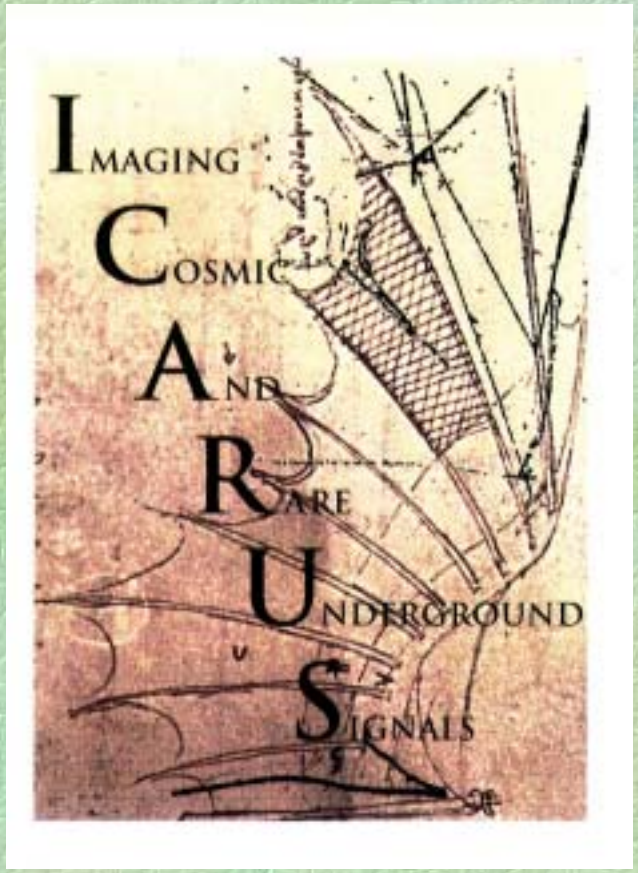
Neutrino Oscillation in Venice

The Solar neutrino Experiment with the ICARUS T600 detector @ Gran Sasso Lab

The ICARUS Collaboration



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- Inst. of Exp. Physics, Warsaw University, Warsaw-Poland
- Inst. for Particle Physics, ETH, Zurich-Switzerland
- Dip.to di Fisica e INFN, Padova-Italy
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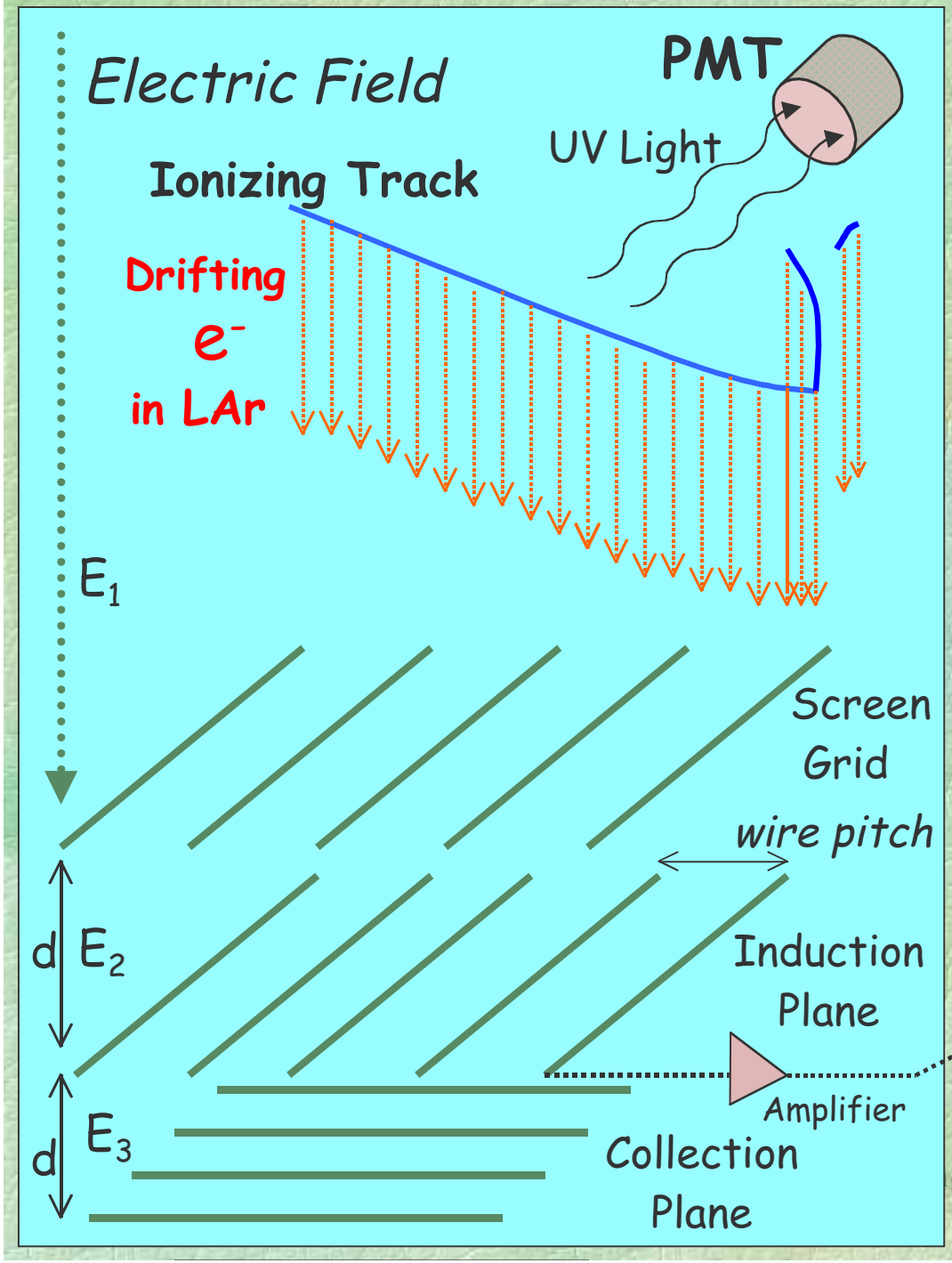
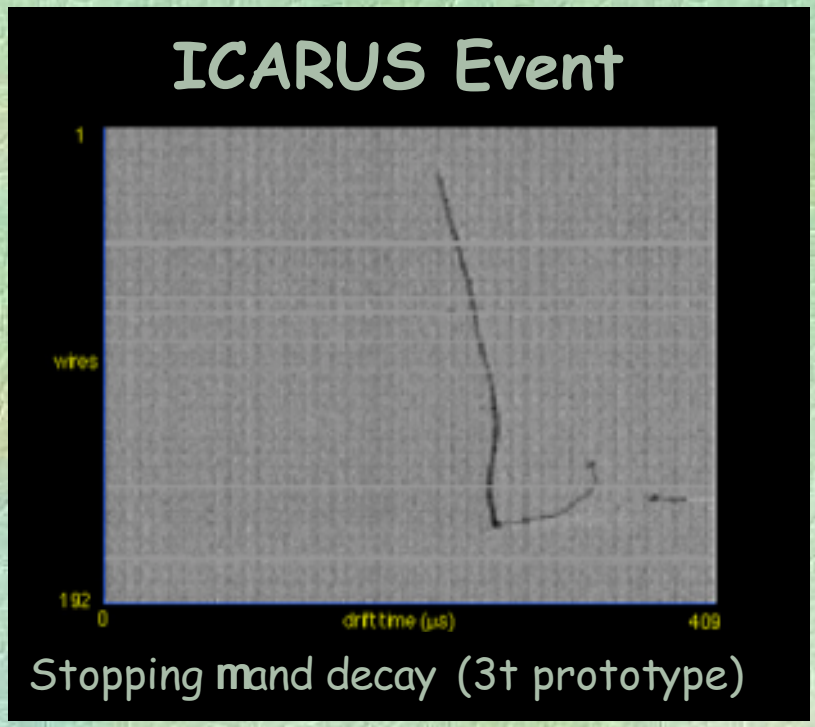
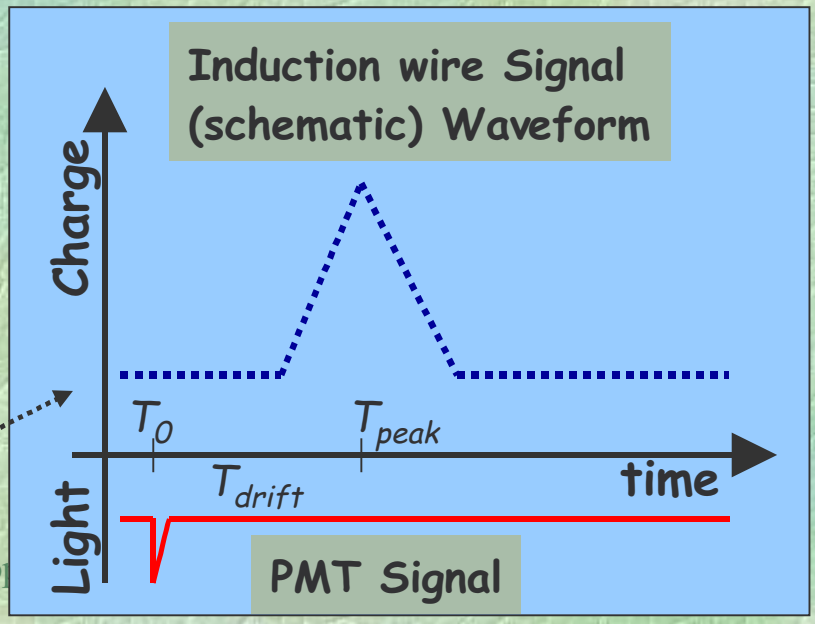
OUTLINE:

