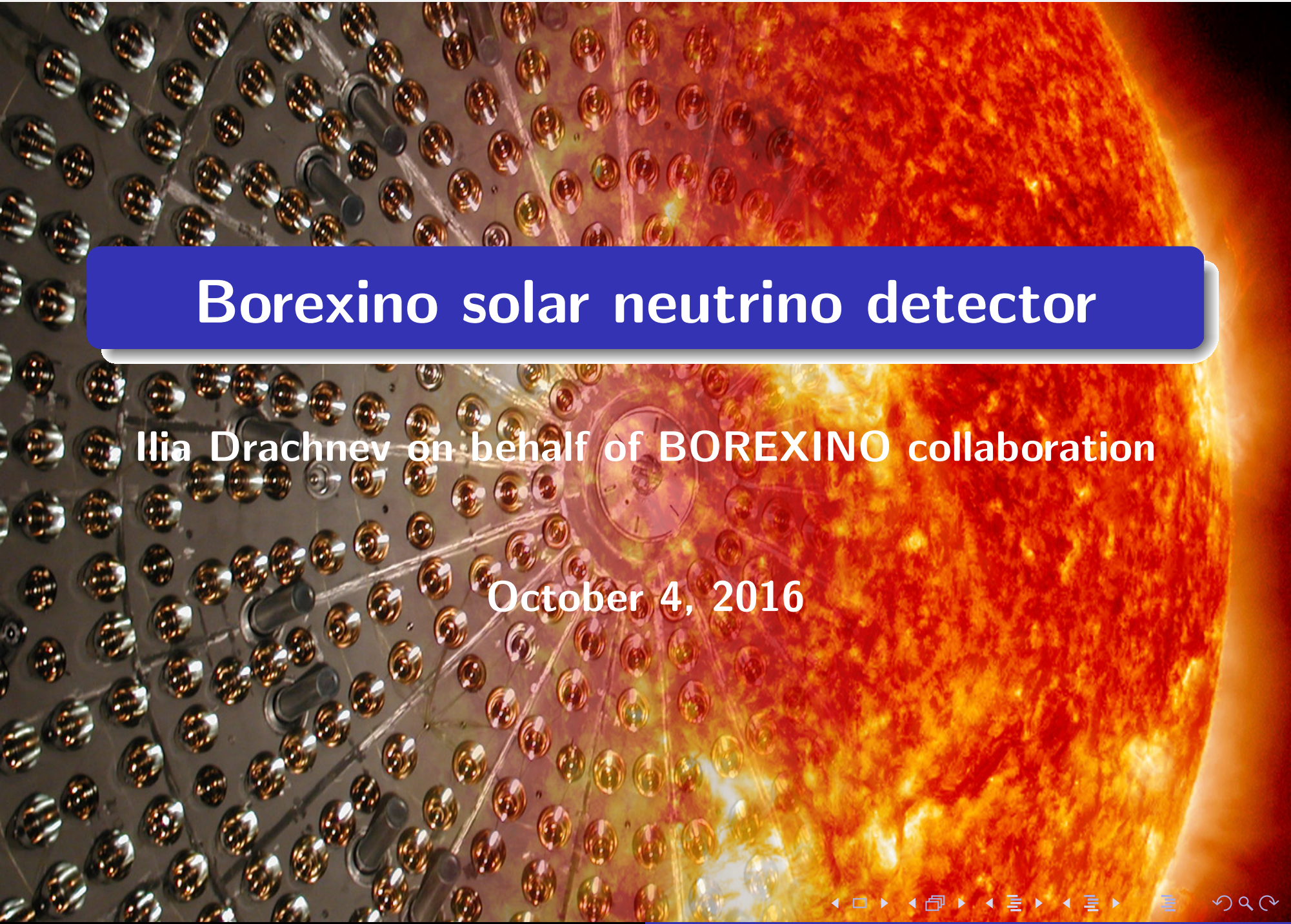
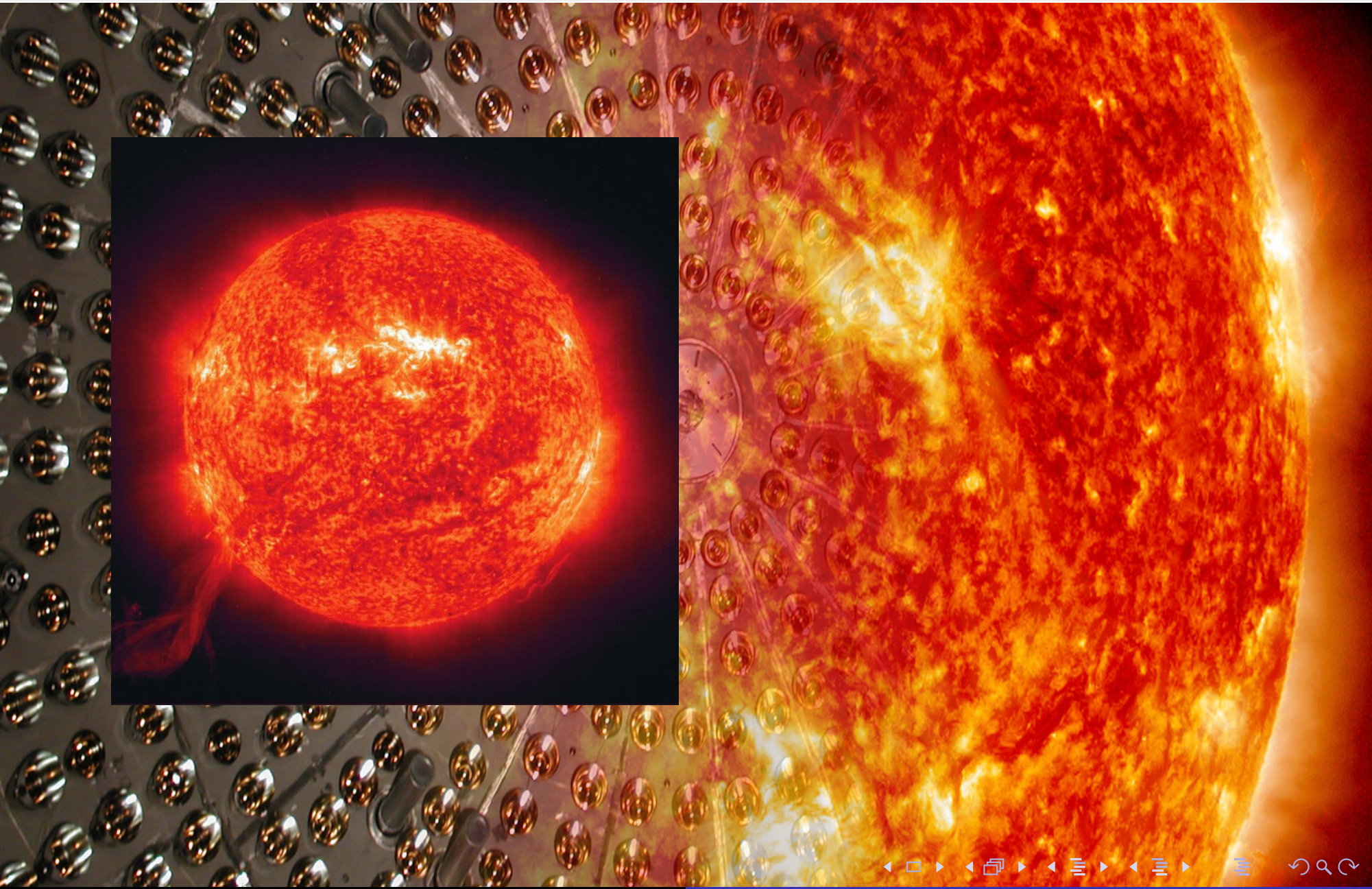


Borexino solar neutrino detector

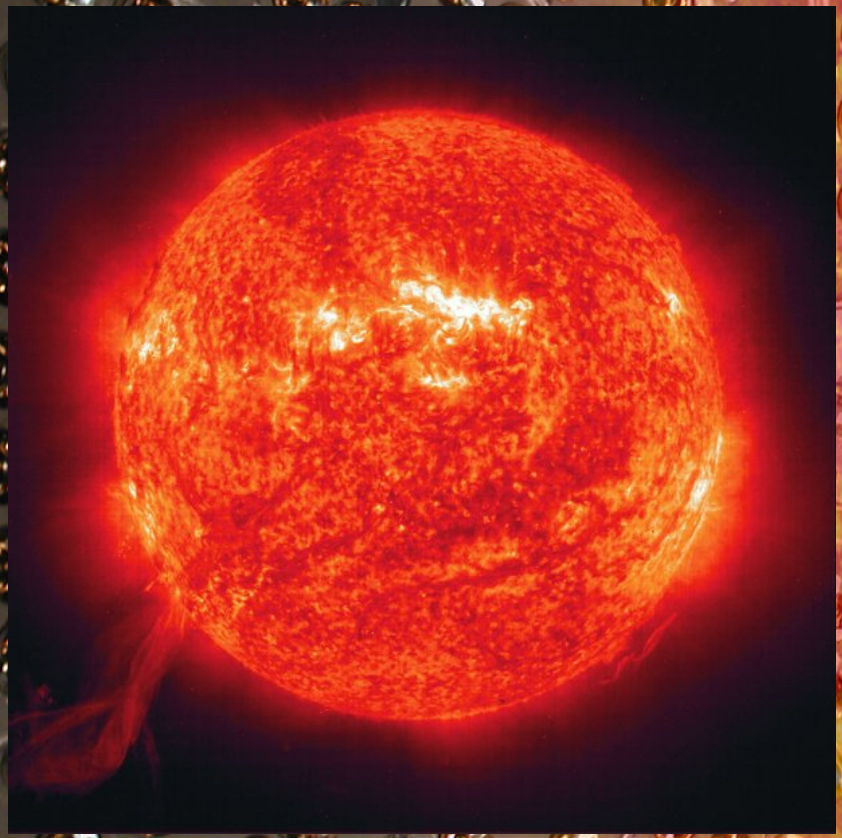
Ilia Drachnev on behalf of BOREXINO collaboration

October 4, 2016

What powers up the Sun?

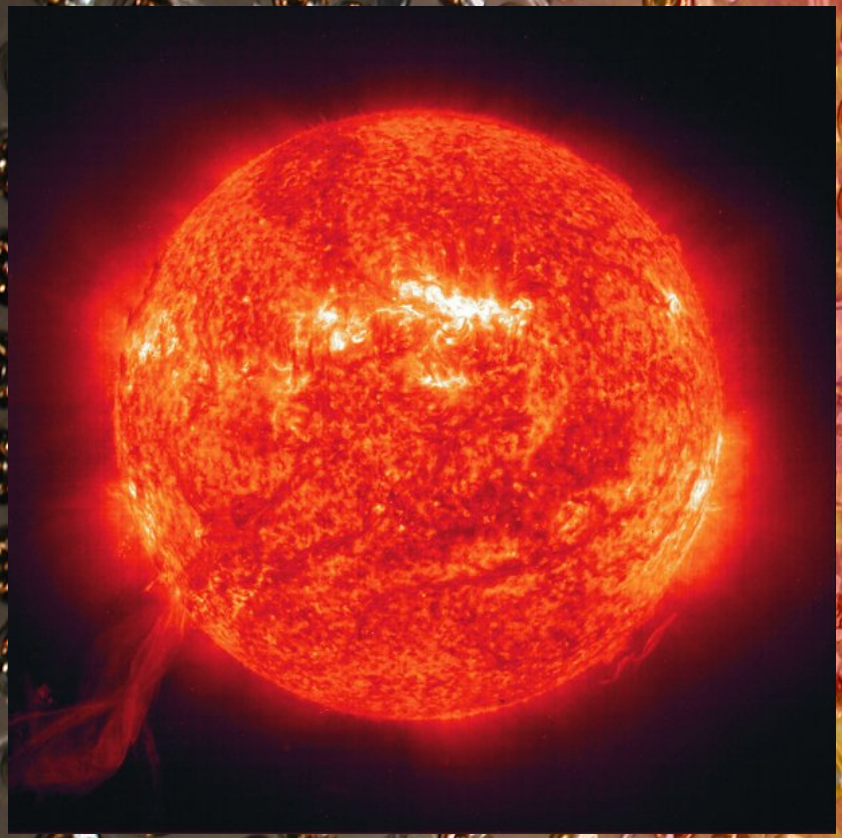


What powers up the Sun?



Could gravity produce the solar heat?

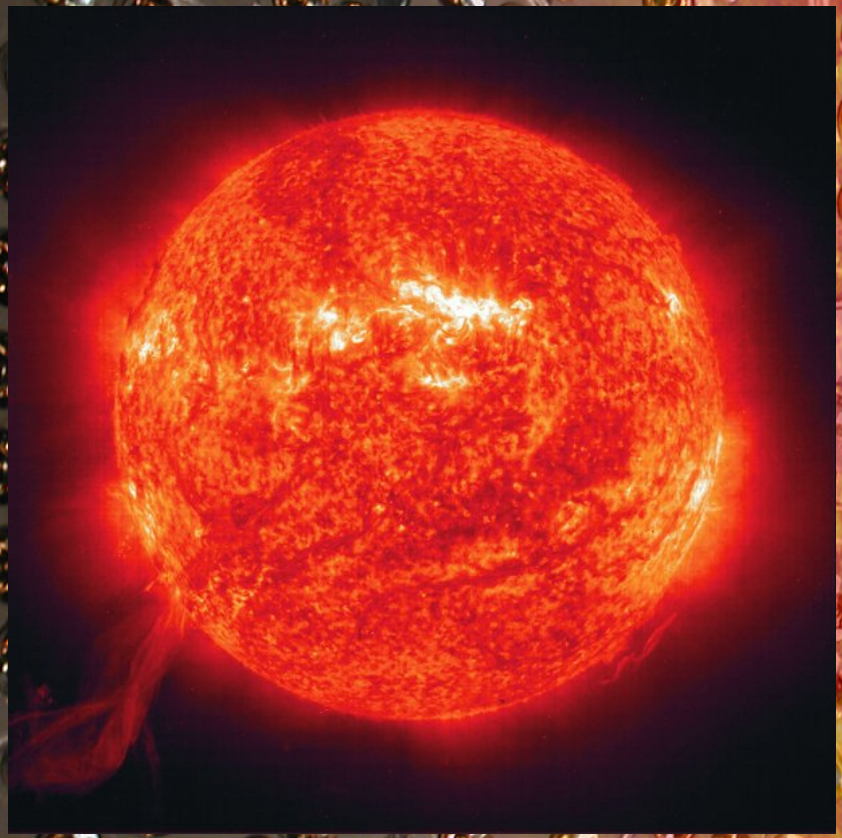
What powers up the Sun?



