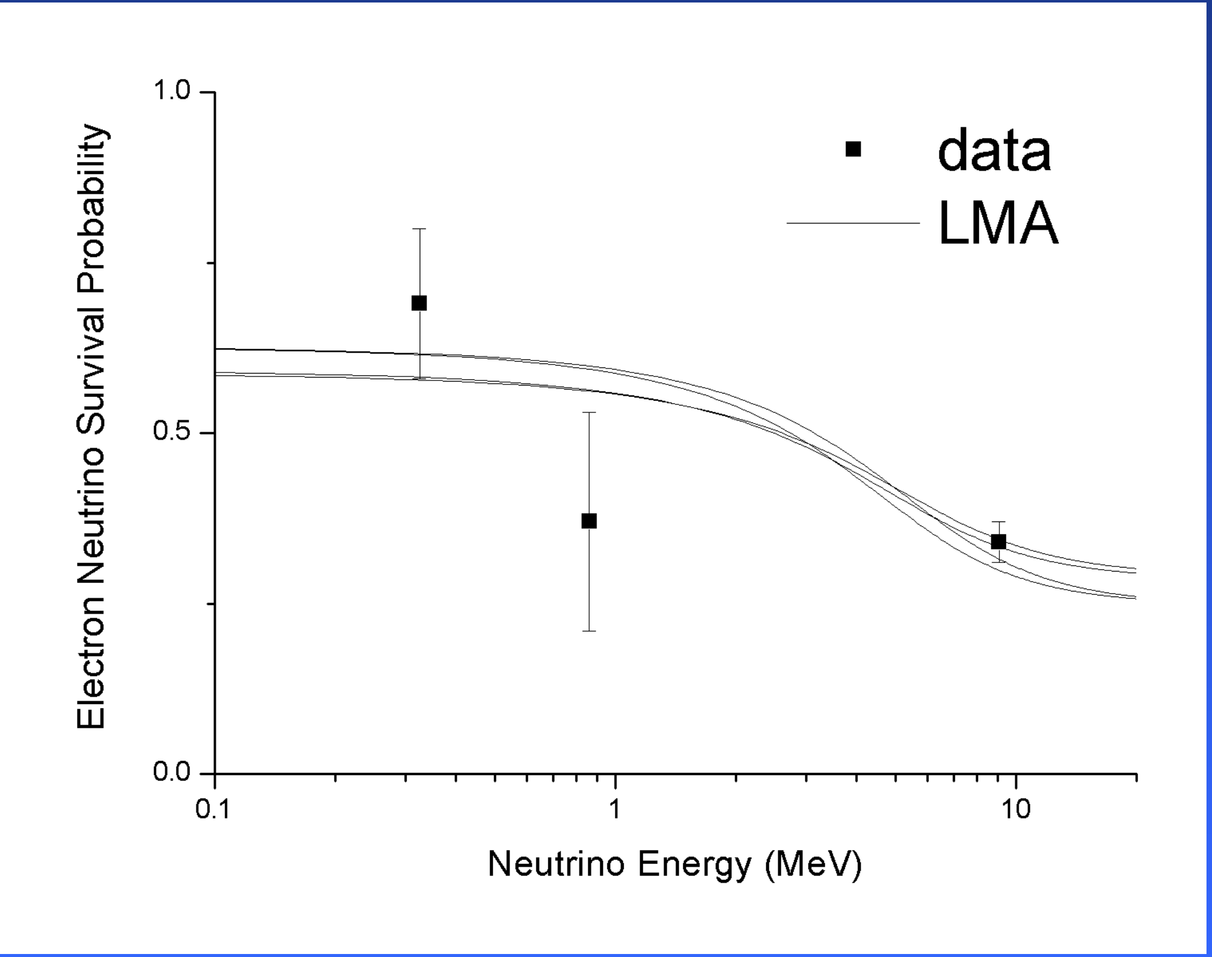


- **phenomenology best explained by the matter transition MSW-LMA**

Solar Neutrinos in Borexino

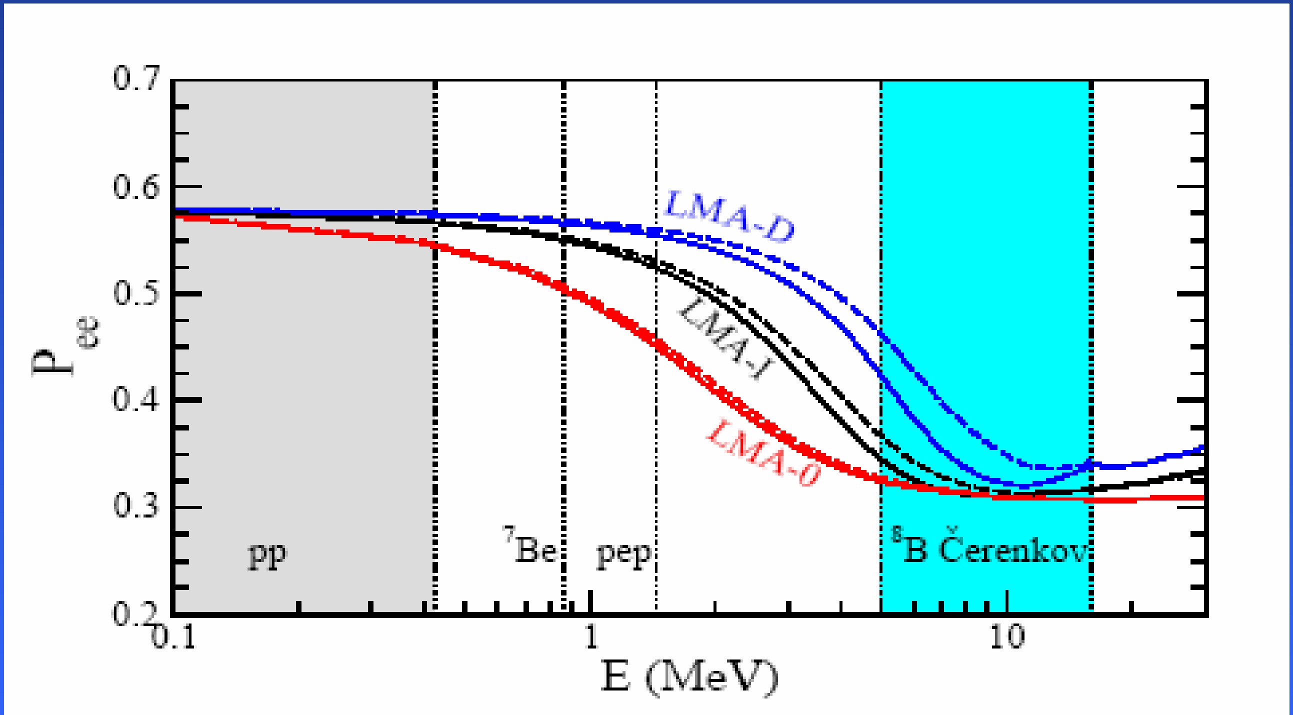
- ^{7}Be solar neutrinos spectroscopy by resolving the Compton-like edge (neutrino-electron elastic scattering)
- $1/R^2$ effect gives 3σ integral evidence of neutrinos in 2yr of data taking (^{7}Be + CNO)
- pep neutrinos by three-fold coincidence tagging

How robust is the LMA?