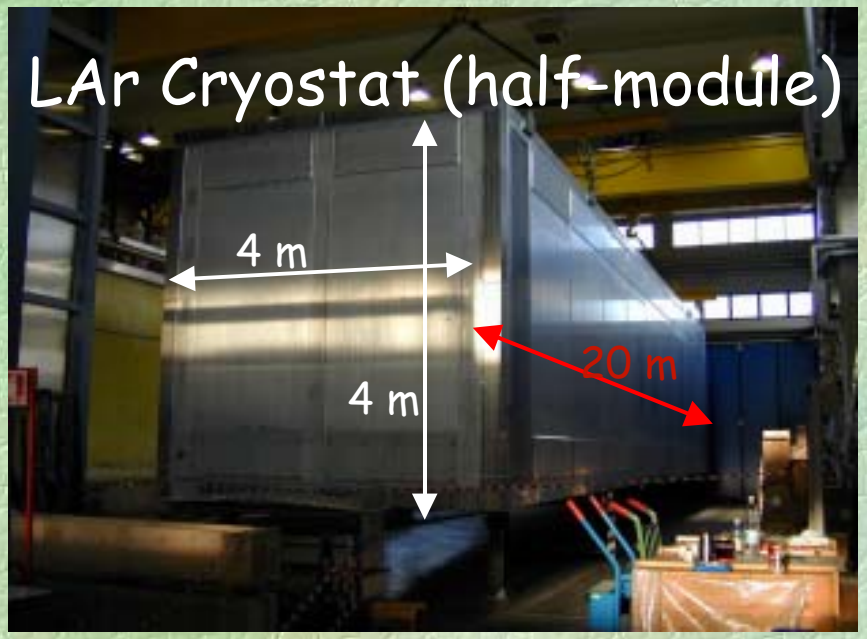
- The ICARUS Technology (available for solar **n** exp.)
- ICARUS T600: status of the detector
  - 1997- 2000: Realization completed (Pavia-INFN Exp. Hall)
  - **April-Aug. 2001:** Full Test in experimental conditions (Pavia)
  - 2001-2002: Transportation to LNGS (Underground Site)
    re-mounting and start physics run
- *The solar neutrino experiment:*
  - Signal and Background event Rate Evaluation
    - Signal: Based on BP98 Solar **n** Flux
    - Bckgd: based on neutron flux direct measurement performed by ICARUS Collaboration at LNGS (Hall C)
  - Signal to Background Discrimination: from full MC simulation
  - **Sensitivity to Oscillations:** for different exposure time and active/sterile scenarios