Could gravity produce the solar heat?

Yes, for several thousand years.

What powers up the Sun?

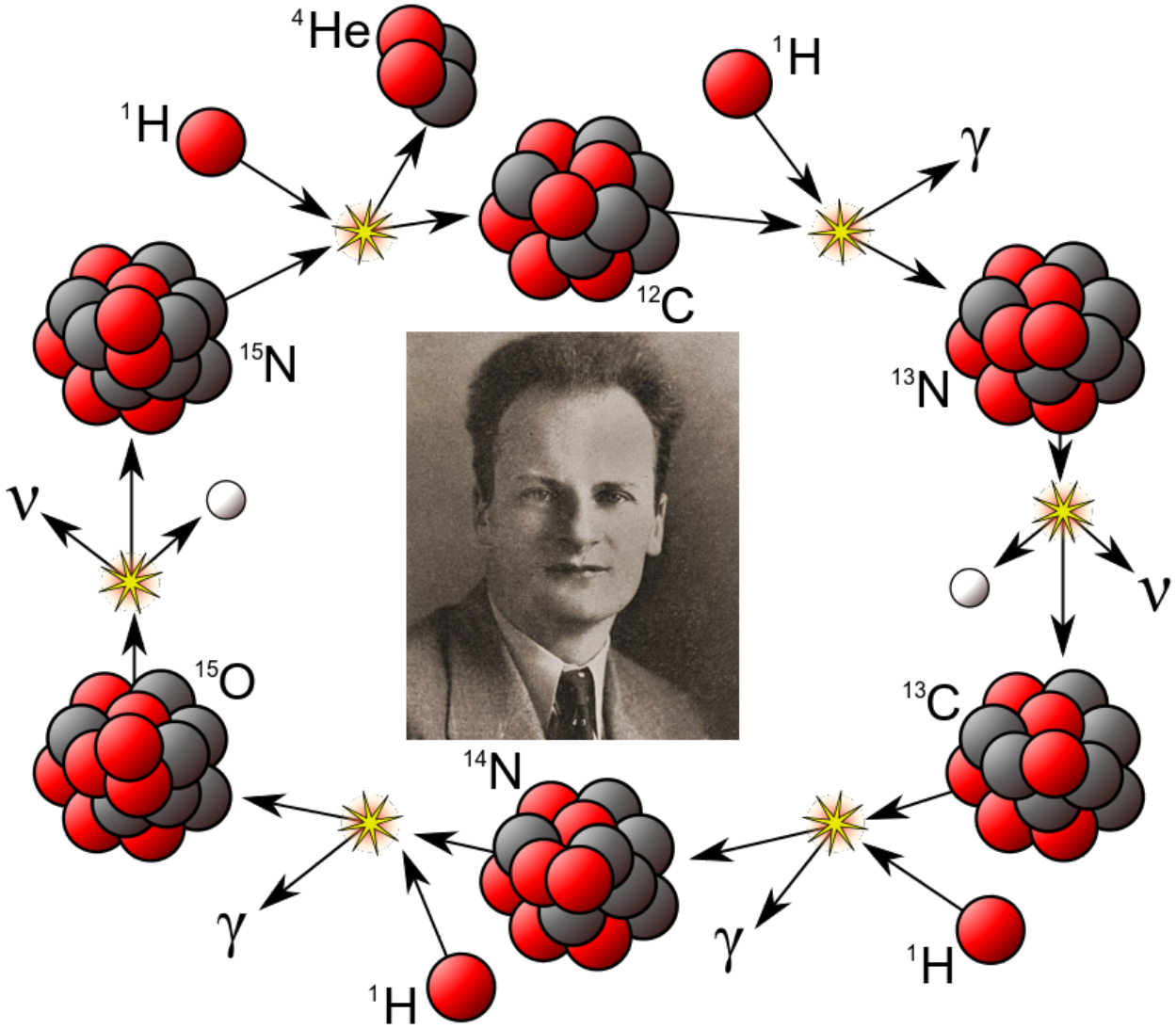


Could gravity produce the solar heat?

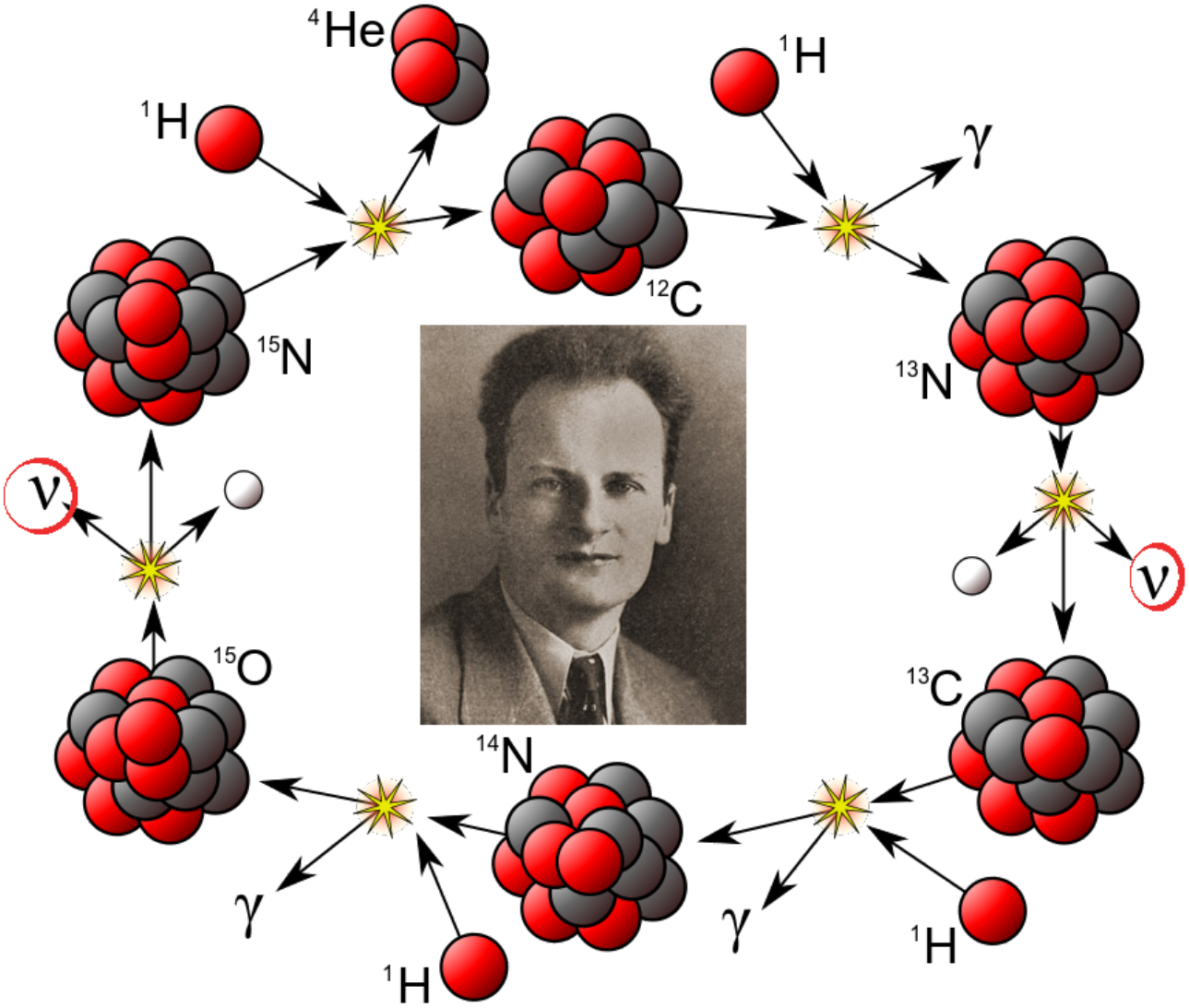
Yes, for several thousand years.

...but the Earth is too old for just gravity to produce it...