Test LMA Survival Probability with Low Energy Solar Neutrinos (just one of many examples)

$$\nu_l + q \rightarrow \nu_f + q$$



Miranda, Tortola, Valle, hep-ph/0406280

pep neutrinos in Borexino @ Gran Sasso

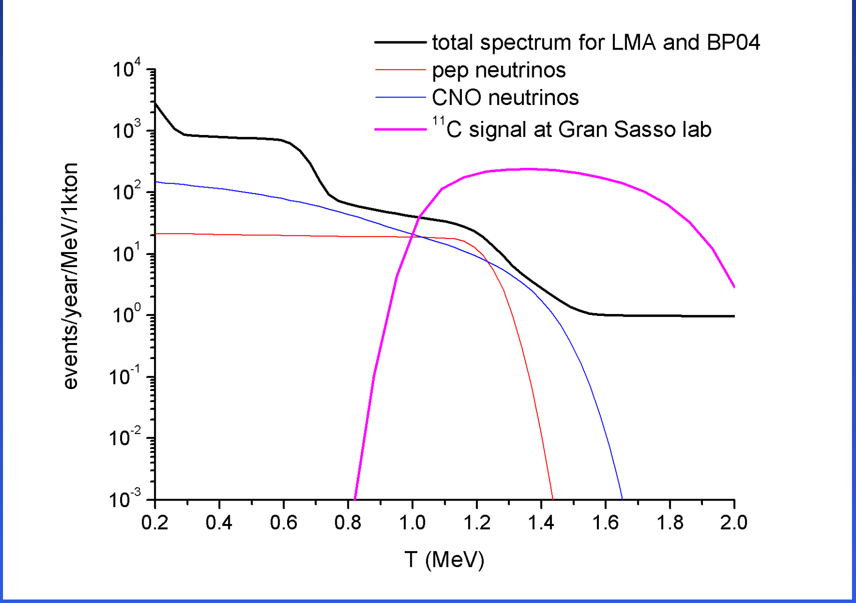
Detection window=[0.8,1.3] MeV

Signal/noise = 0.4[for KamLAND=0.06] due to ^{11}C background

^{11}C produced mainly from $^{12}C(\gamma,n)^{11}C$
Only 5% of ^{11}C produced are not associated with a neutrons:

