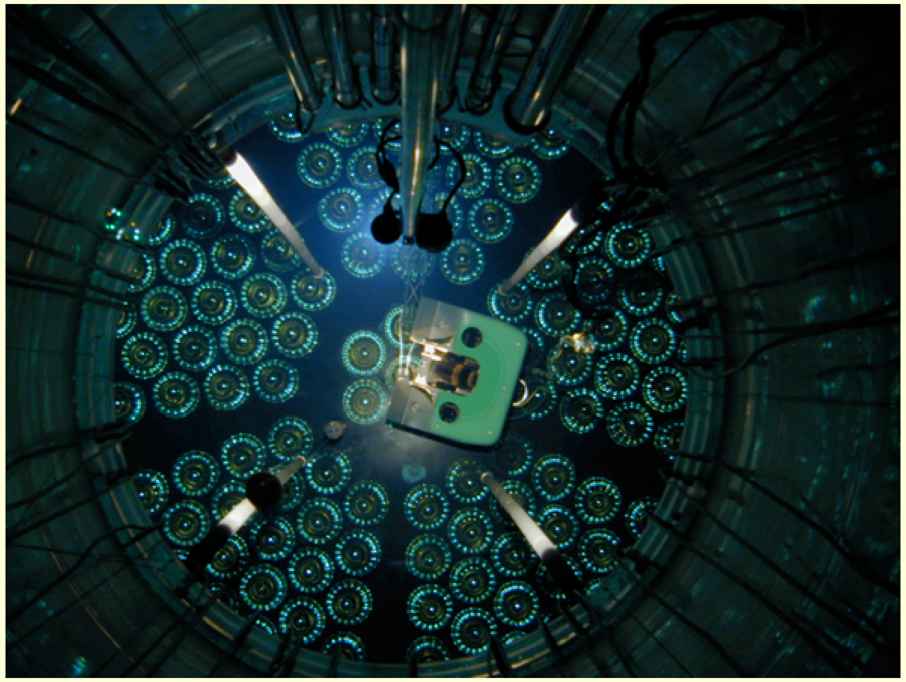
News from the Sudbury Neutrino Observatory (SNO)