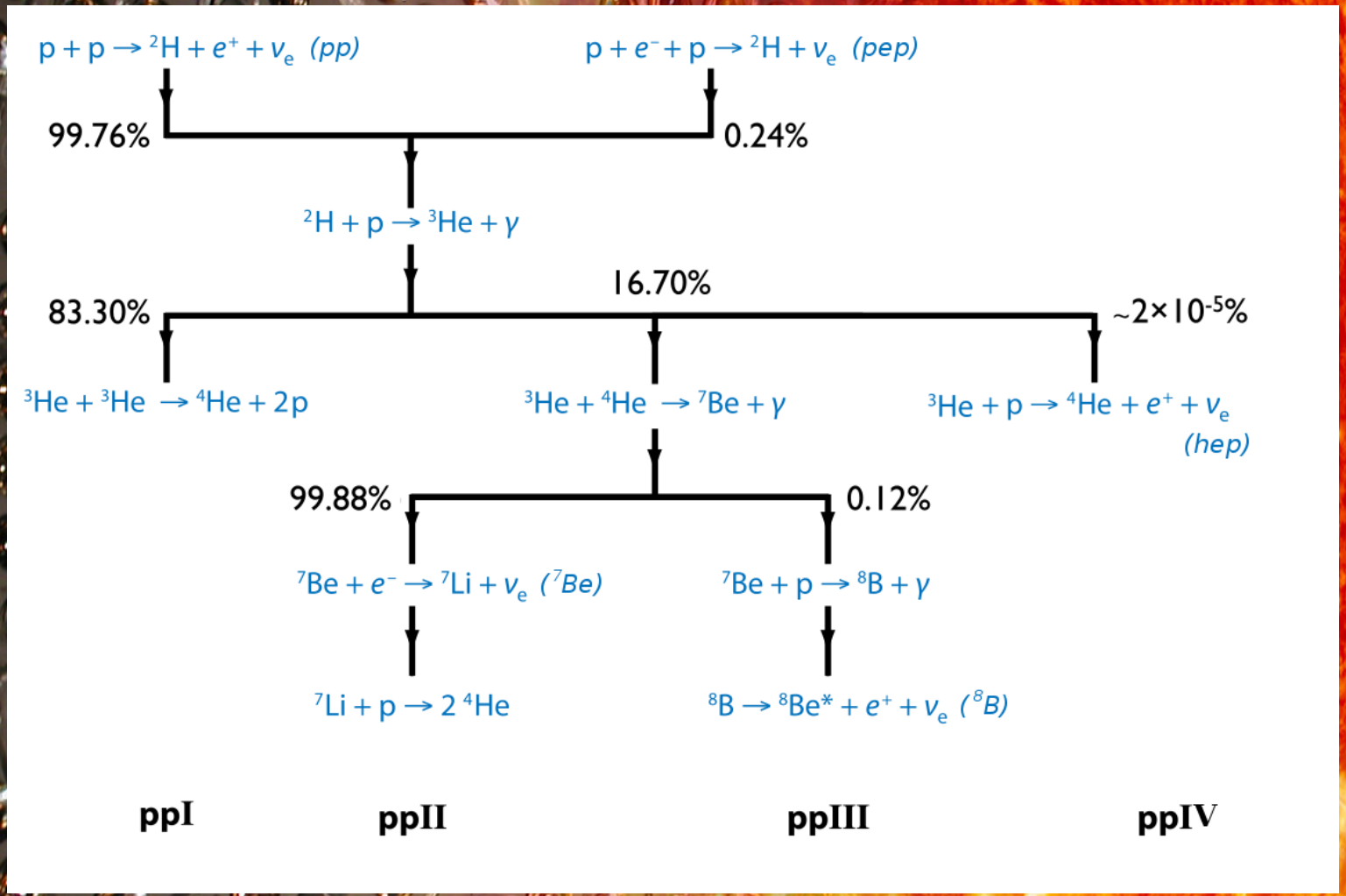
Fusion reactions: CNO cycle



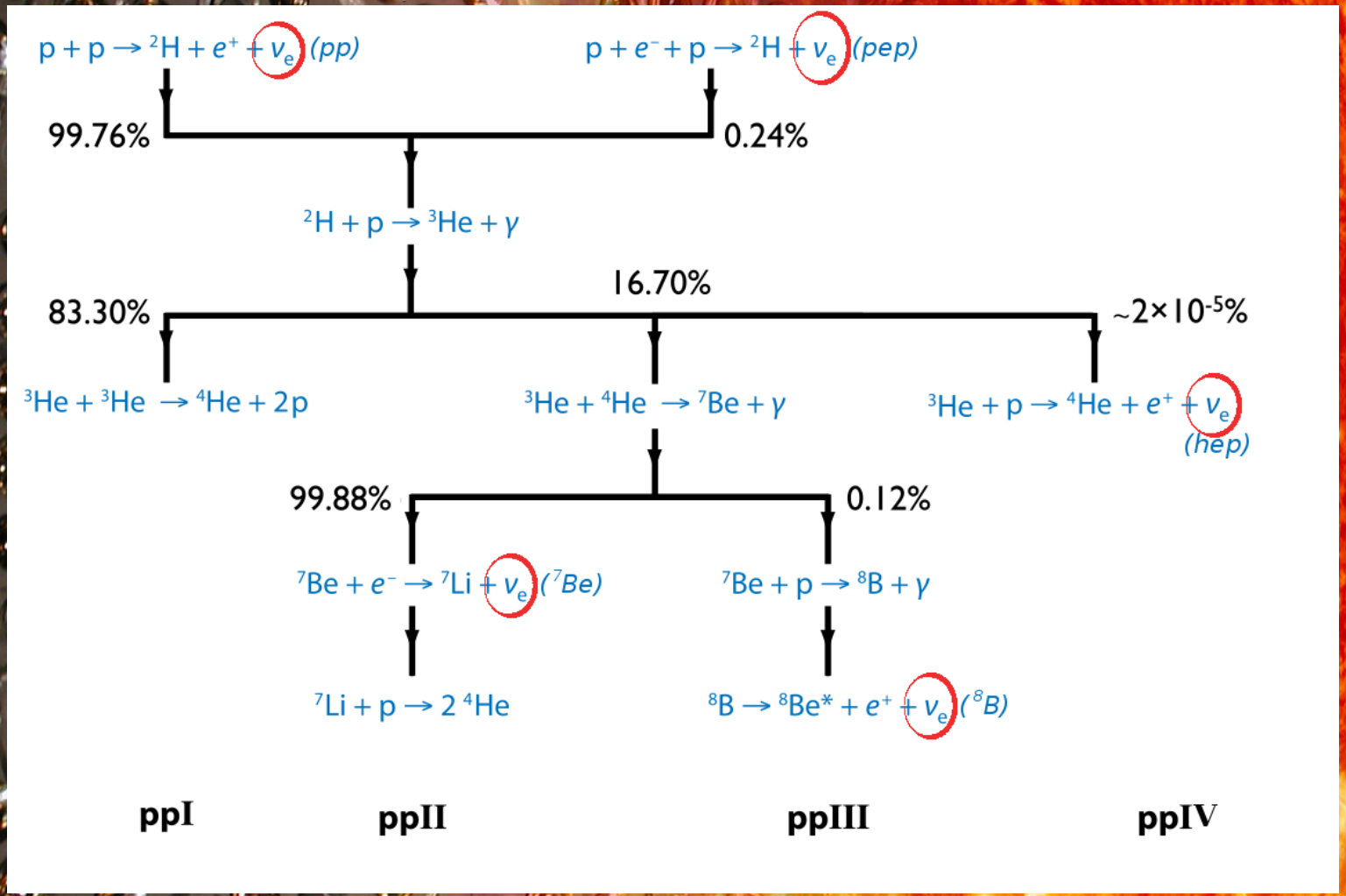
Fusion reactions: CNO cycle



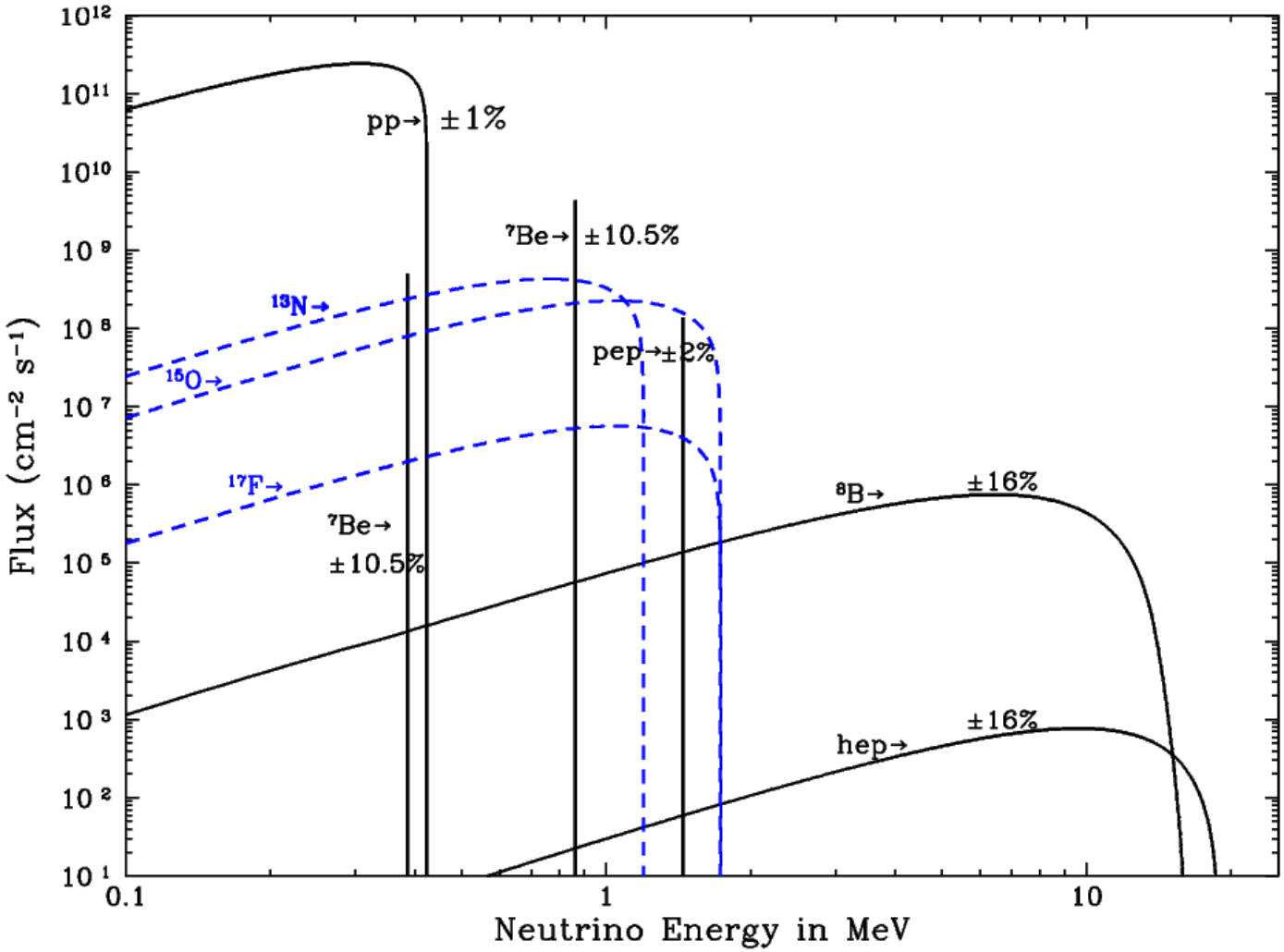
Neutrinos from the fusion reactions: pp-chain



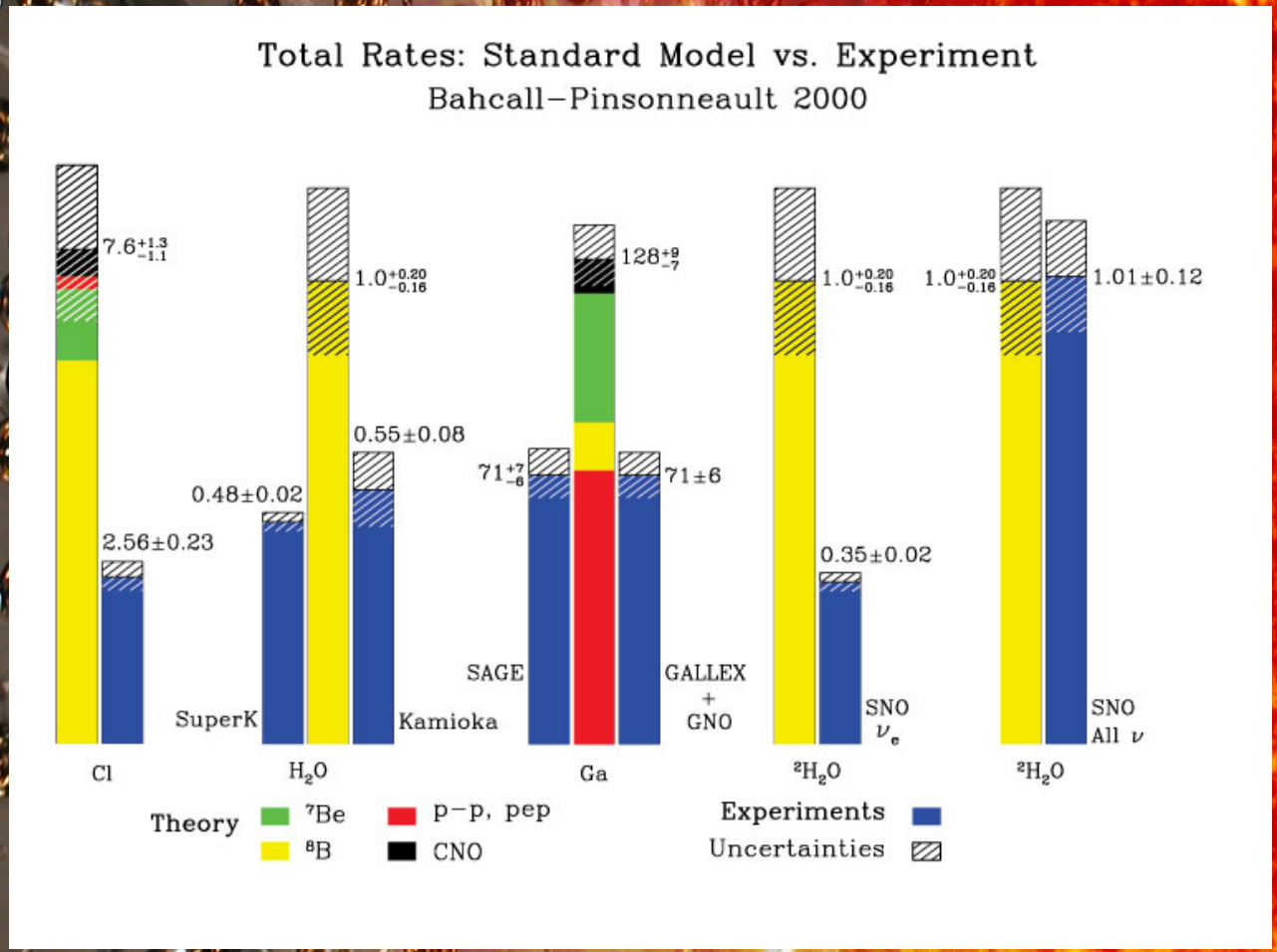
Neutrinos from the fusion reactions: pp-chain



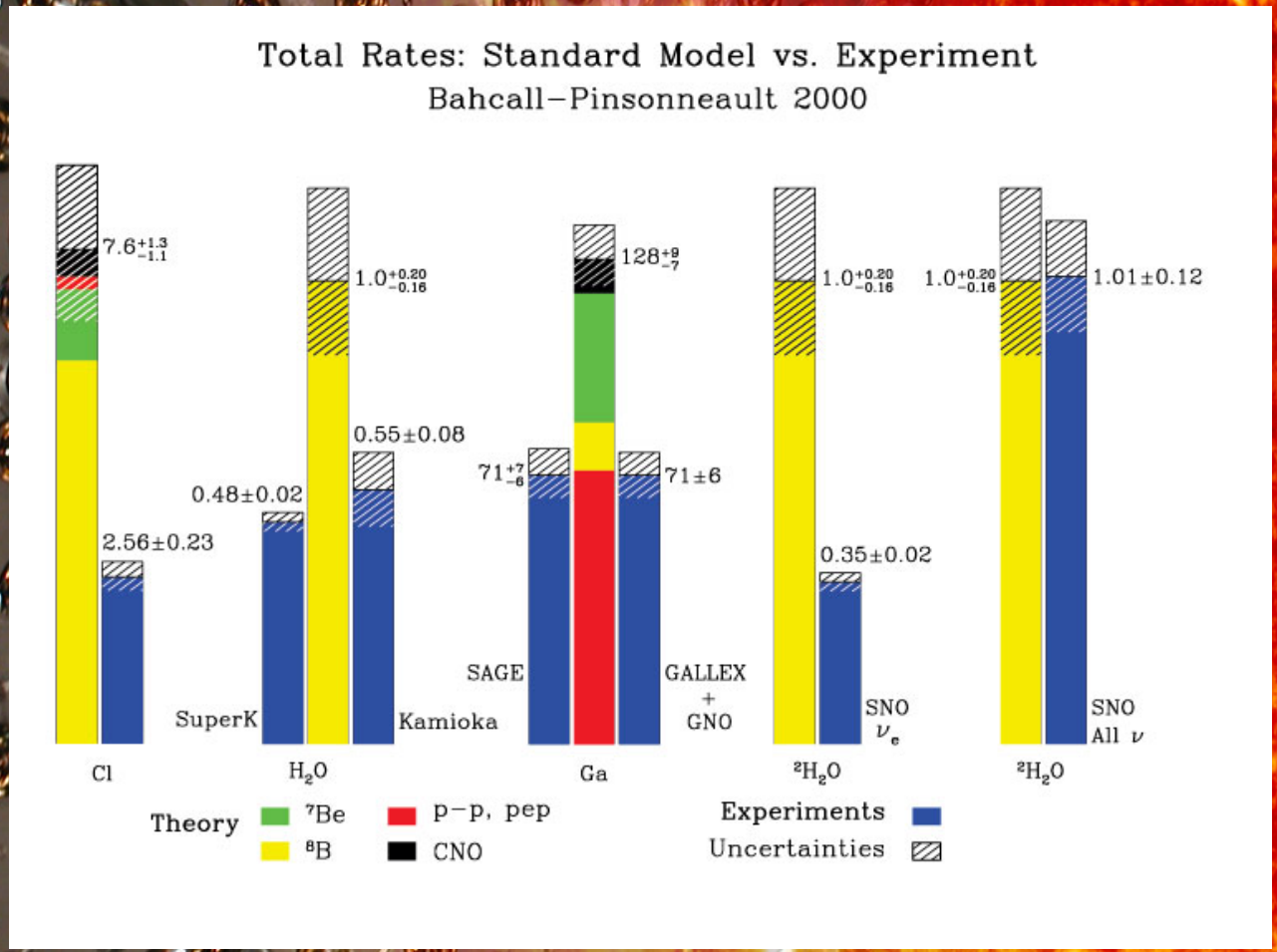
Neutrinos from the fusion reactions: neutrino spectrum