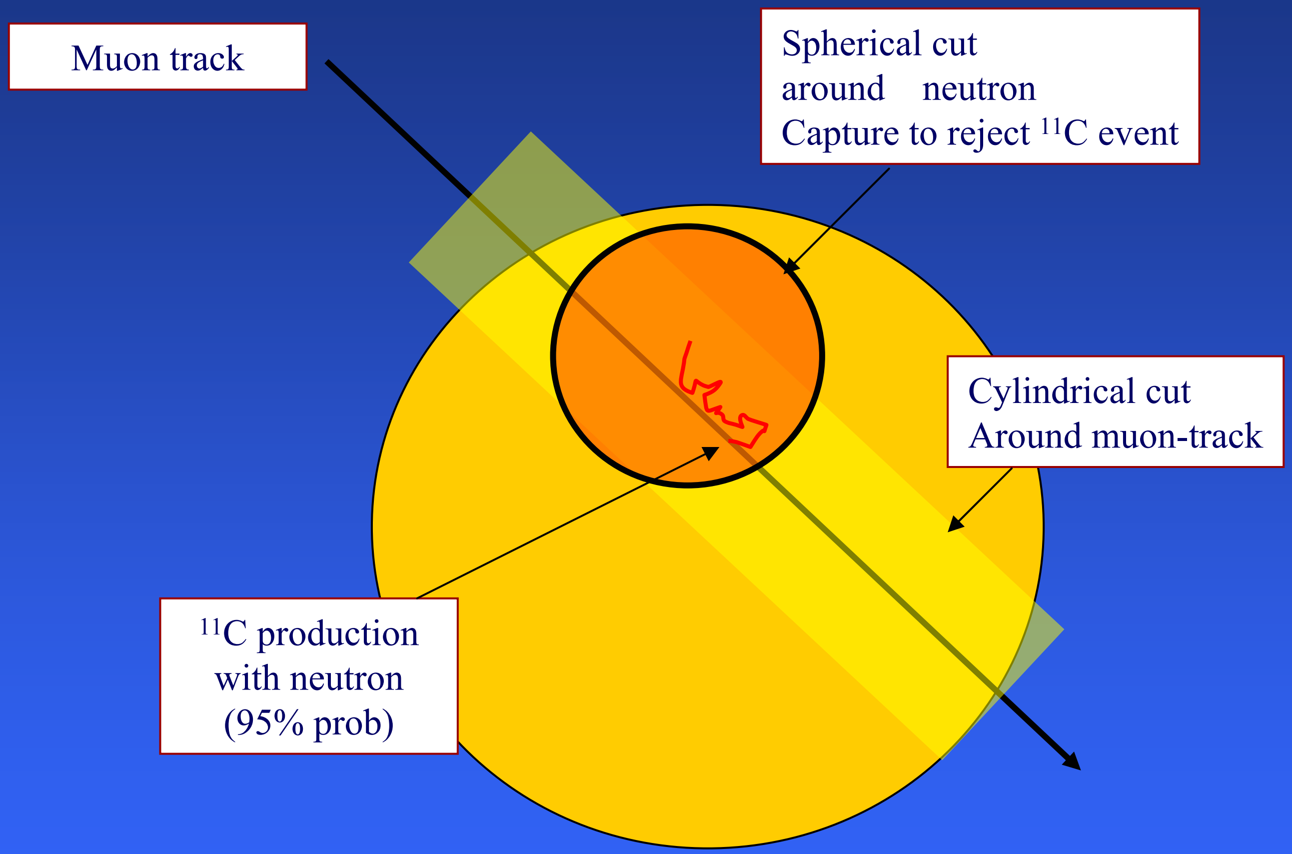
Possibility to apply a rejection cut using three-fold coincidence (muon+neutron tagging) as in CTF