Christine Kraus

TAUP conference, Sendai, Japan

September 12th, 2007

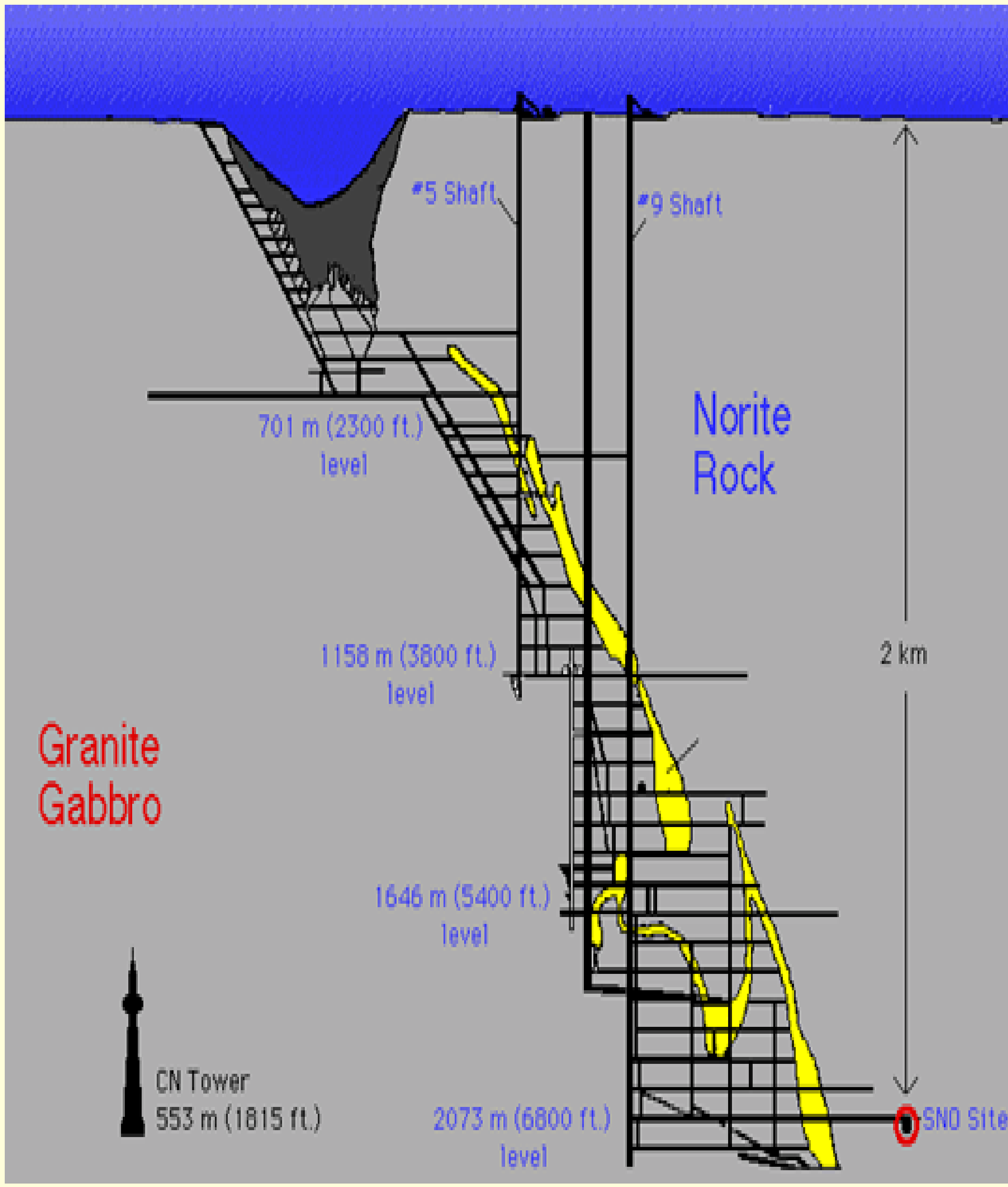


- SNO experiment
- Phase III analysis - Status
- What to expect (next few Month)

The SNO detector

located: INCO Creighton mine, Sudbury, Ontario, Canada

2039 m underground (6000 mwe)



DCR = Deck Clean Room

1000 tonnes D2O

12 m acrylic vessel

1700 t H2O (inner)

18 m PSUP

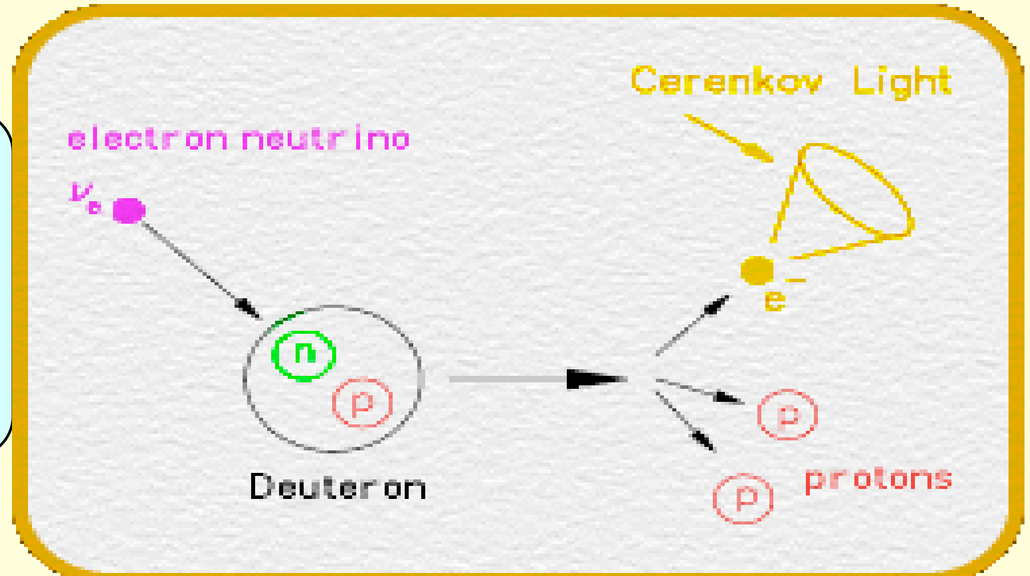
5300 t H2O (outer)

~9500 PMTs
54% coverage

Reactions in the SNO detector

Charged Current (CC)