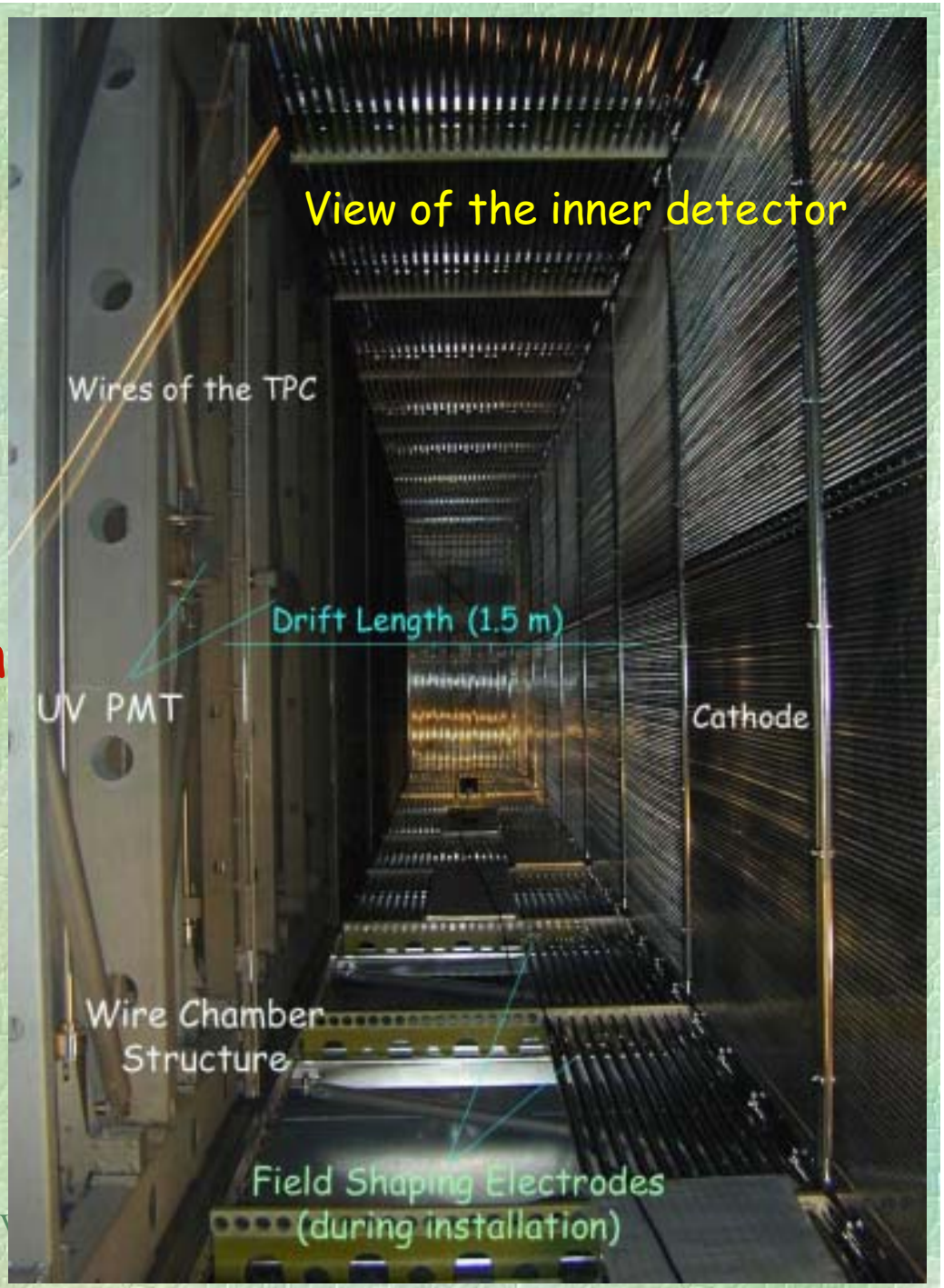


Stopping mand decay (3t prototype)