Signal/noise can be as high as 2(4) with rejection of 3%(50%) of data volume



Galbiati,Franco,Pocar,Ianni,Cadonati,Schoenert, hep-ph/0411002, now on PRC

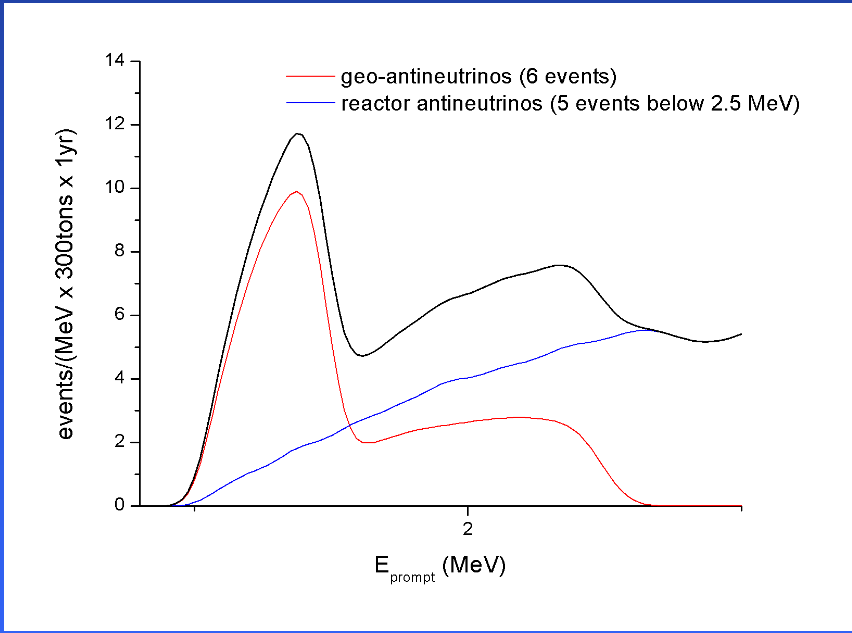
Muon+neutron tagging



^{11}C is removed blinding the intersection of the two volumes for 5-10 ^{11}C-lifetime

Geo-Neutrinos in Borexino

- Geo-neutrinos: neutrinos/antineutrinos produced by natural radioactivity (from U,Th and K) within the earth
- Geo-neutrinos from U and Th can be detected via the inverse-beta decay (background free!)
- Models suggest that radioactivity contribution to total heat from the earth (~40 TW) is 40-100%
- Geo-neutrino measurement will help understanding earth's thermal history
- Borexino a great opportunity!