$\nu_e + d \rightarrow p + p + e^-$



some directional info

$(1-1/3\cos\theta_{sun})$

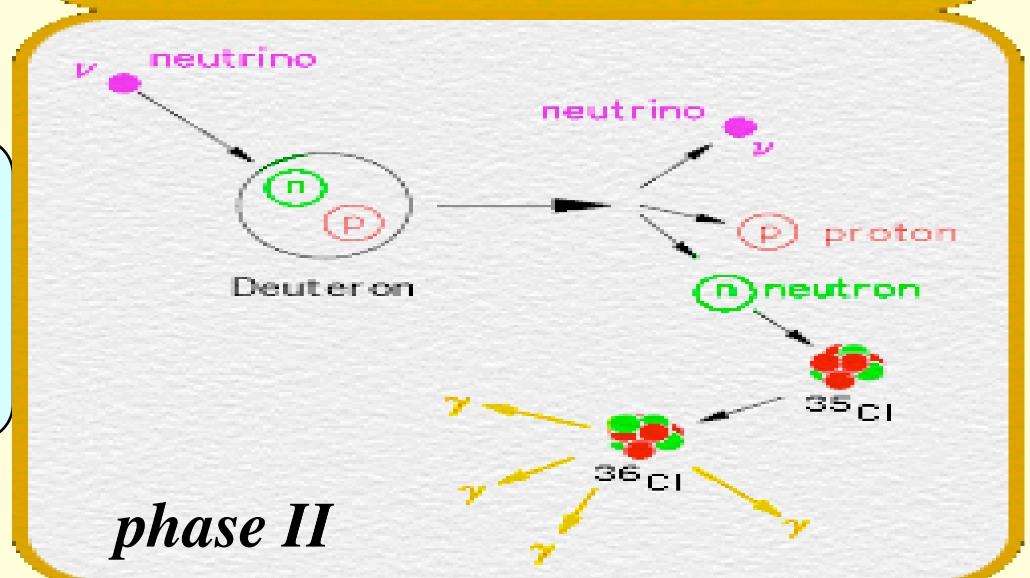
only sensitive to ν_e

good E_ν sensitivity

unique!

Neutral Current (NC)

$\nu_x + d \rightarrow \nu_x + p + n$



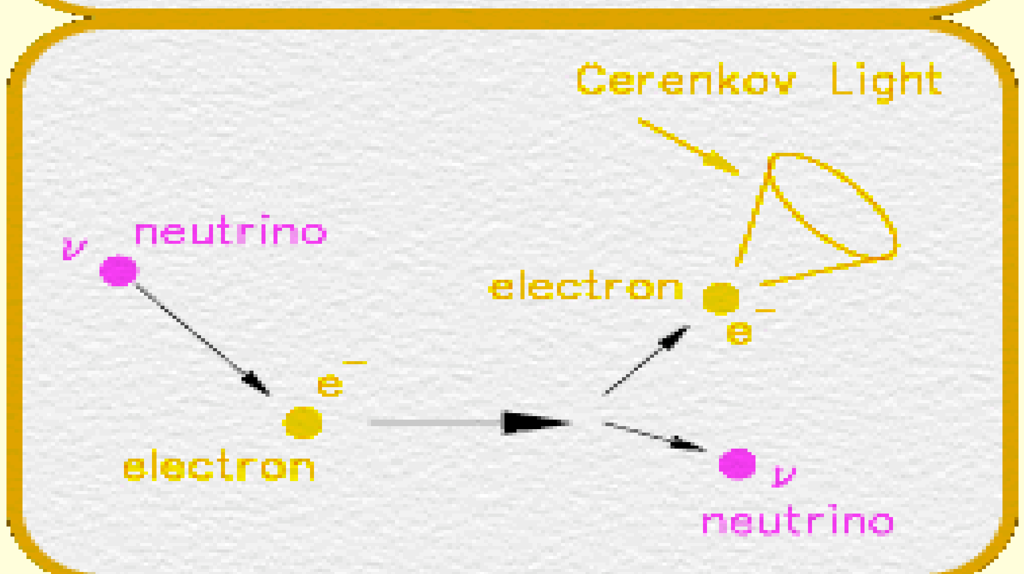
equally sensitive to all

active flavours

detect neutron capture

Elastic Scattering (ES)