Neutrino propagation from the sun: solar neutrino problem

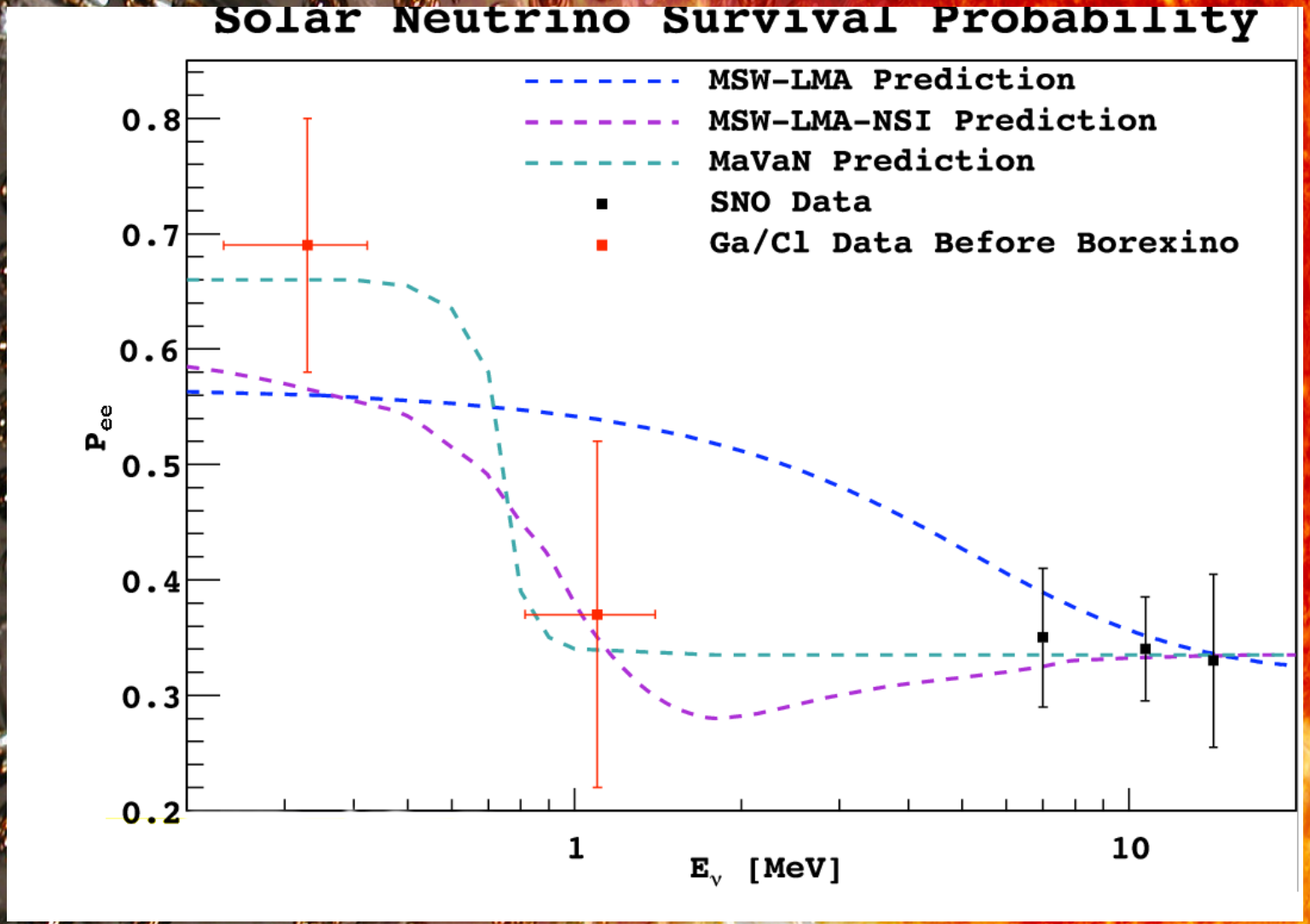


Neutrino propagation from the sun: solar neutrino problem



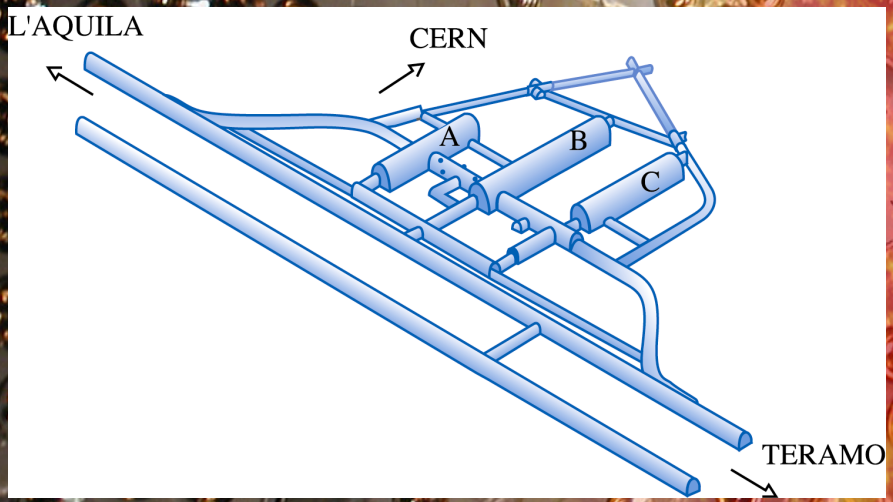
Solar neutrino fluxes are decreased differently depending upon energy

Neutrino propagation from the Sun: matter oscillation

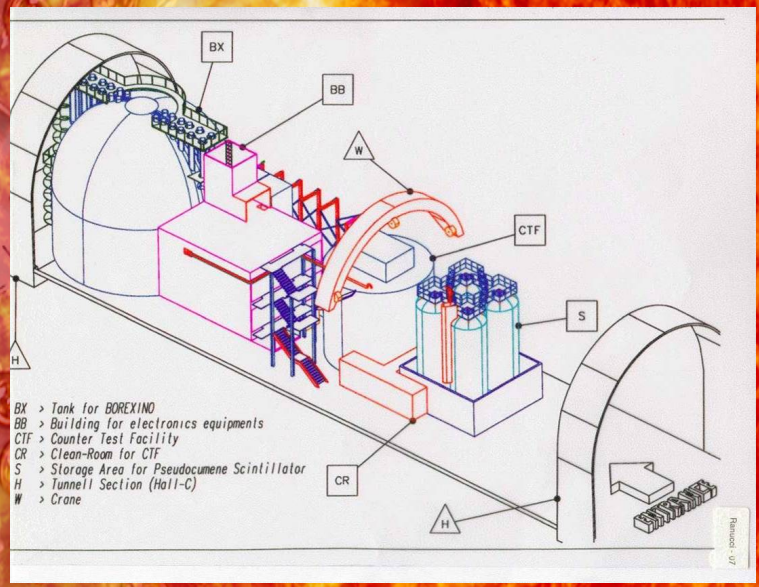


Borexino detector

Borexino is a liquid scintillator neutrino detector, located in Hall C of Gran Sasso National Laboratory (LNGS)



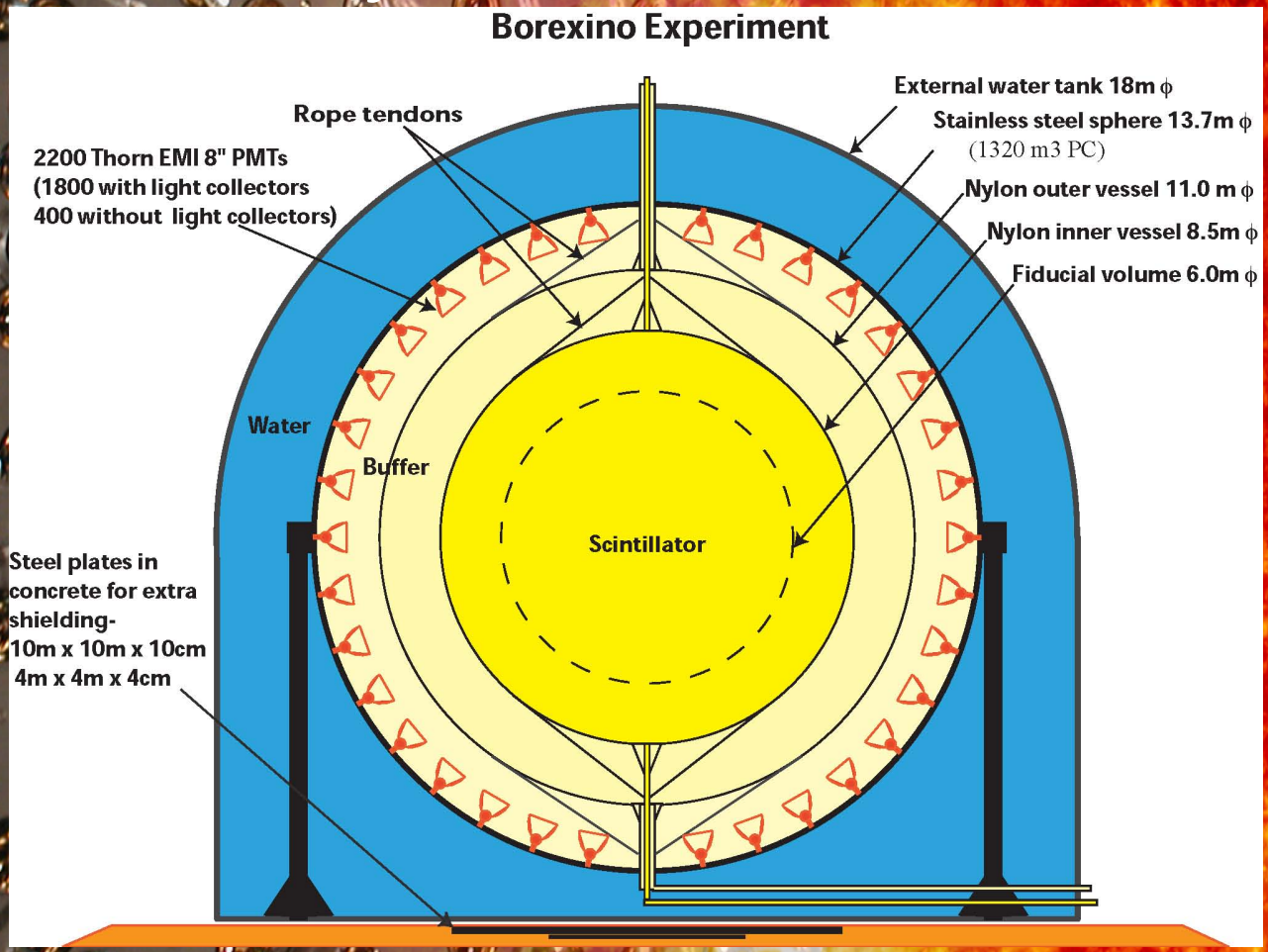
LNGS tunnels



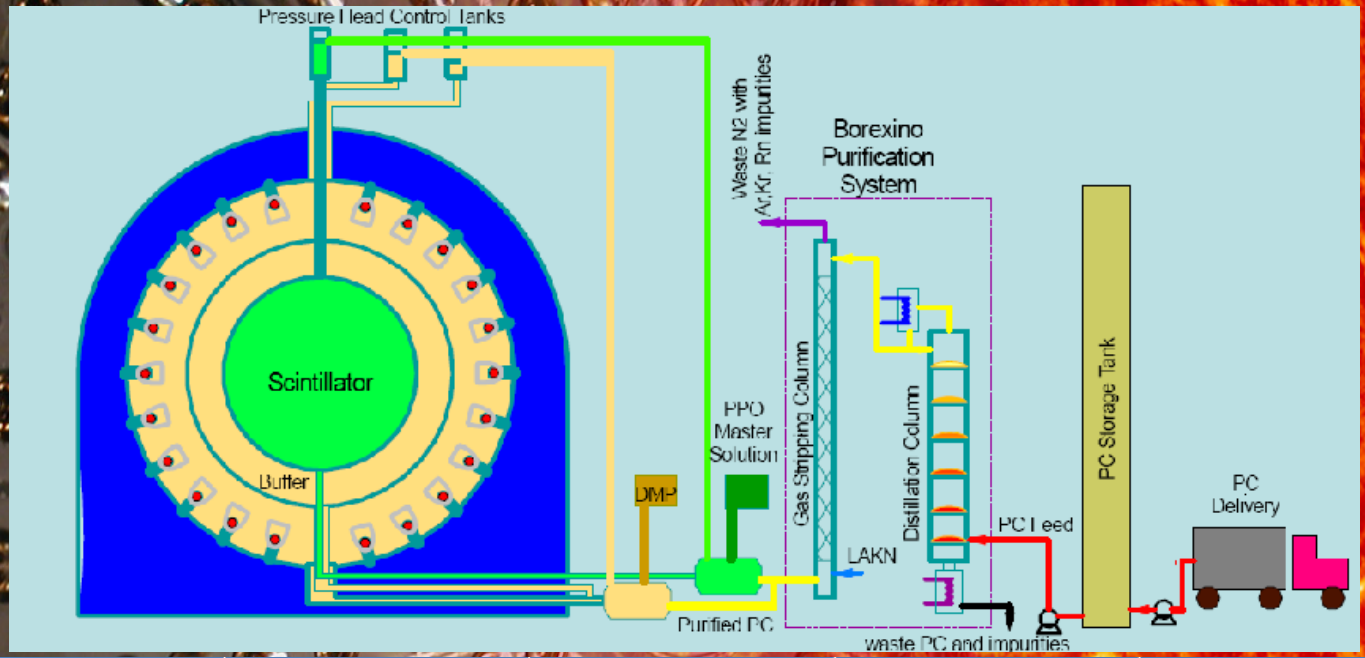
Borexino detector location

Introduction: Borexino construction

Borexino is constructed of a stainless steel water tank,inside which is located a steel sphere with two nylon balloons inside