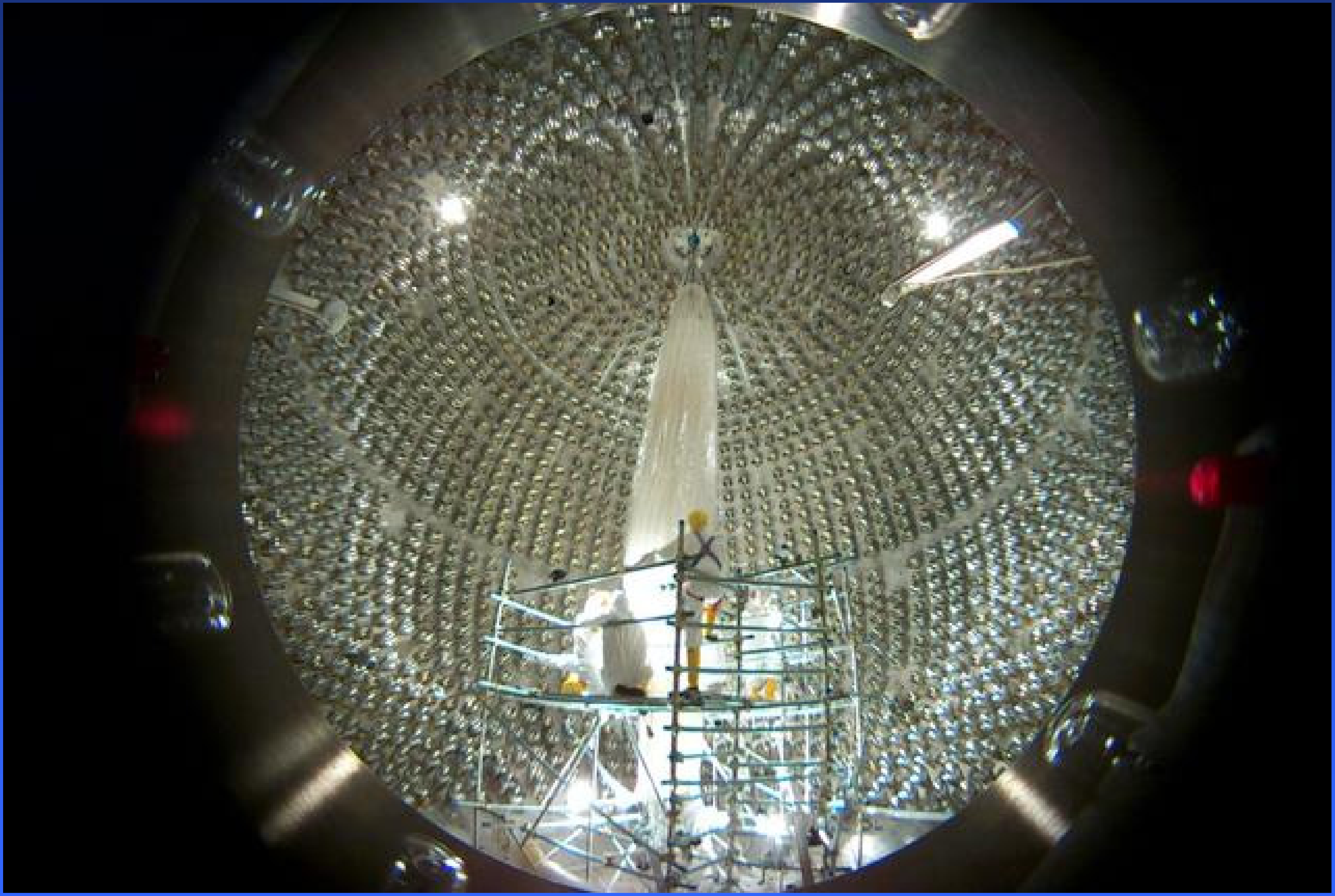
SN Neutrinos in Borexino

- **Neutrinos from Supernovae**
  - **We use 300tons target mass and a SN at 10kpc, 2.5×10^{53}ergs**
  - **~17 ev from $\nu(\nu)^{12}C$ NC: $\nu + {}^{12}C \to \nu + {}^{12}C^*$(15.1 MeV γ)**
  - **~81 from inverse-β decay**
  - **Inverse-beta decay gives information on spectrum at low energy ($\geq$2 MeV)**