$\nu_x + e^- \rightarrow \nu_x + e^-$

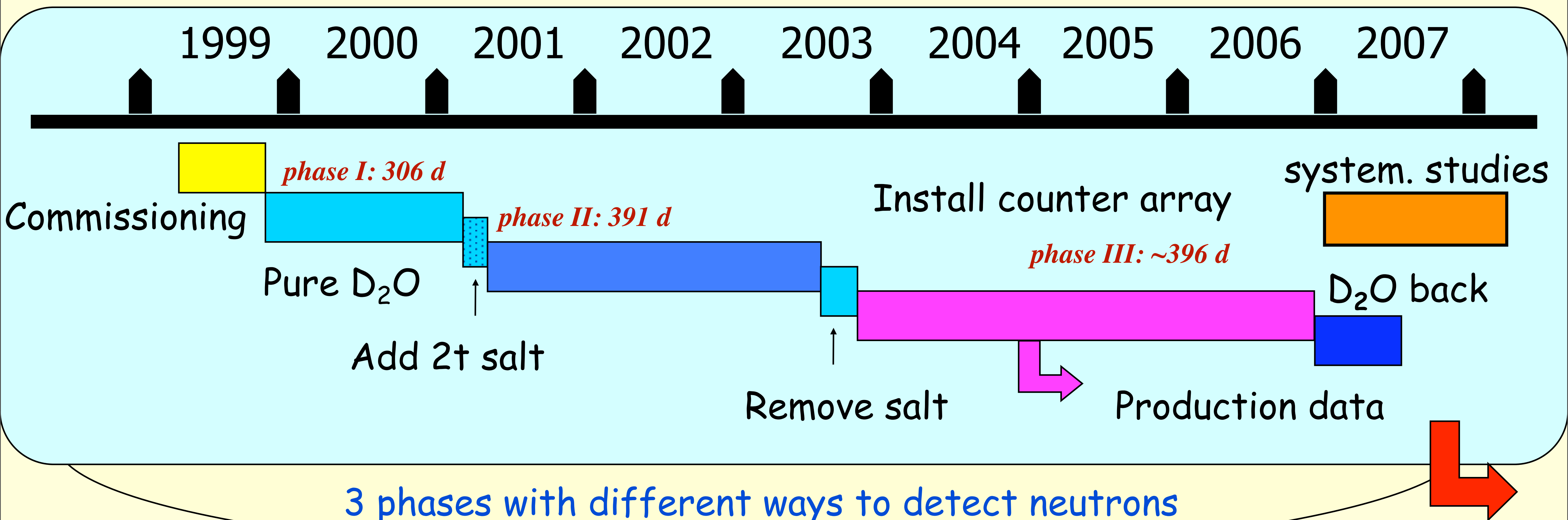


directional sensitivity

mostly ν_e (factor 6.5)

smaller cross section

Time line



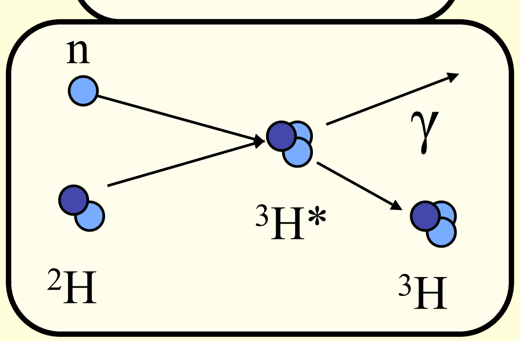
3 phases with different ways to detect neutrons