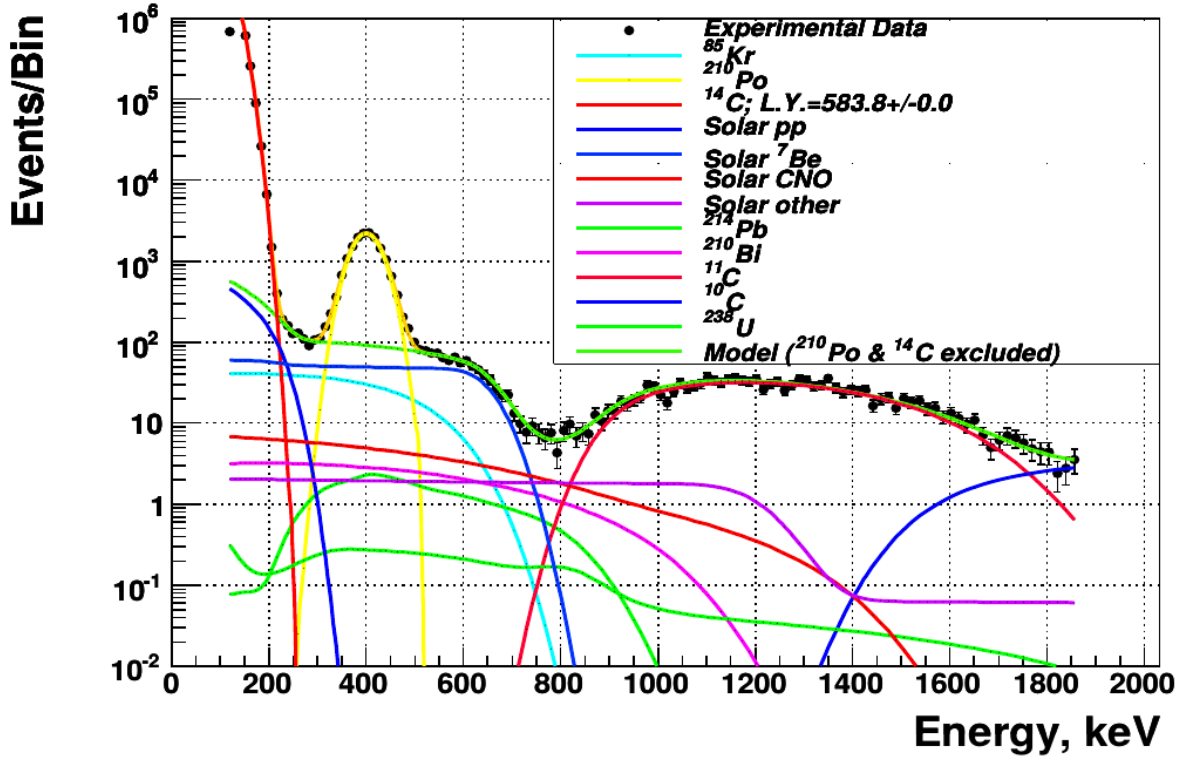
Phase II of Borexino: radiopurity



Contaminant	Source	Normal Conc.	Borexino Achieved	Reduction Method
^{14}C	Scintillator	10^{-12} g/g	10^{-18} g/g	Old oil
^{238}U	Dust	10^{-6} g/g	~5×10^{-18} g/g	Purification
^{232}Th	Dust	10^{-6} g/g	~4×10^{-18} g/g	Purification
^{85}Kr	Air	1 Bq/m^3	~2×10^{-3} Bq/m^3	LAKN
^{222}Rn	Air	20-100 Bq/m^3	<10^{-6} Bq/m^3	Air exclusion
K_{nat}	Dust	~10^{-3} g/g	<2×10^{-19} g/g	Purification
μ	Cosmic	200 s^{-1}m^{-2}	10^{-10} s^{-1}m^{-2}	Underground, active veto

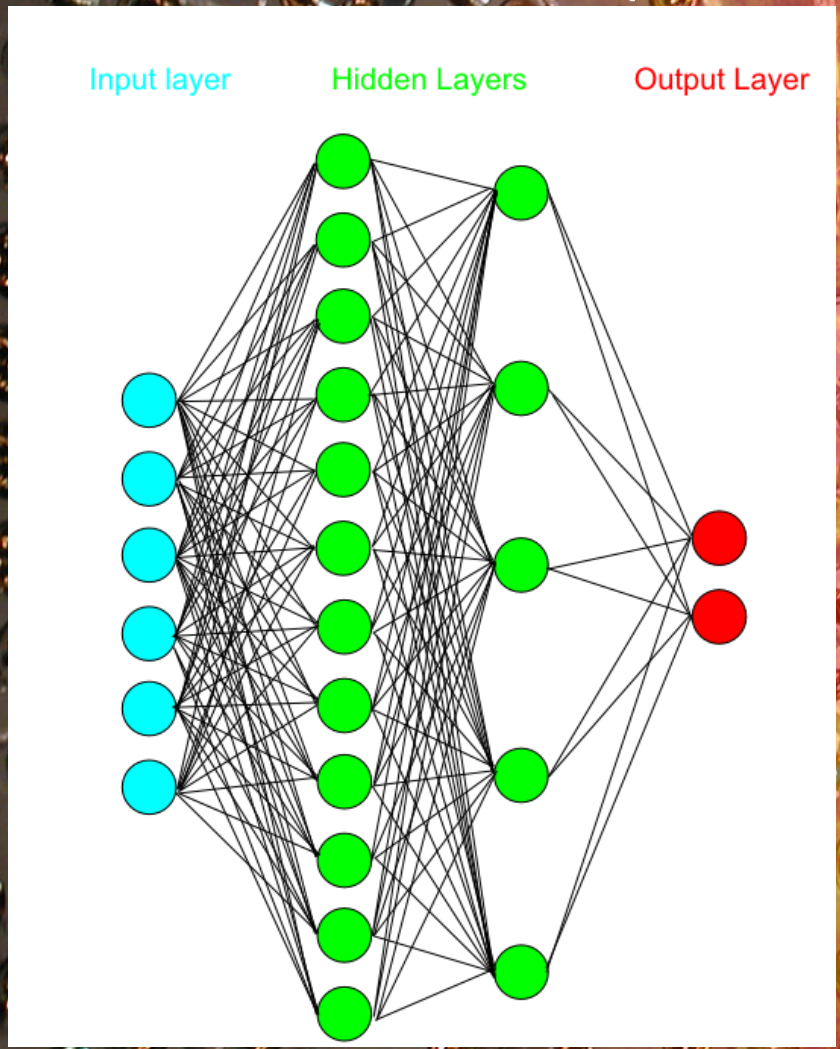
Phase II Borexino: backgroungs

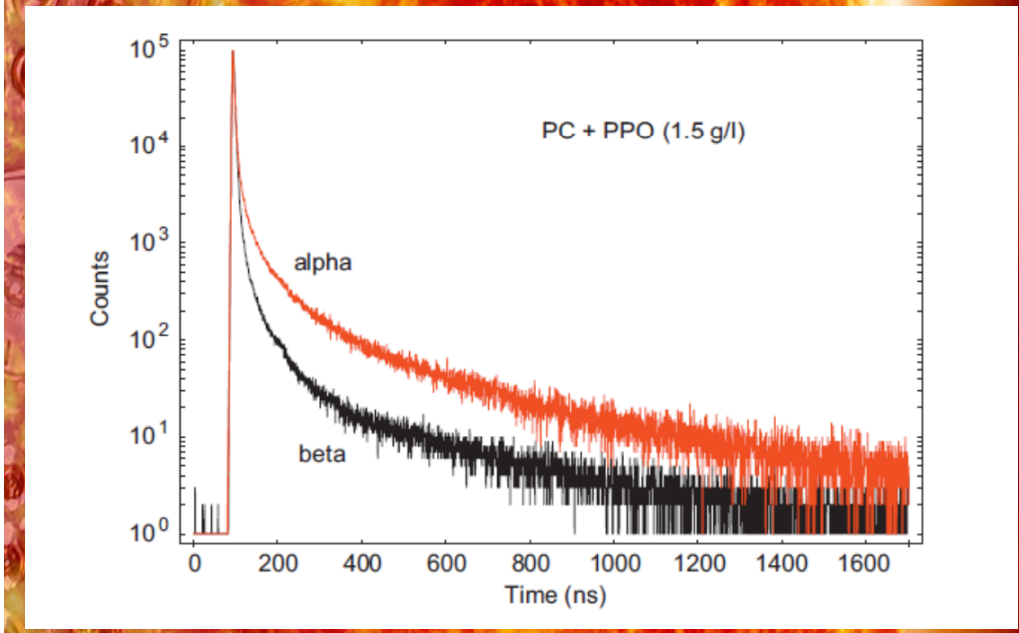
Borexino background includes natural/cosmogenic external/internal backgrounds. Most important ones are ^{14}C, ^{210}Bi, ^{210}Po, ^{214} Po/^{214}Bi, $^{10/11}$ C, U and Th families, ^{85}Kr and External γ-lines of ^{214}Bi, ^{40}K and ^{208}Tl



Phase II of Borexino: α-discrimination: MLP

Alpha-particles could be discriminated using multi-layer perceptron training (neural network system)

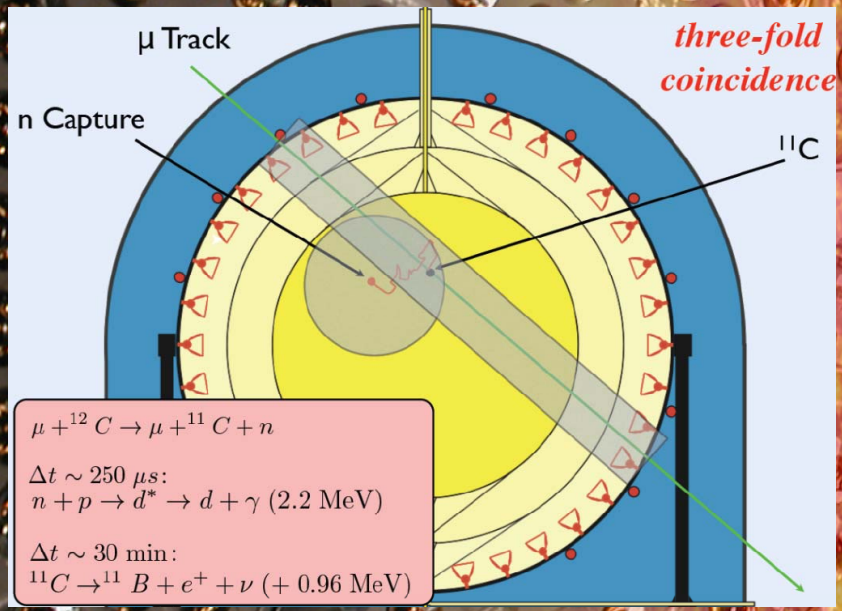


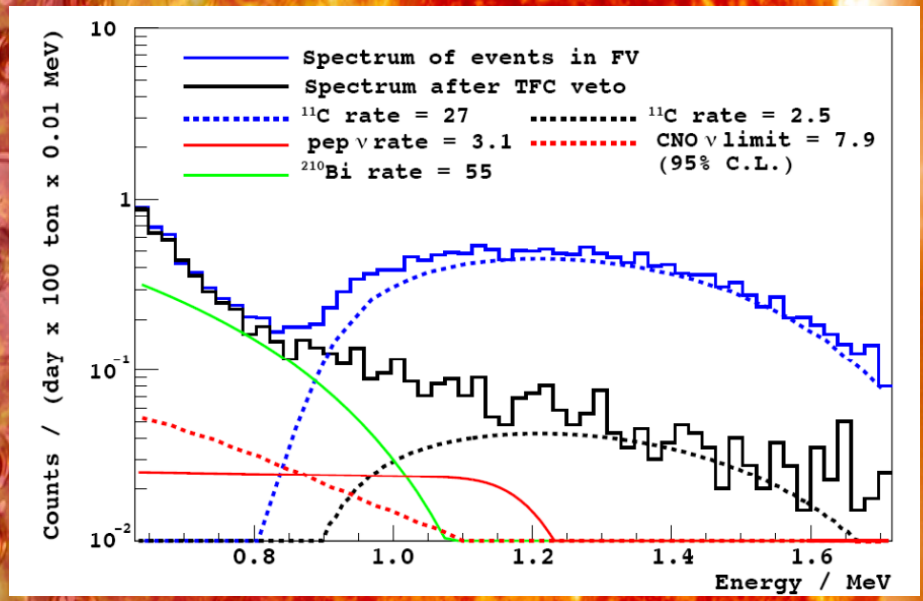


pulse shape of electron/alpha samples

Phase II of Borexino: ^{11}C-discrimination: TFC

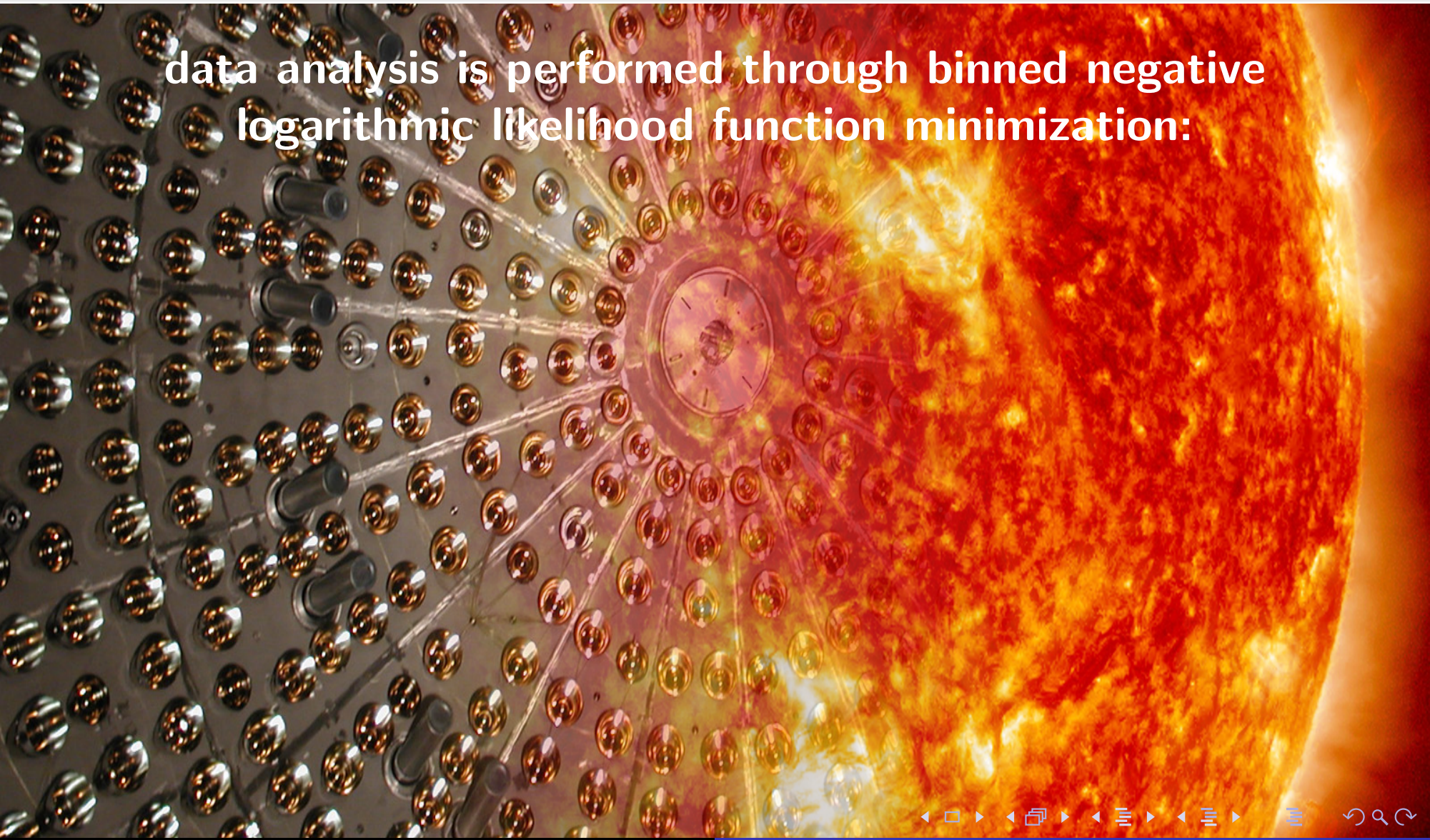
^{11}C and ^{10}C could be removed by applying a veto according to muon/aftermuon neutron events