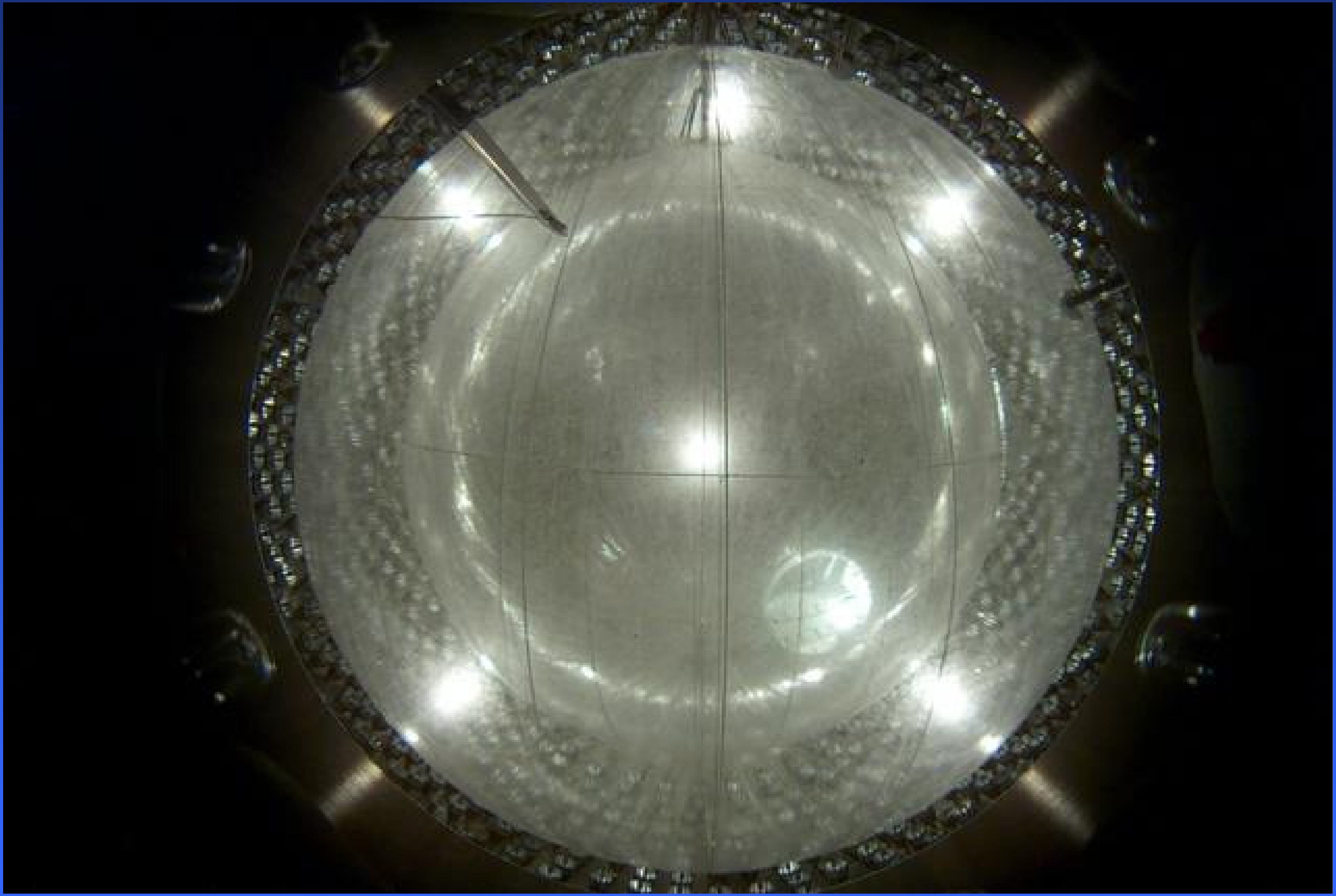
Status of the project

- Following August 2002 accident, Borexino activity has suffered from severe restrictions especially for what concerns fluid handling operations;
- In spite of this, the detector installation has continued and was completed in july 2004;
- INFN and NSF approved fundings for 2005-2006;
- In march 2005: authorization to handle water and scintillator;

Nylon vessels installation



Nylon vessels installed and inflated (May 2004)



Final closure of the SSS (june 2004)

Operations group & contribution from collaborators

- **At present: Strong group based at Gran Sasso to push ahead the commissioning**
  - 3 external technicians with experience on petrochemical plants
  - 3 collaborators from Princeton
  - 2 collaborators from Russia (1 full time based)
  - 6 collaborators from INFN

Expected STRONG support from the WHOLE collaborators in 2006 for detector filling (shifts)

Status of the project (cont.)

- re-commissioning of all ancillary plants in progress
  - **Cleaning of systems**
  - **Tuning for distillation of PC and of Master Solution (PC+PPO@200g/l)**
  - **Preparing CTF for distillation test (^{210}Pb – ^{210}Po contamination issue)**

- Software for data analysis
  - **Monte Carlo chain, on-line code, tests, physics codes**
  - **Tests of software chain by so-called “air runs”**

Satus of the project (cont.)

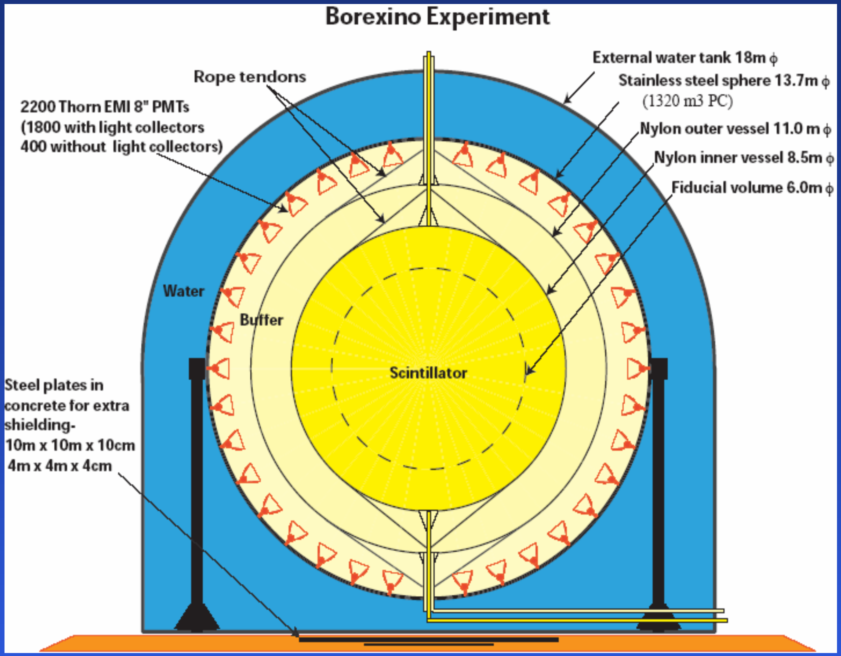
- After CTF distillation test (beginning of 2006)
  - Filling of the detector, expected before spring 2006
  - Data taking, expected beginnig of 2007