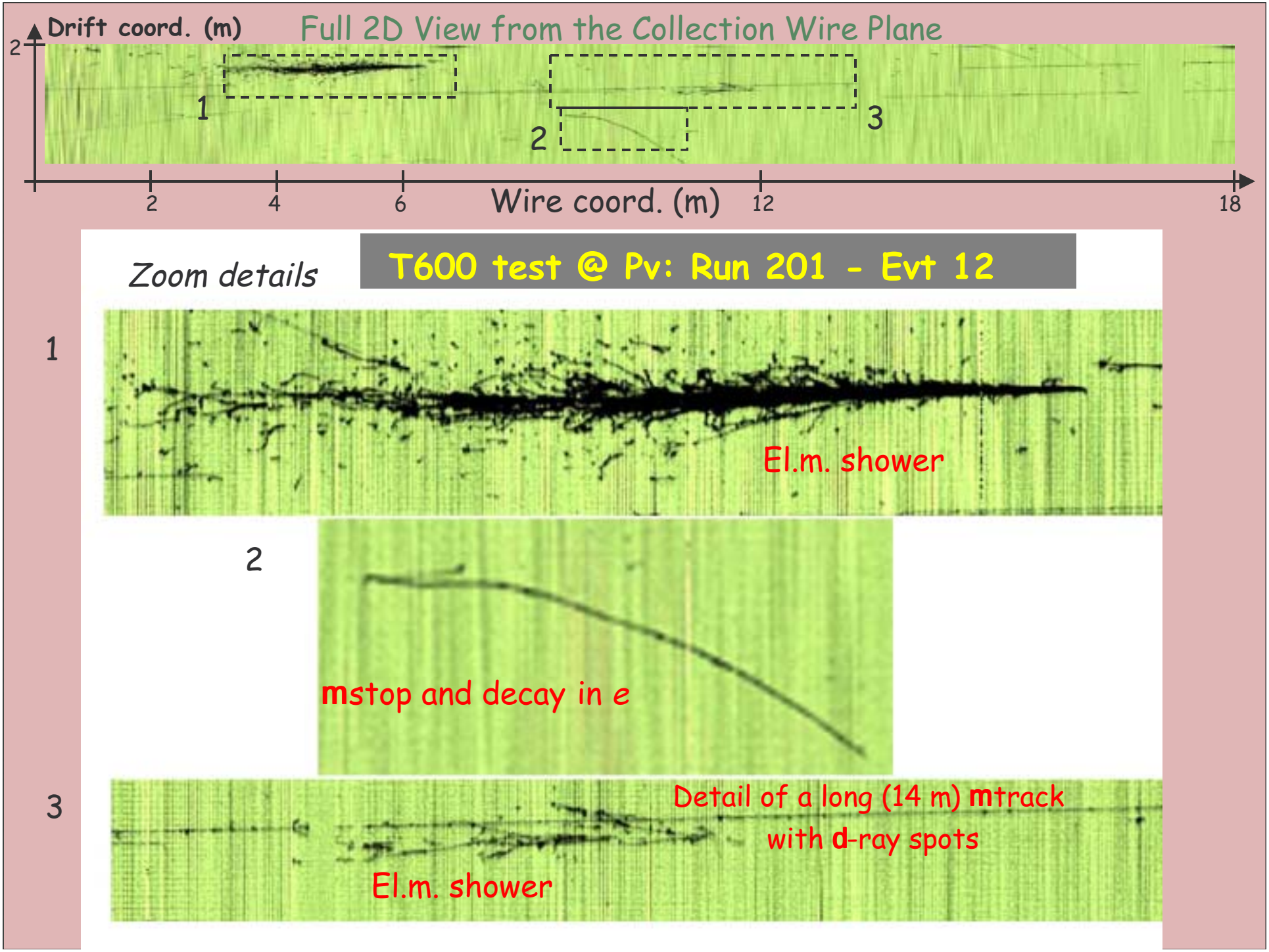


Detector during construction

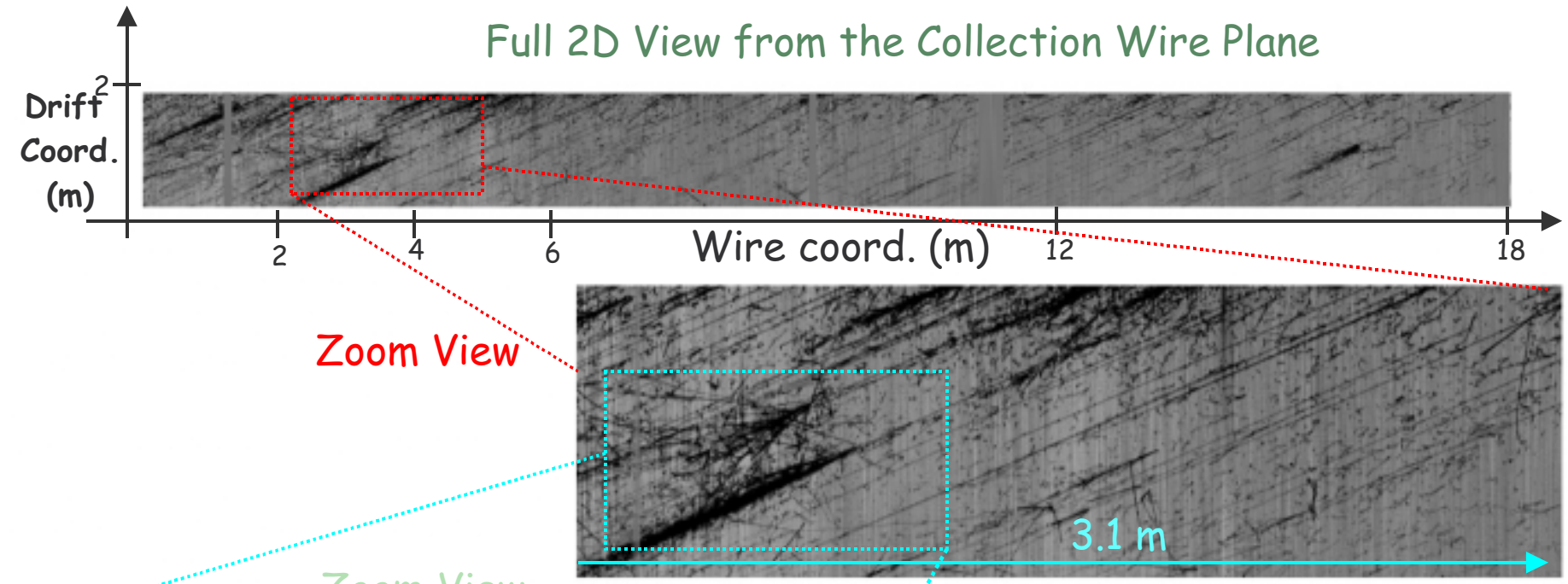


Run @ Pv:
full test in final experimental configuration (May-Aug)

Collection of large statistics of cosmic ray data with various trigger configurations: from long **m**tracks (up to 18 m length) to high multiplicity **m**bundles, to large el.m. and hadronic showers


Drift coord. (m)
Full 2D View from the Collection Wire Plane
2
1
2
3
2
4
6
Wire coord. (m)
12
18
Zoom details
T600 test @ Pv: Run 201 - Evt 12
1
El.m. shower
2
mstop and decay in e
3
Detail of a long (14 m) mtrack
with d-ray spots
El.m. shower