The method is strongly dependent on tracking and position reconstruction quality

spectral analysis: maximum likelihood approach likelihood



data analysis is performed through binned negative logarithmic likelihood function minimization:

spectral analysis: maximum likelihood approach

likelihood

data analysis is performed through binned negative logarithmic likelihood function minimization:

$$
\begin{aligned}
-ln(L_i) = &\sum_i \left(ln(\theta_i) + \frac{\lambda_{enhanced\ \beta\ i}}{\theta} + ln(\Gamma(\frac{x_{enhanced\ \beta\ i}}{\theta_i} + 1)) - \frac{x_{enhanced\ \beta\ i}}{\theta_i} \times ln(\frac{\lambda_{enhanced\ \beta\ i}}{\theta_i}) \right) \\
&+ \sum_i \left(ln(\theta_i) + \frac{\lambda_{enhanced\ \alpha\ i}}{\theta} + ln(\Gamma(\frac{x_{enhanced\ \alpha\ i}}{\theta_i} + 1)) - \frac{x_{enhanced\ \alpha\ i}}{\theta_i} \times ln(\frac{\lambda_{enhanced\ \alpha\ i}}{\theta_i}) \right) \\
&+ \sum_i \left(ln(\theta_i) + \frac{\lambda_{subtracted\ \beta\ i}}{\theta_i} + ln(\Gamma(\frac{x_{subtracted\ \beta\ i}}{\theta_i} + 1)) - \frac{x_{subtracted\ \beta\ i}}{\theta_i} \times ln(\frac{\lambda_{subtracted\ \beta\ i}}{\theta_i}) \right) \\
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&+ \sum_{additional\ histograms} \left[\sum_i \left(\frac{\lambda_{k\ i}}{\theta_i} + ln(\Gamma(\frac{x_{k\ i}}{\theta_i} + 1)) - \frac{x_{k\ i}}{\theta_i} \times ln(\frac{\lambda_{k\ i}}{\theta_i}) + ln(\theta_i) \right) \right] \\
&+ \sum_{pull\ terms} \left(\frac{(V_i - V_{expected\ i})^2}{2\delta^2_{V_i}} + \frac{1}{2} log(2\pi\delta^2_{V_i}) \right),
\end{aligned}
$$

spectral analysis: maximum likelihood approach likelihood

data analysis is performed through binned negative logarithmic likelihood function minimization:

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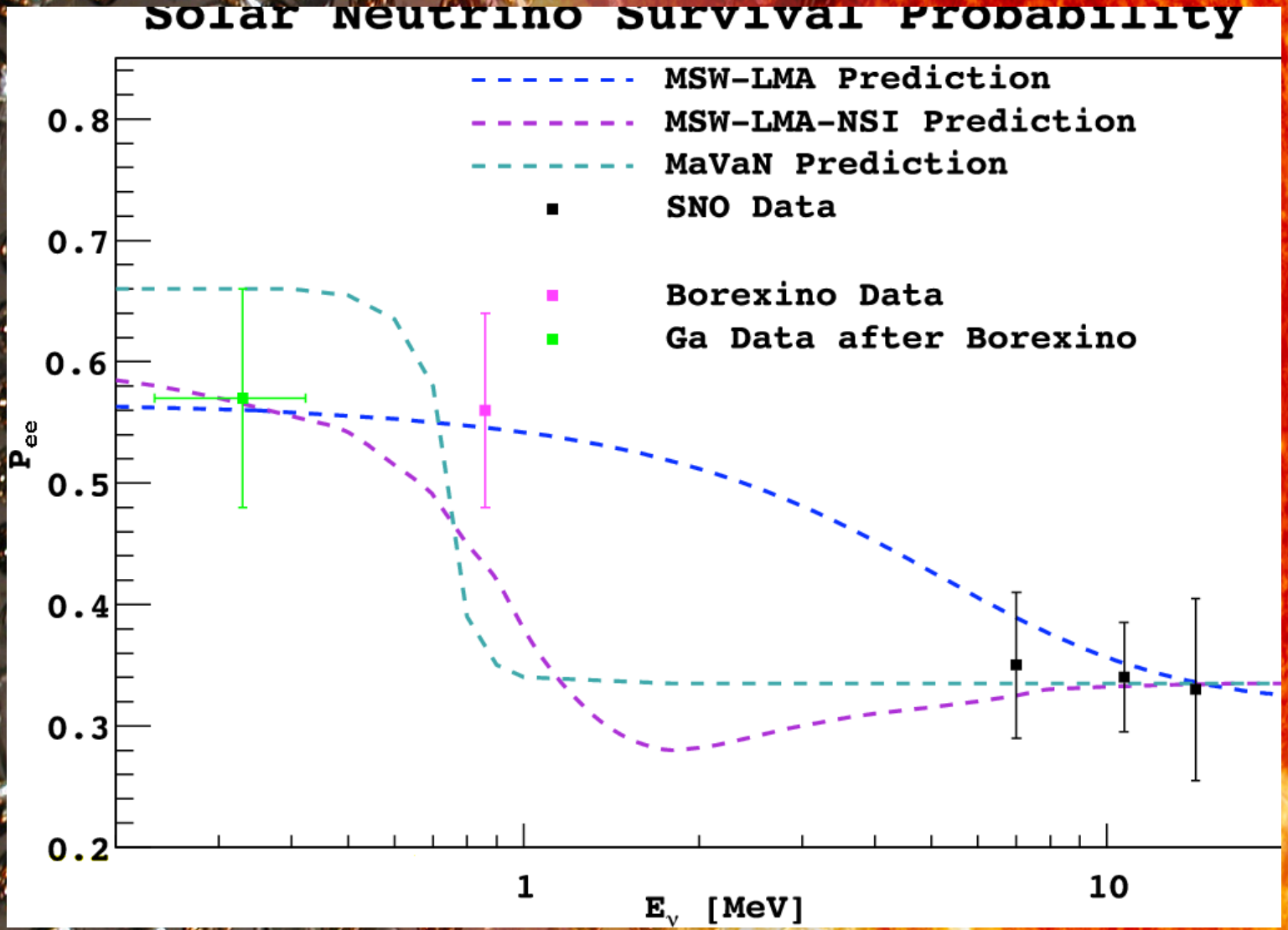
\end{aligned}
$$

The function has up to 40 parameters and makes the analysis very complex; correlation negotiation is the main analysis puzzle

matter oscillation after Borexino



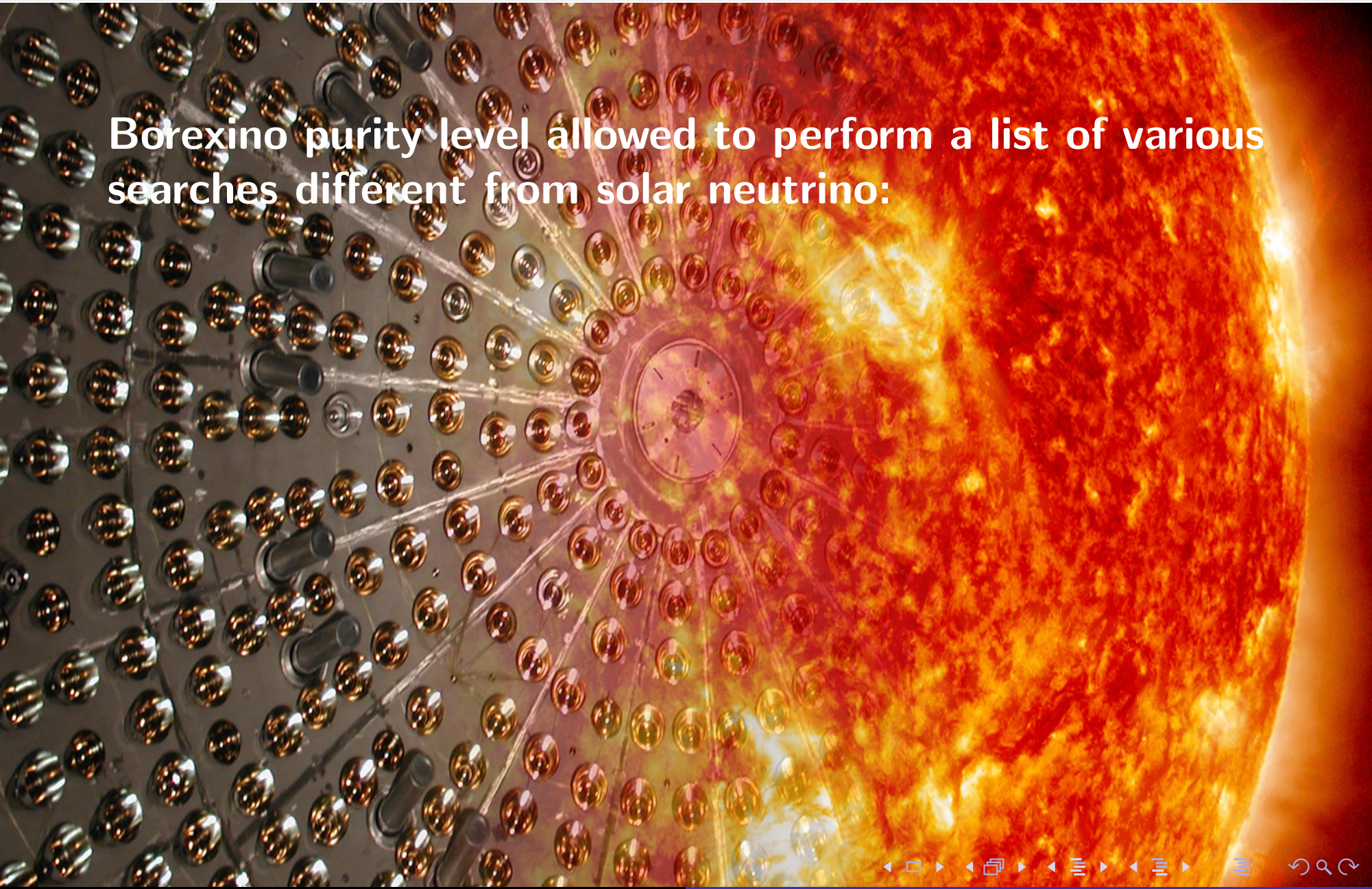
Solar neutrinos: results and plans

Borexino has already performed a lot of interesting measurements in solar neutrino region.

#	component	current result	future goal
1	^{7}Be neutrino	46 ± 1.5 cpd in 100t	improve precision to 3 %
2	*pp*-neutrino	144 ± 17 cpd in 100t	improve precision to 5 %
3	*pep*-neutrino	3.1 ± 0.7 cpd in 100t	improve precision
4	*CNO*-neutrino	< 7.9 cpd in 100t	attempt a measurement
5	^{8}B neutrino	0.22 ± 0.04 cpd in 100t above 3 MeV	increase precision and lower threshold

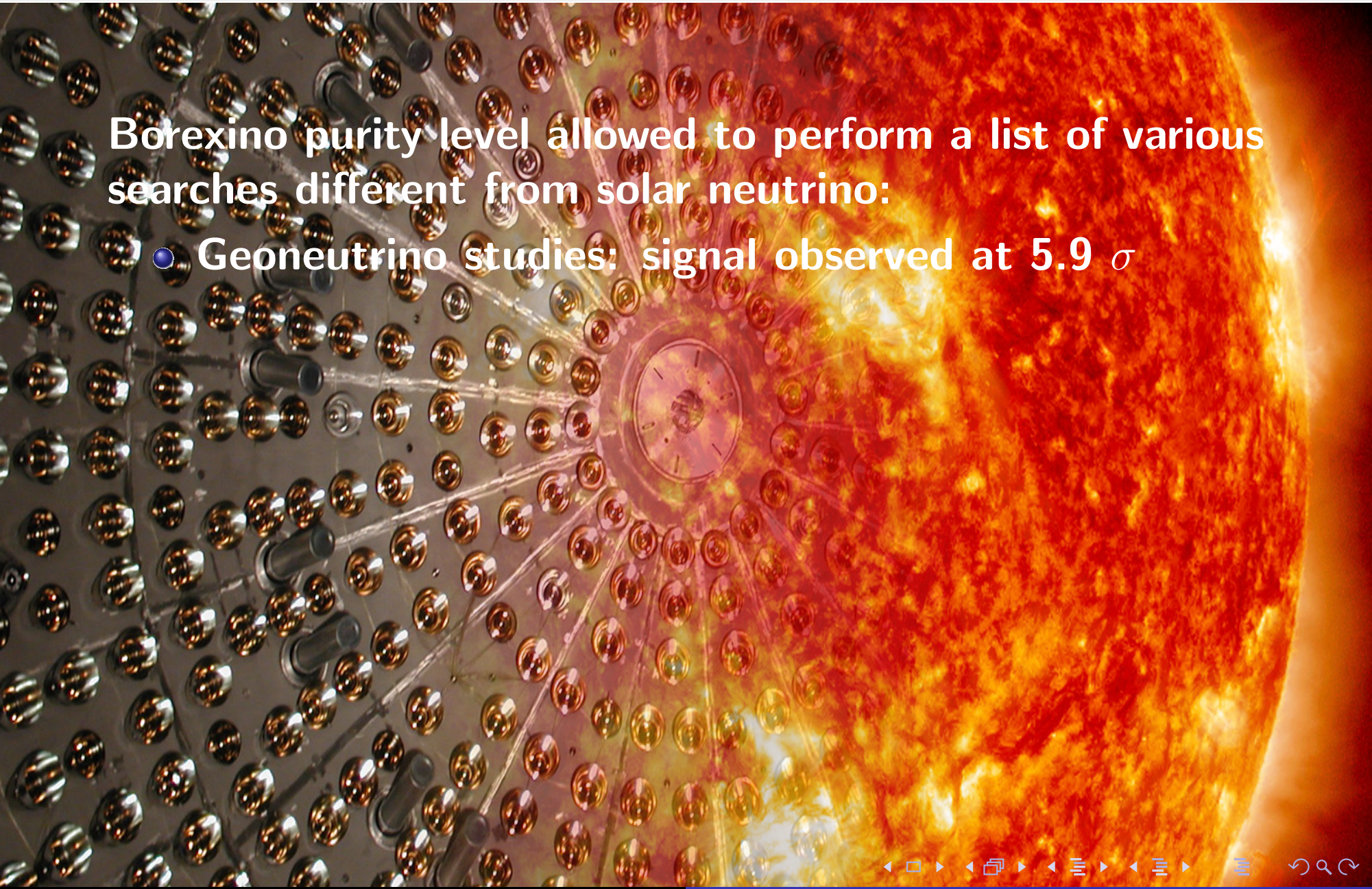
But it is still possible to significantly improve current results. The work is ongoing.