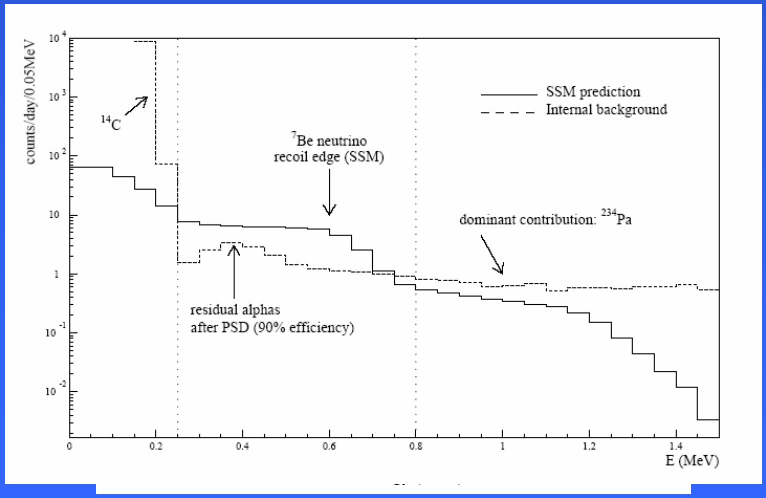
Conclusions

- Detecting low-energy solar neutrinos in real-time is crucial
- Years of R&D studies by the Borexino collaboration has addressed all the relevant radio purity issues which are needed to lower the detection threshold down to ~200 keV for a ton-scale detector;
- Borexino detector is built, tested with several ”air-runs” and ready to be filled;
- Strategy of filling from CTF distillation test (soon)
- 2006 crucial year for Borexino: strong effort by the collaboration expected
- Data-taking is expected beginning of 2007;

Borexino: the detector

- 300tons high purity liquid scintillator: PC (C_9H_{12}, ρ=0.88 g/cm^3)
- 100tons target mass for ^{7}Be solar neutrinos
- Detector design: self-shielding technique. In target mass external background negligible; purification methods (distillation, water extraction, nitrogen stripping) to remove impurities in the scintillator
- Expected ~35 events in [0.25,0.8]MeV against ~20 background counts after off-line cuts



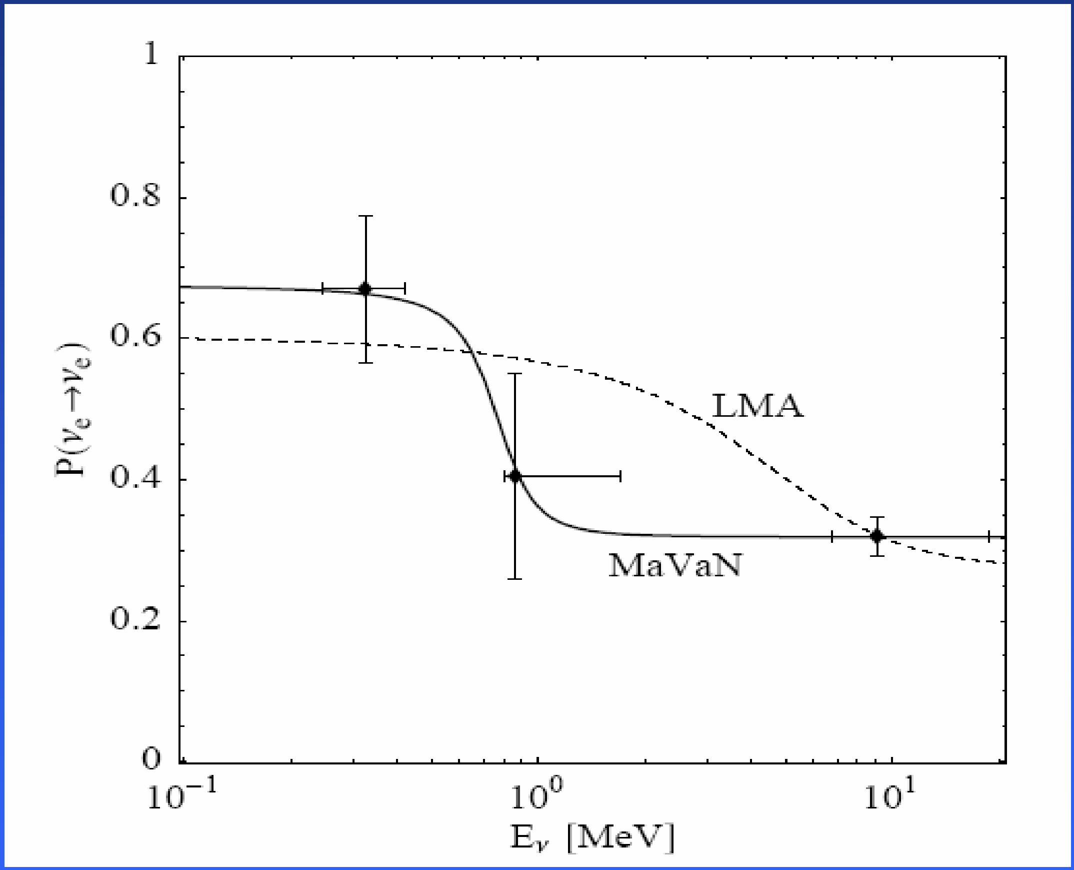


Future low energy solar neutrino experiments* : How?