Full 2D View from the Collection Wire Plane

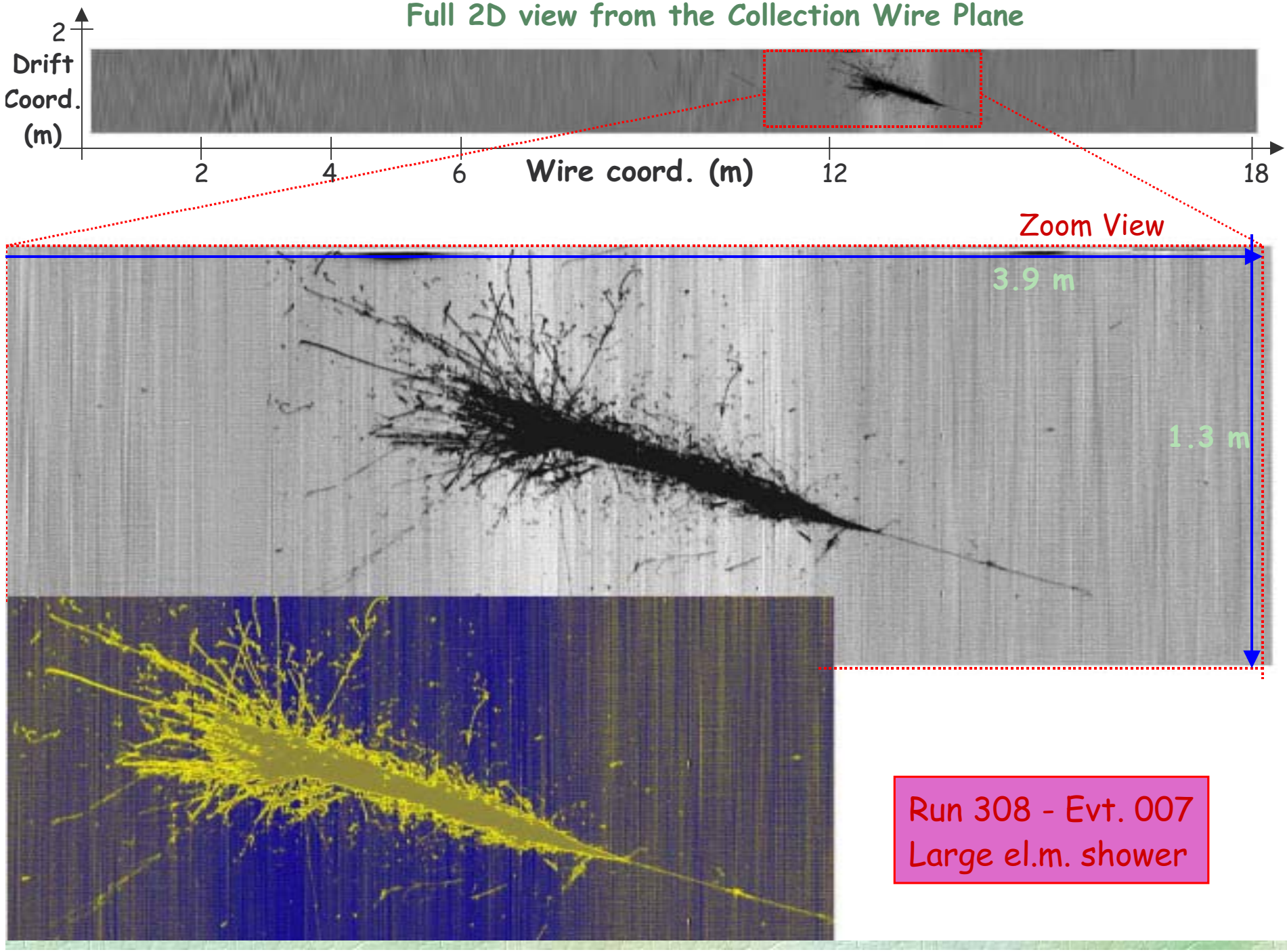


A spectacular event showing a dense Air Shower formed by hundreds of parallel tracks (muons and pions) and low energy gs converting into electrons.

Also visible in the zoom views a hadr. shower, an el.m. shower and a highly collimated muon bundle.

T600 test @ Pv: Run 308 - Evt 4 (July 2nd, 2001)

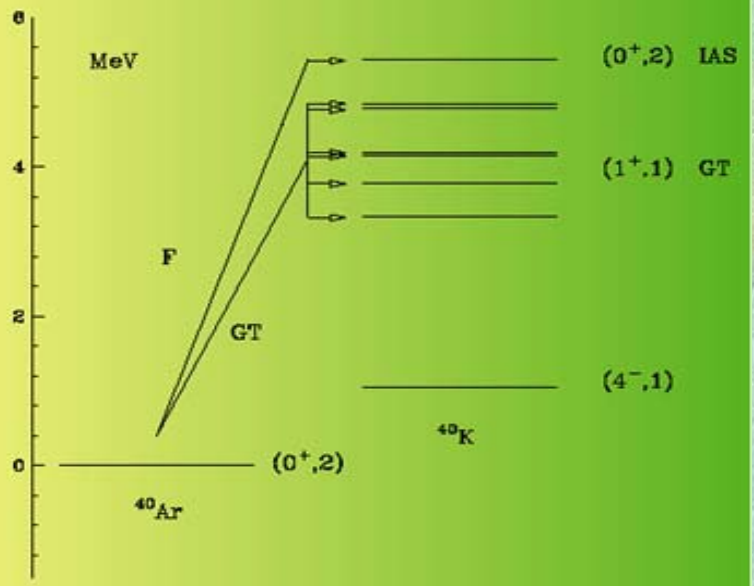
Full 2D view from the Collection Wire Plane



Solar neutrino Physics with ICARUS

GT: Gamow-Teller
F : Fermi

Nuclear K* level Diagram



Solar ν interaction on Argon:

$\nu + Ar \rightarrow K^* + e$

- Sensitive to ^8B component of the Solar **n** Spectrum
- Two reactions can be exploited for Solar model independent studies

&

n Elastic Scattering on Atomic Electrons:

$\nu_x + e \rightarrow \nu_x + e$

One primary e-track (above threshold)
+
M secondary e-tracks from Compton conversion of K* de-excitation gamma's

One isolated e-track (above threshold) with high angular correlation to the Sun direction

(Relatively) High Statistics available and reduced background, depending on the actual energy threshold:

$T_{thr}(e)$ = 5 MeV
(limited by background)

EVENT Rates

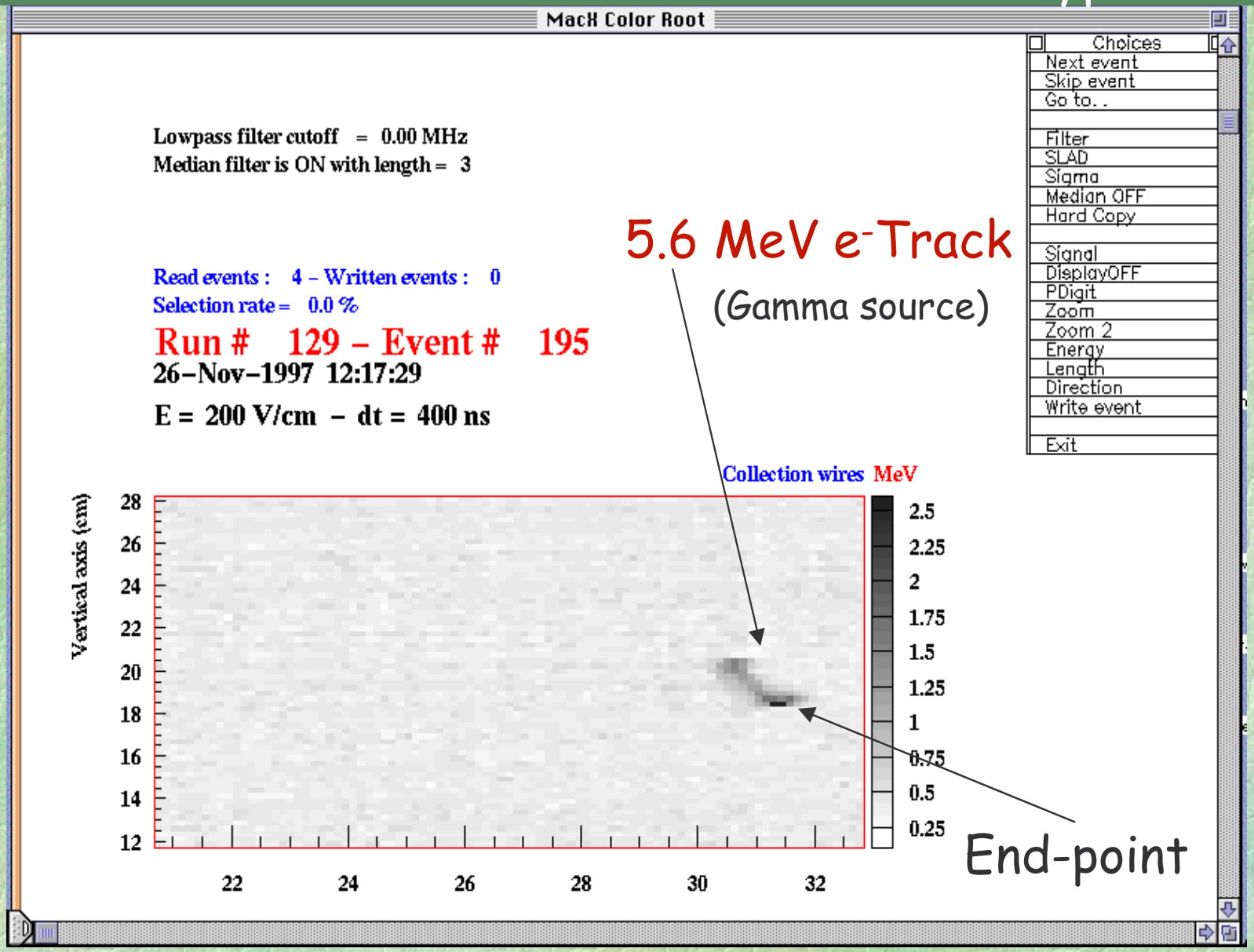
Inputs:

- BP98 **n** Flux (^{8}**B**)
- Ar nuclear shell model calculation and measures on mirror nucleus
- **n** meas. @ LNGS
- **g** meas. @LNGS

T_{th}	Events				
(MeV)	Elastic	Fermi	Gamow-Teller	Photons	Neutrons
0.0000	2674	1964	1902	1.40×10^8	15745
1.0000	2238	1928	1902	3.83×10^7	7243
2.0000	1826	1792	1868	2.14×10^6	3306
3.0000	1438	1530	1832		1481
4.0000	1092	1151	1702		677
5.0000	**792**	**730**	**1453**		**306**
5.5000		530	1094		
6.0000	540	355	694		140
6.5000		213	504		
7.0000	347	111	338		64
7.5000		47	204		
8.0000	204	15	106		28
8.5000		4	45		
9.0000	106		15		
9.5000			4		
10.000	49				

Table 1: Calculated solar neutrino reactions for an exposure of 1 kton × year, as a function of the primary electron kinetic energy threshold T_{th}.

Real Event recorded with 50lt ICARUS Prototype



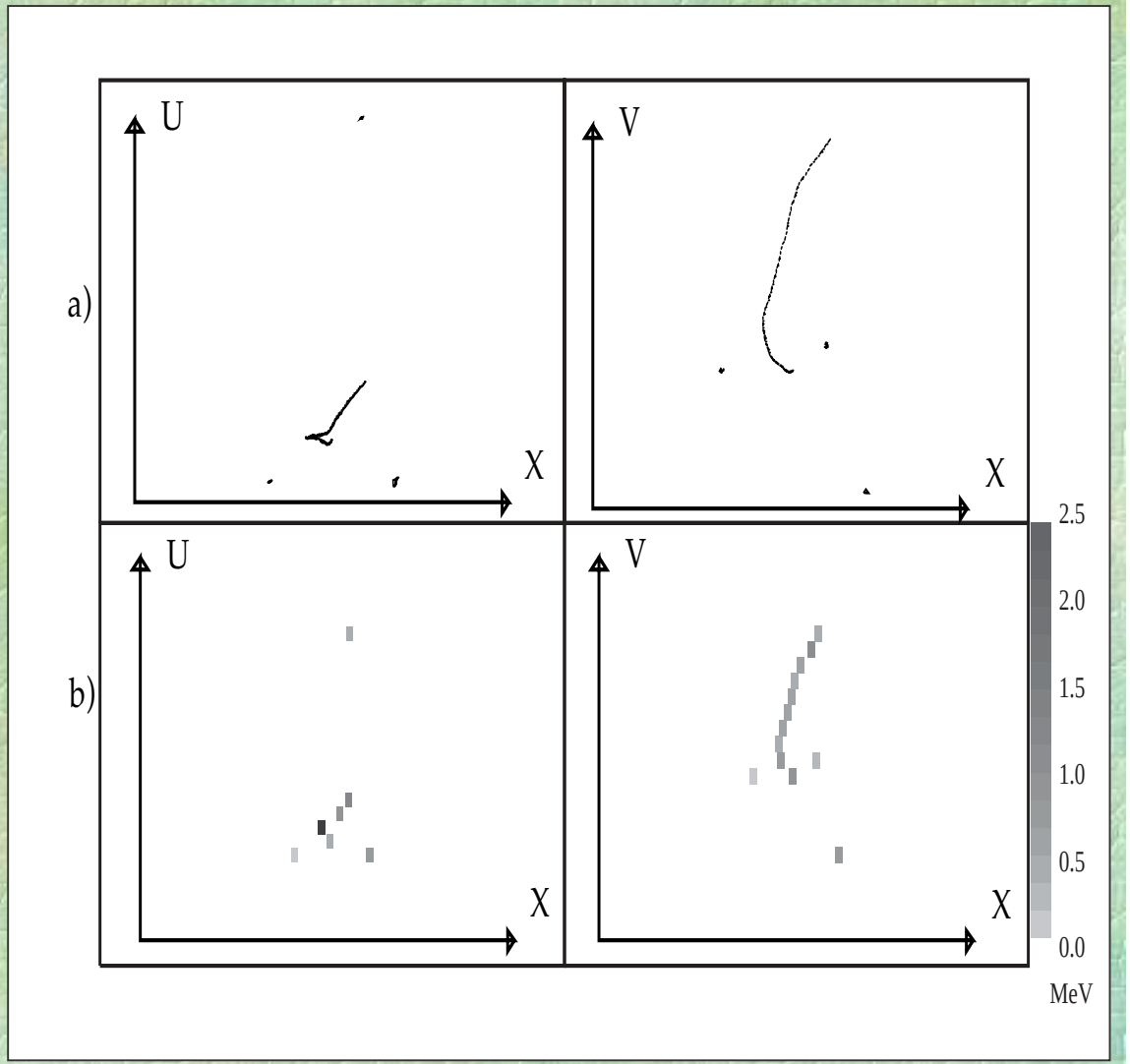
The off-line selection between elastic and absorption events is based on the energy of the main electron (primary track) and on the total associated energy and multiplicity of secondary tracks (Compton)

a) **Absorption event in two 2D views.** (*GEANT Montecarlo*)