...and not only solar neutrinos



Borexino purity level allowed to perform a list of various searches different from solar neutrino:

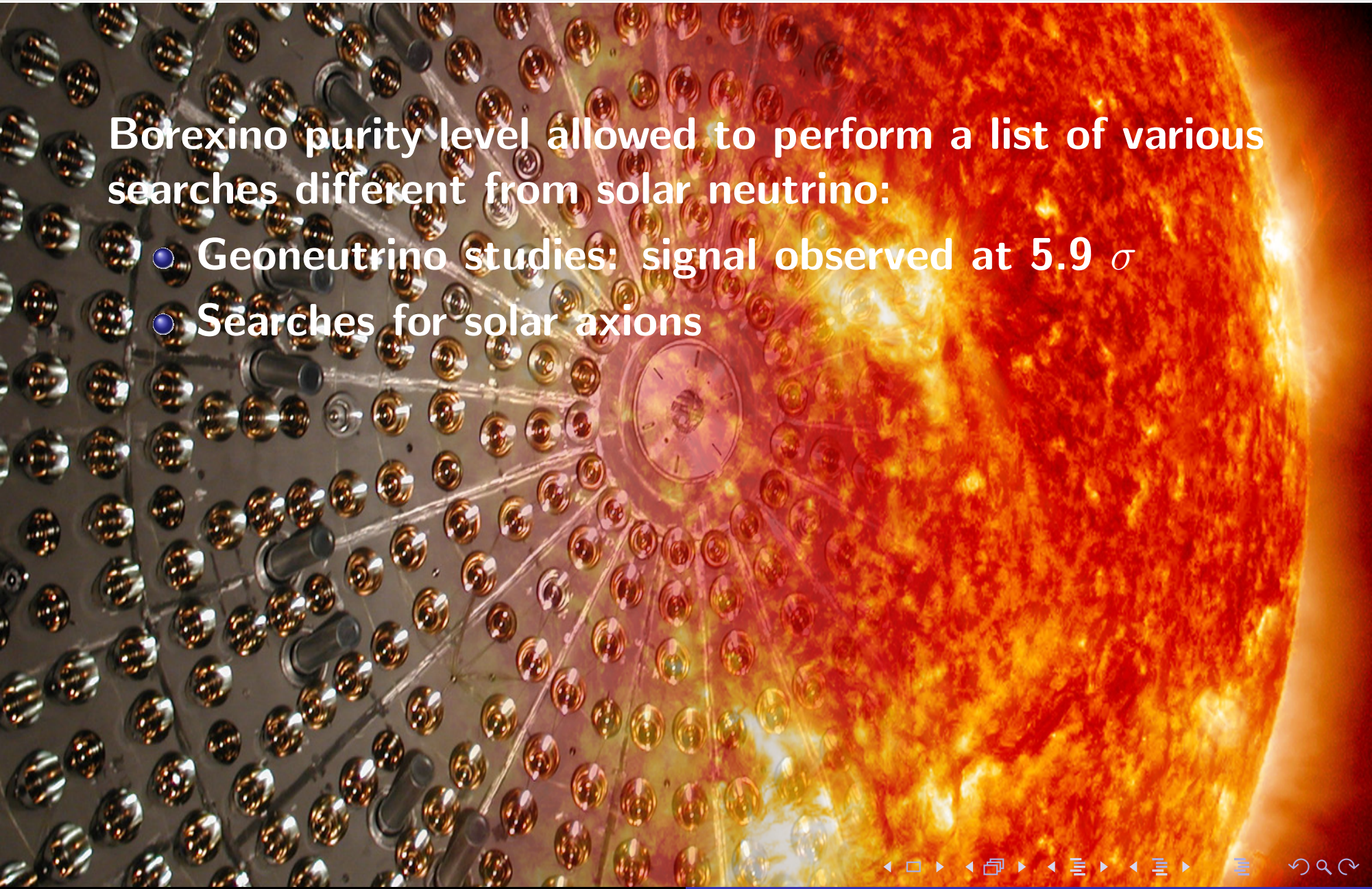
...and not only solar neutrinos



Borexino purity level allowed to perform a list of various searches different from solar neutrino:

- **Geoneutrino studies: signal observed at 5.9 σ**

...and not only solar neutrinos



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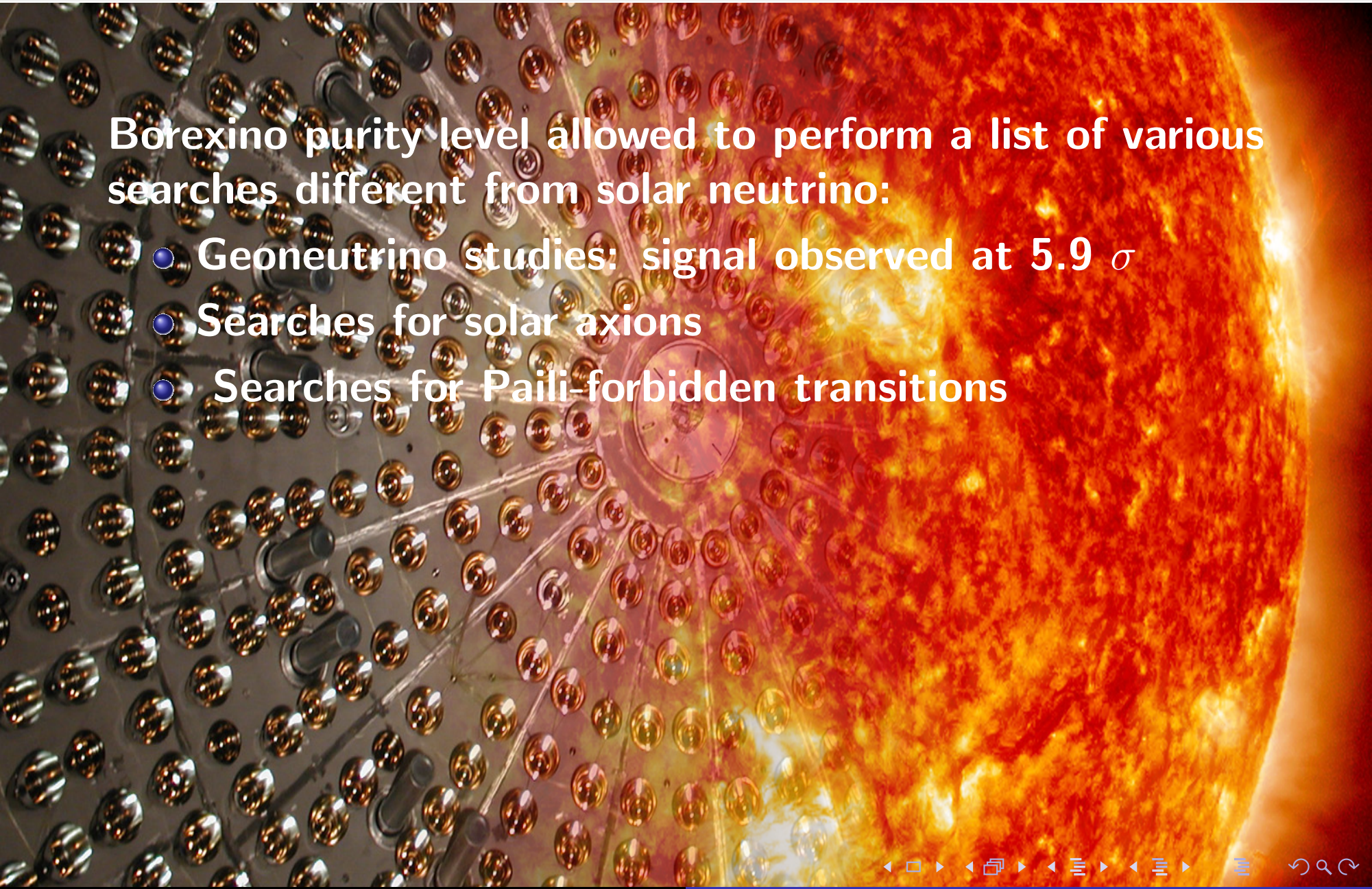
...and not only solar neutrinos



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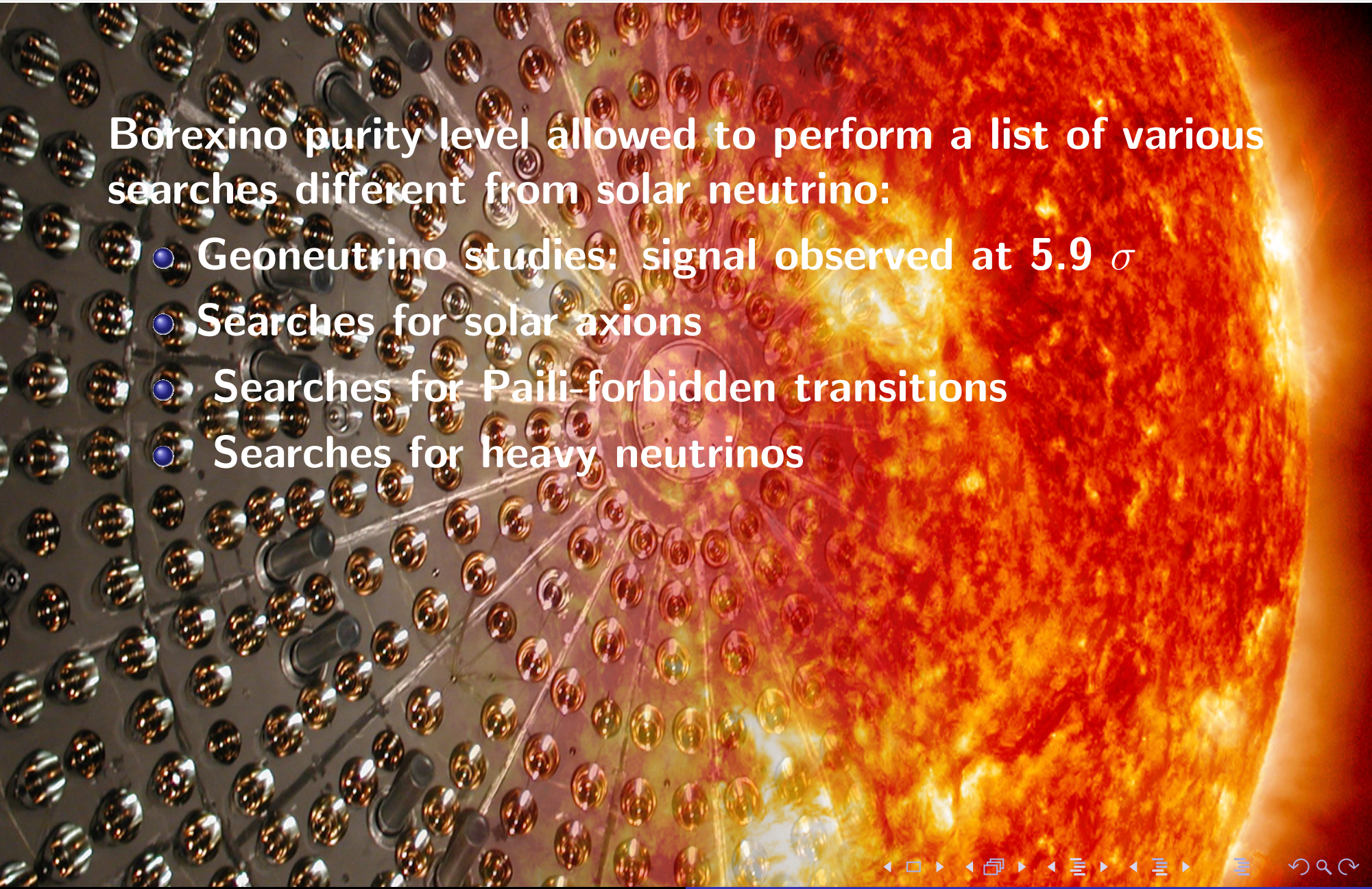
...and not only solar neutrinos