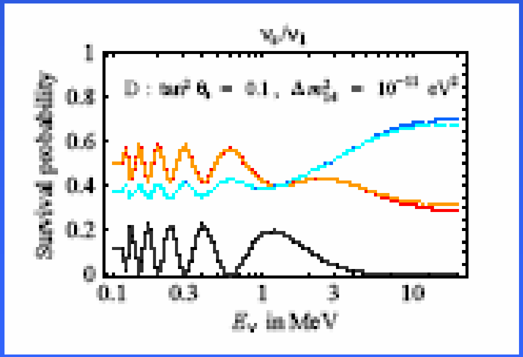
Experiment	Detection channel	target	Data taking	Expected signal counts/year for pp(Be)
Borexino	Elastic Scattering	100tons target mass Organic Liquid Scintillator**	2007	30cpd only Be
KamLAND	Elastic Scattering	~600 target mass Organic Liquid Scintillator	2007	~180cpd only Be
LENS	**CC channel** $^{115}In+\nu_e \rightarrow e^- + ^{115}Sn,\gamma$	**~20ton In-loaded scintillator cells**	**?**	**2190(511)**
MOON	**CC channel** $^{100}Mo+\nu_e \rightarrow e^- + ^{100}Tc(\beta)$	**3.3ton Mo foils + plastic scintillator**	**?**	**240(77)**
XMASS	**Elastic Scattering**	**10ton liquid Xe**	**?**	**2373(1241) with 50keV thres.**
CLEAN	**Elastic Scattering**	**10ton liquid Ne**	**?**	**2869(1518) with 50keV thres.**

*only mentioned those which have a stronger R&D in progress!
**see also next speaker!

Test LMA Survival Probability with Low Energy Solar Neutrinos



Barger,Huber,Marfatia,hep-ph/0502196



Cirelli,Marandella,Strumia,Vissani, hpe-ph/0403158

Low Energy Solar Neutrinos: how?

- Below 1 MeV radioactivity from ^{238}U, ^{232}Th, ^{40}K, ^{210}Pb, ^{222}Rn, ^{85}Kr, ^{39}Ar must be reduced to extremely low levels to be able to detect solar neutrinos
- As an example: ^{238}U and ^{232}Th <=1mBq/ton to get S/N>1
- Organic liquid scintillators offer high light yield (10^4 γ/MeV) and high intrinsic radiopurity but limited to ^{7}Be and pep due to ^{14}C [Borexino, KamLAND]
- Liquid noble gases (Xe, Ne) offer high light yield, high purity and no ^{14}C: pp spectroscopy [XMASS, CLEAN]
- Loaded (^{115}In, ^{100}Mo) liquid scintillators may offer good tagging [LENS, MOON]

Borexino Calibration Program

Borexino Parameters

Energy Scales

- Beta
- Alpha
- Gamma

Position Reconstruction

- Fiducial Volume
- Correlated Events
- Internal/External/Surface

α/β Separation

Stability

- Chemical
- Optical
- Mechanical
- Solar Signature

Kamland	
Fiducial Volume	4.1
ν_e spectra	2.5
Energy Threshold	2.3
Reactor Power	2.1
Cut efficiency	1.6
Fuel Consumption	1.0
cross section	0.2
Live Time	0.06
Karsten Heeger, DNP 2004	

SNO (ES)	
Energy Scale	-3.5,+5.4
Vertex Shift	3.3
Angular resolution	2.2
Cut efficiency	0.7
Vertex Resolution	0.4
Non-Linearity	0.4
Energy Resolution	0.3
cross section	0.5
Aksel Hallin, Blaubeuren 2001	

Calibration systems

- **Inter-PMT equalization for timing and vertex reconstruction**
  - by means of optic fibers at each PMT (requirement: < TTJ (~1ns))
- **Optical calibration of liquid scintillator**
  - by optic fibers
    - 226nm with decay time characteristic of charged particles excitation for position and energy
    - 355nm to optimize MC
- **Calibration with radioactive sources**
  - External from stainless steel sphere with Th
  - Internal from on-axis and off-axis insertion system with Rn-loaded scintillator or beta/gamma sources
- **Source position measurement with 7-CCD camera system installed on the stainless steel sphere (2cm accuracy)**

Rn loaded source used in the CTF