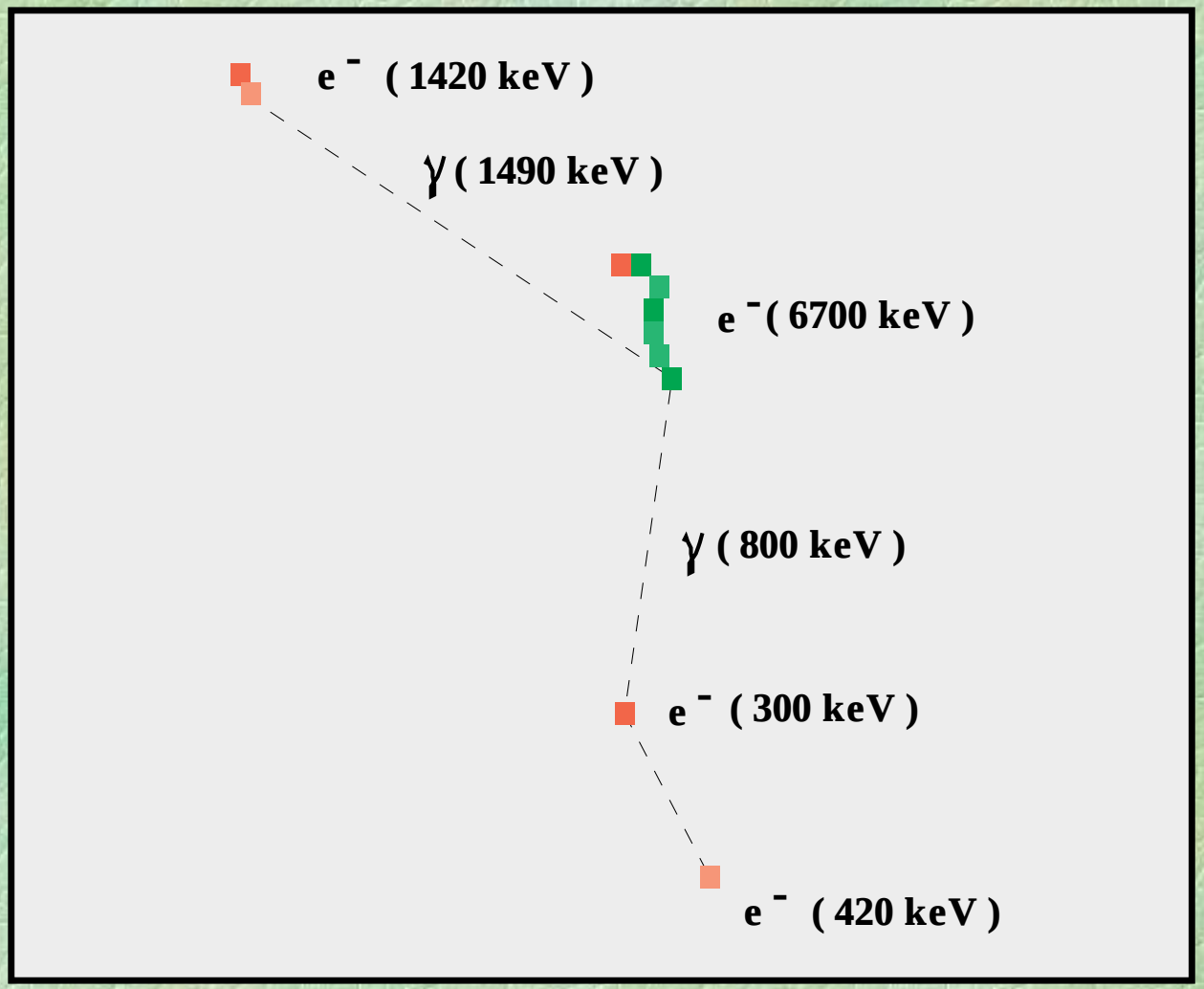
b) **Same event after digitization and hit finding algorithm.**

- *The gray scale of each pixel is proportional to the deposited charge.*
- *The resolution in the horizontal axis (drift direction) is 0.4 mm, and in the vertical axis is 3 mm (wire pitch).*
- *The projected track length is about 3 cm. The main electron energy is 7 MeV.*
- *The associated Compton energy is 2 MeV and the associated multiplicity is M=3.*

Assumed threshold for single Compton electron 150 keV



... an other *Montecarlo event* (Gamow-Teller reaction)

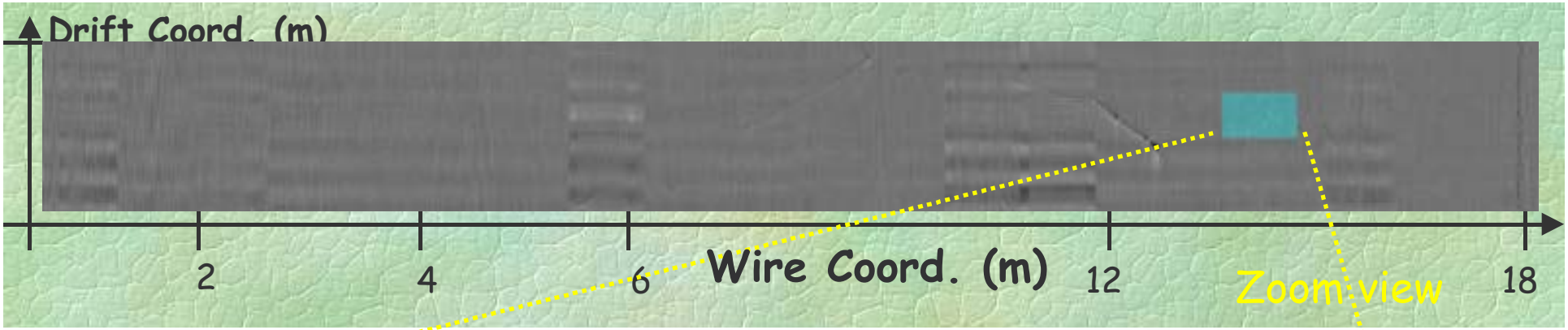


$E_{\text{primary electron track}}$ = 6700 keV

Associated Compton energy= 2140 KeV

Multiplicity of secondary tracks= 3

Compton activity limited to volume of about 50 cm radius around the primary vertex



Cosmic ray event containing a "Solar neutrino"-**like** signature

"inverse **b** reaction" type with:

- e-like track ~6.5 MeV
- 2 e-like spots from Compton conversion

End-point

~800KeV

~800KeV

0.5 m

1 m

T600 test @ Pv: Run 785 - Evt 4 (July 22nd, 2001)

Full MC simulation for determination of:

- Signal (ES, F and GT reactions) detection efficiency
- Background rejection power
- Sample contamination