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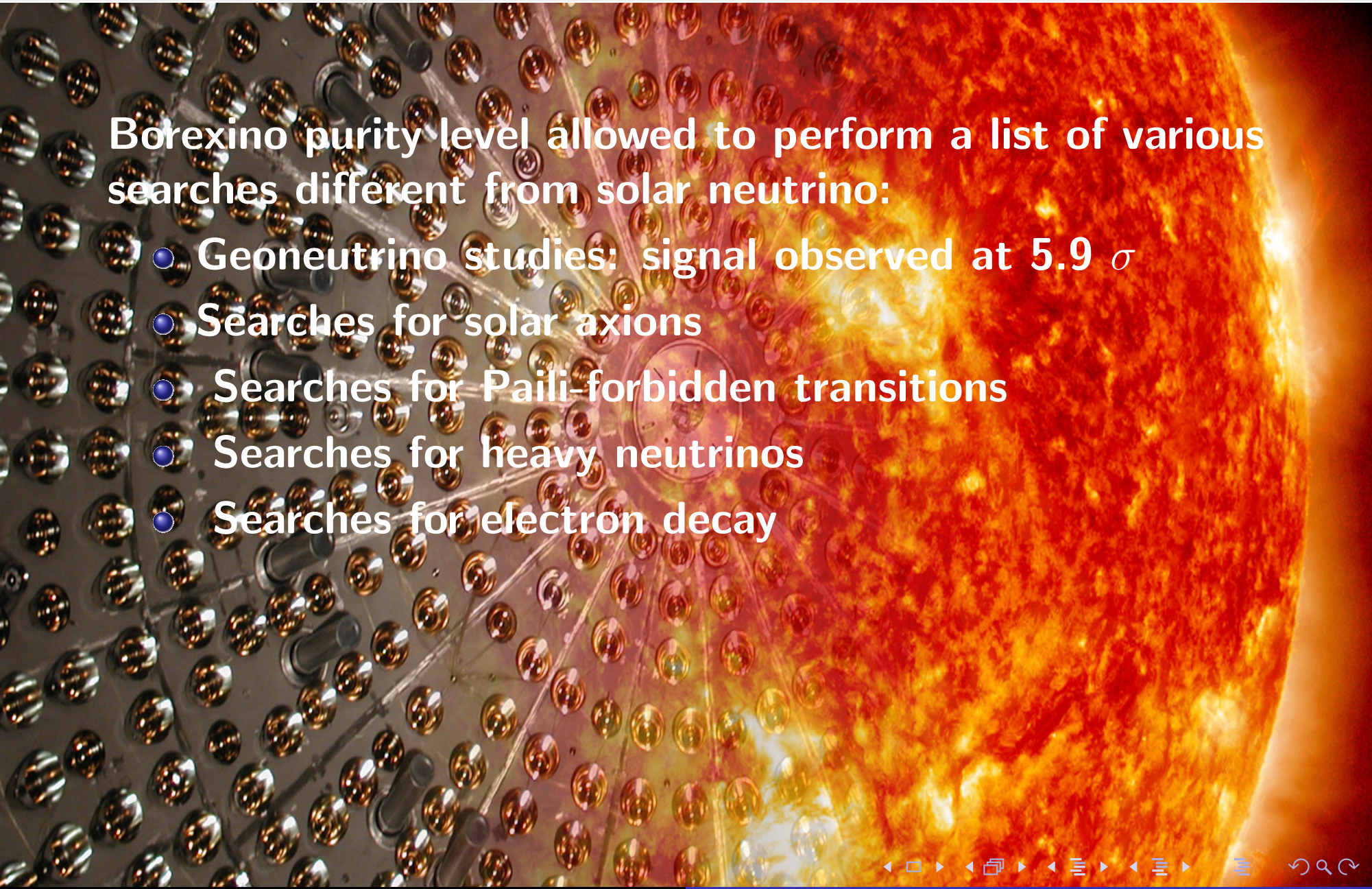

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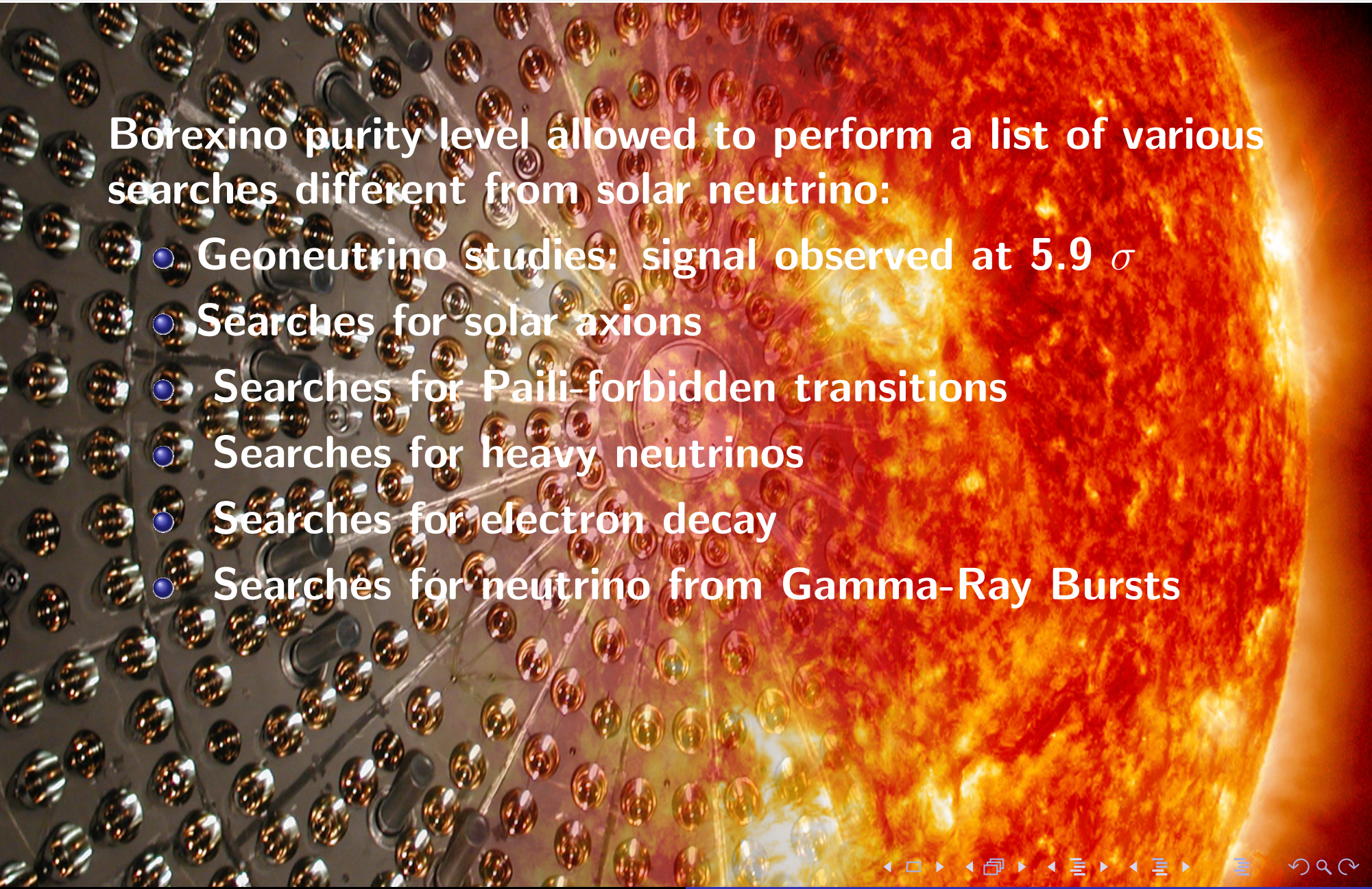
...and not only solar neutrinos



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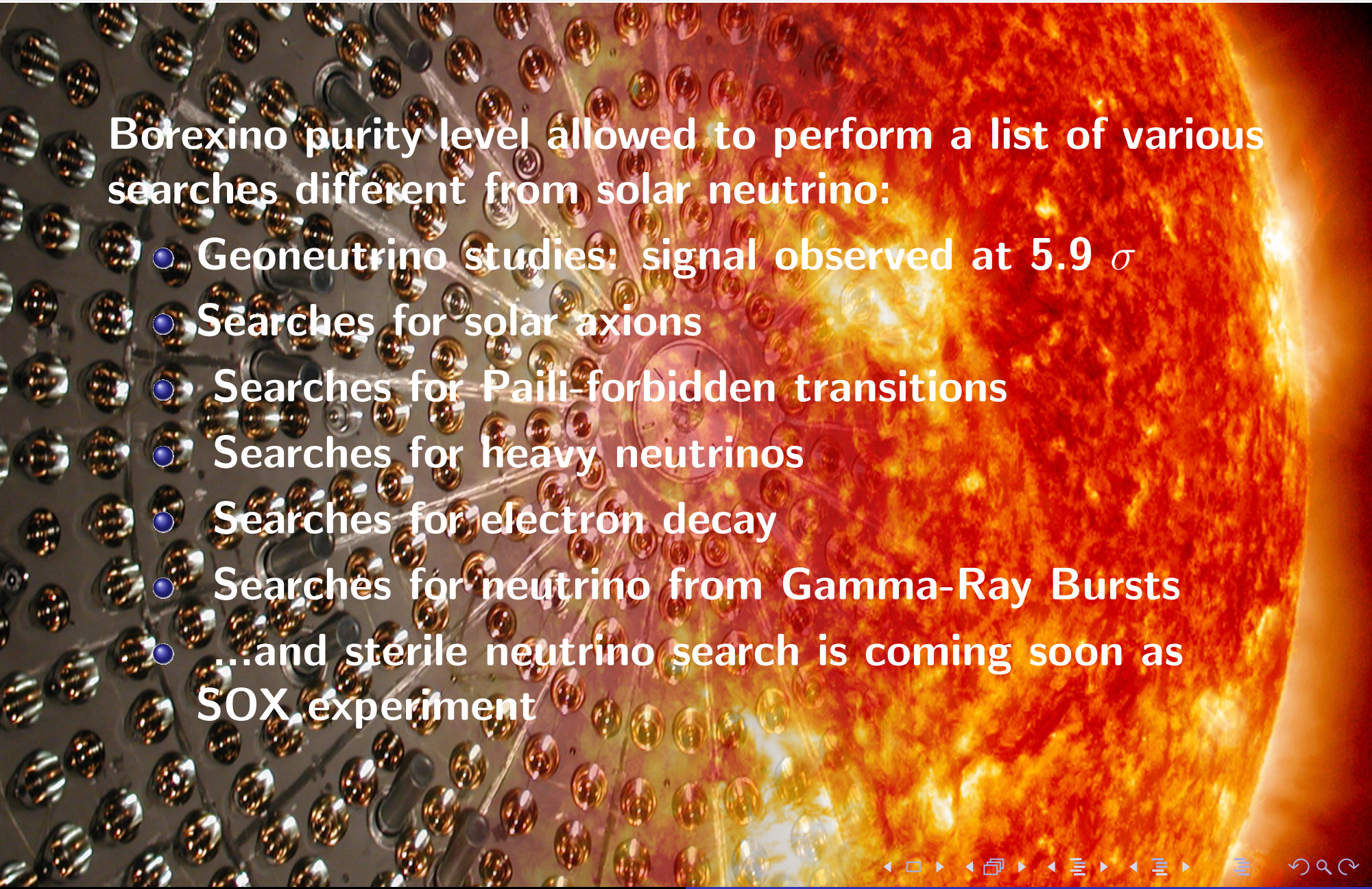
- **Searches for neutrino from Gamma-Ray Bursts**

...and not only solar neutrinos



Borexino purity level allowed to perform a list of various searches different from solar neutrino:

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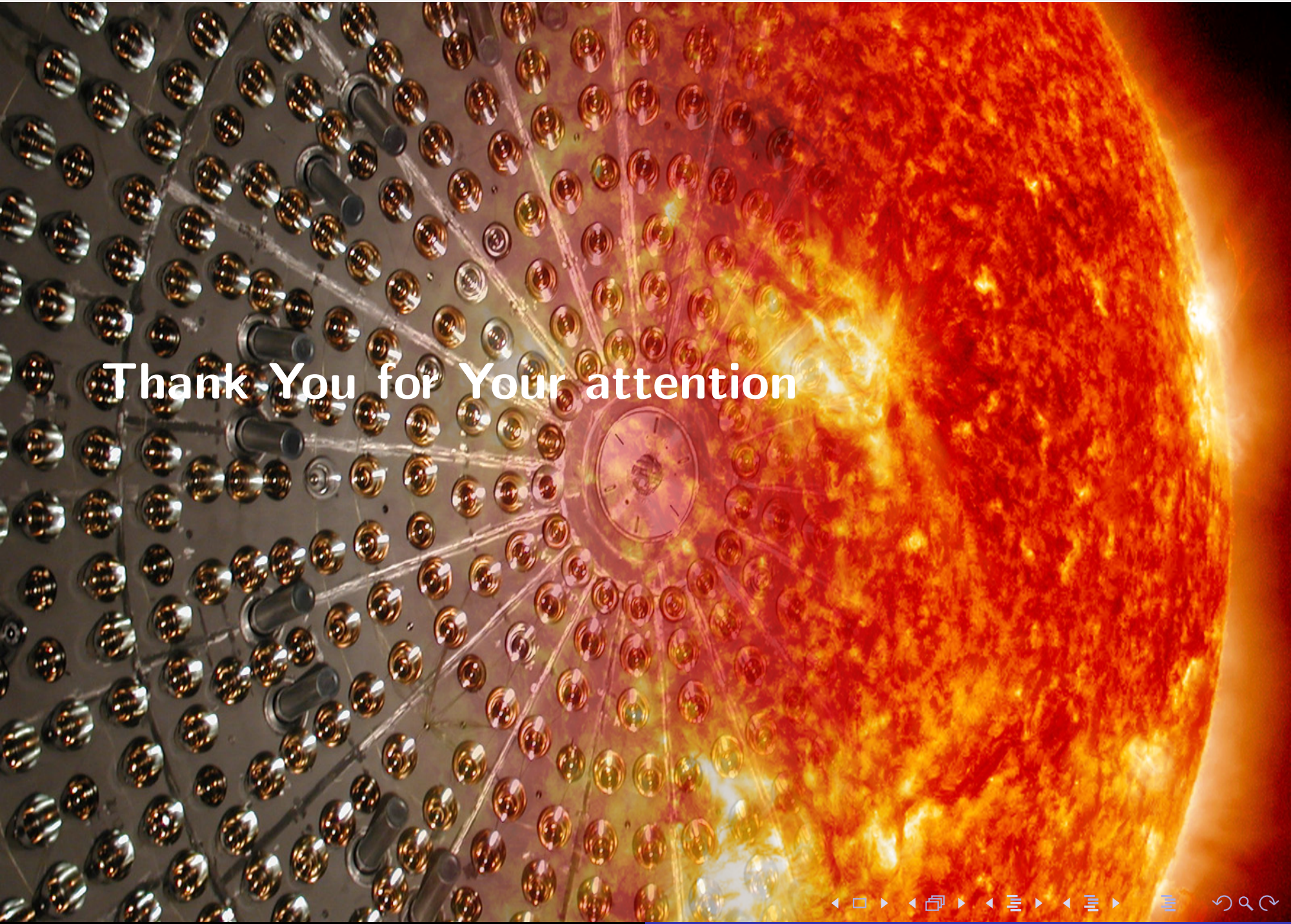
- Searches for heavy neutrinos
- Searches for electron decay
- Searches for neutrino from Gamma-Ray Bursts
- ...and sterile neutrino search is coming soon as SOX experiment


Thank You for Your attention