ES Channel	453
Background	14
F+GT Contamination	11
F+GT Channel	1616
Background	55
ES Contamination	17

1 Kton X year Exposure

July 24th, 2001

a) Elastic scattering events

Associated Energy	Compton electron multiplicity 0	1	2	3
$E < 1$ MeV	0.880	0.073	0.008	0
$E \geq 1$ MeV	0	0.015	0.015	0.009

b) Gamow-Teller events

Associated Energy	Compton electron multiplicity 0	1	2	≥ 3
$E < 1$ MeV	0.083	0.168	0.049	0
$E \geq 1$ MeV	0	0.075	0.297	0.328

c) Fermi events

Associated Energy	Compton electron multiplicity 0	1	2	≥ 3
$E < 1$ MeV	0.032	0.039	0.018	0
$E \geq 1$ MeV	0	0.081	0.221	0.519

d) Neutron capture events

Associated Energy	Compton electron multiplicity 0	1	2	> 2
$E < 1$ MeV	0.46	0.26	0.10	0
$E \geq 1$ MeV	0	0.05	0.07	0.06

Table 1: Fraction of events with at least one electron with kinetic energy larger than 5 MeV, as a function of the Compton electron multiplicity and its associated energy. Data obtained after digitization are used.

Physics outcomes

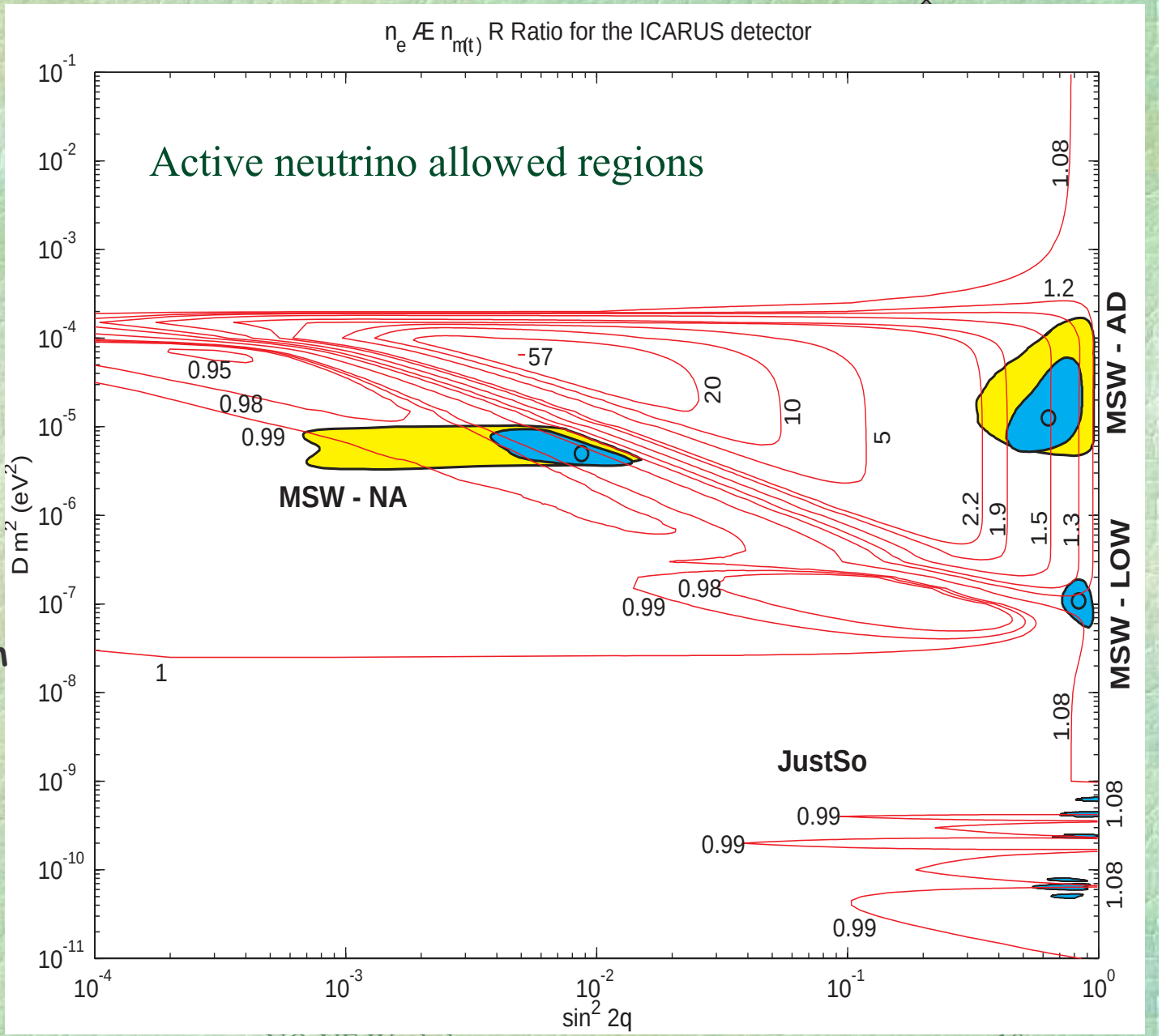
- Cross-check the present solar neutrinos phenomenology with a real-time high resolution technique
- Direct test of the oscillations hypothesis for a good fraction of the allowed regions by means of the elastic to absorption channels ratio
- Discriminate active from sterile neutrino oscillations
- Precision test of the MSW mechanism by observation of spectral distortions (with Absorption events).

ICARUS Sensitivity:

Iso-R Curves

$$R = \frac{\frac{N^{elastic}}{N_0^{elastic}}}{\frac{1}{2}\left(\frac{N^{GT}}{N_0^{GT}} + \frac{N^{F}}{N_0^{F}}\right)}$$

Shaded regions: Allowed solutions from Present Solar nExp.s (Homestake, Gallex, Sage and SuperK) [90% and 95% CL]



active neutrino

Conclusions

• The ICARUS Technology is now fully operational at experimental scale (T600 detector is presently taking data in a surface test).

•After many years of technological development, it may start acting as a new, high resolution, real-time "player" in the Solar-**n** "game" (after installation in the GranSasso underground site).

•Two solar-**n**reactions in LAr are available, well separated in signature and available at rather large statistics for SSM model independent study.

• Possibility of enlarging the LAr mass at GS are under evaluation

☛ to find more about solar neutrino physics with Icarus: **N.I.M.** A455 (2000), 376.
☛ to find more about ICARUS: www.aquila.infn.it/icarus or www.cern.ch/icarus/