now

n captures on deuterium

$\sigma = 0.0005$b

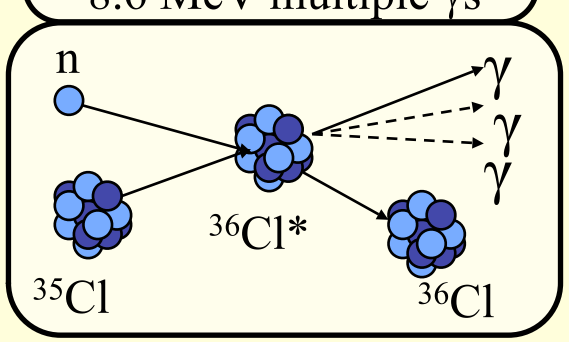
6.25 MeV γ



n captures on chlorine

$\sigma = 44$b

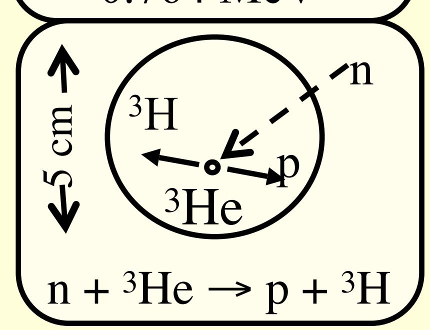
8.6 MeV multiple γs



n captures on ^{3}He prop. counter array

$\sigma = 5330$b

0.764 MeV



determine CC, ES flux --> compare to other exp., find deficit

determine NC flux --> measure total flux from ^{8}B ν's, compare to calculations

391 days salt data – in numbers

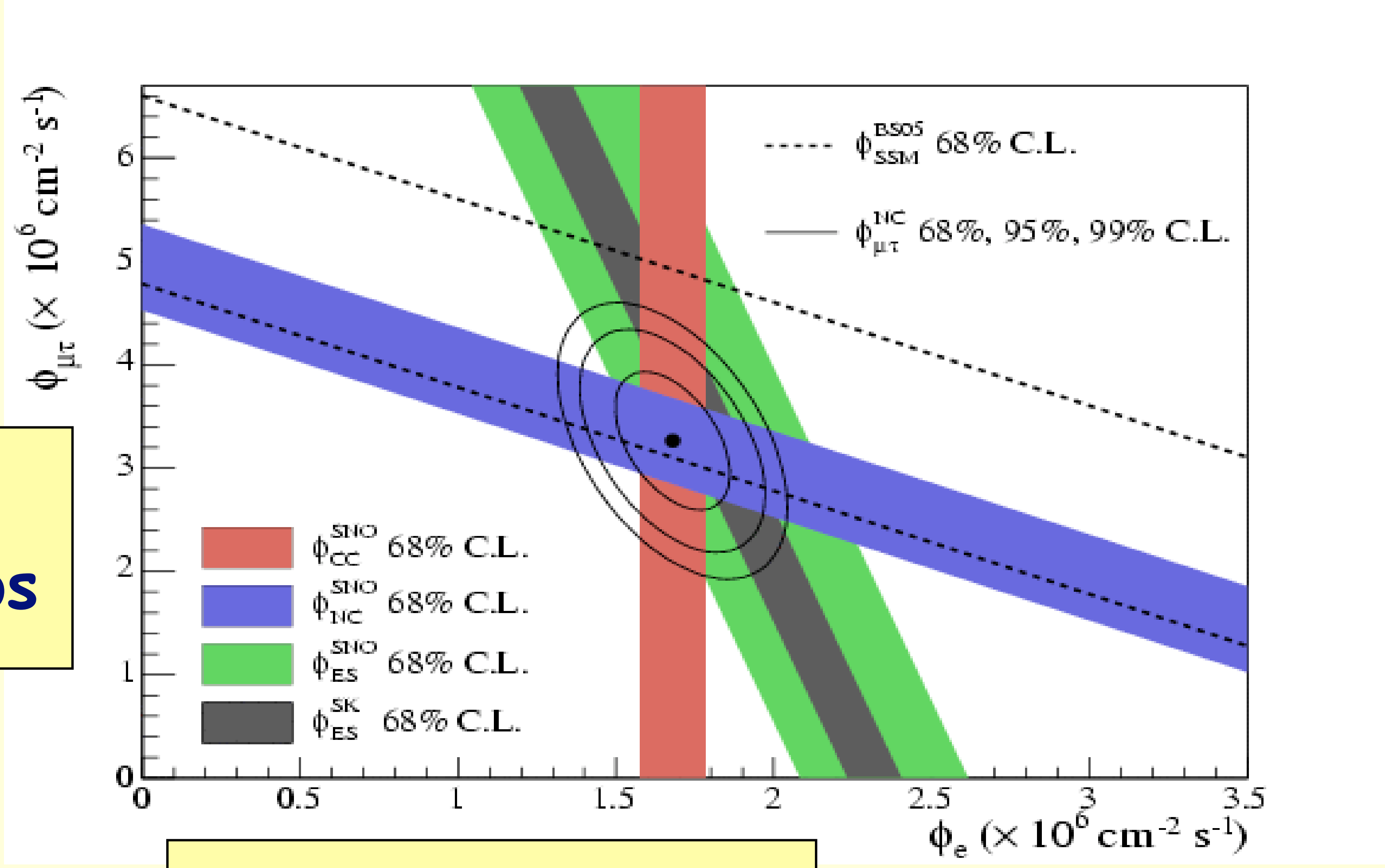
$$\phi_{CC} = 1.68\ ^{+0.06}_{-0.06}(\text{stat.})^{+0.08}_{-0.09}(\text{syst.})$$

$$\phi_{NC} = 4.94\ ^{+0.21}_{-0.21}(\text{stat.})^{+0.38}_{-0.34}(\text{syst.})$$

$$\phi_{ES} = 2.35\ ^{+0.22}_{-0.22}(\text{stat.})^{+0.15}_{-0.15}(\text{syst.})$$

$$\frac{\phi_{CC}}{\phi_{NC}} = 0.340 \pm 0.023(\text{stat.})^{+0.029}_{-0.031}$$

(In units of $10^{6}\,\text{cm}^{-2}\text{s}^{-1}$)



μ, τ **neutrinos**

electron ν

fluxes for all neutrinos

SNO solves the solar neutrino problem

Phase III - He-3 counters (NCDs)

Physics Motivation

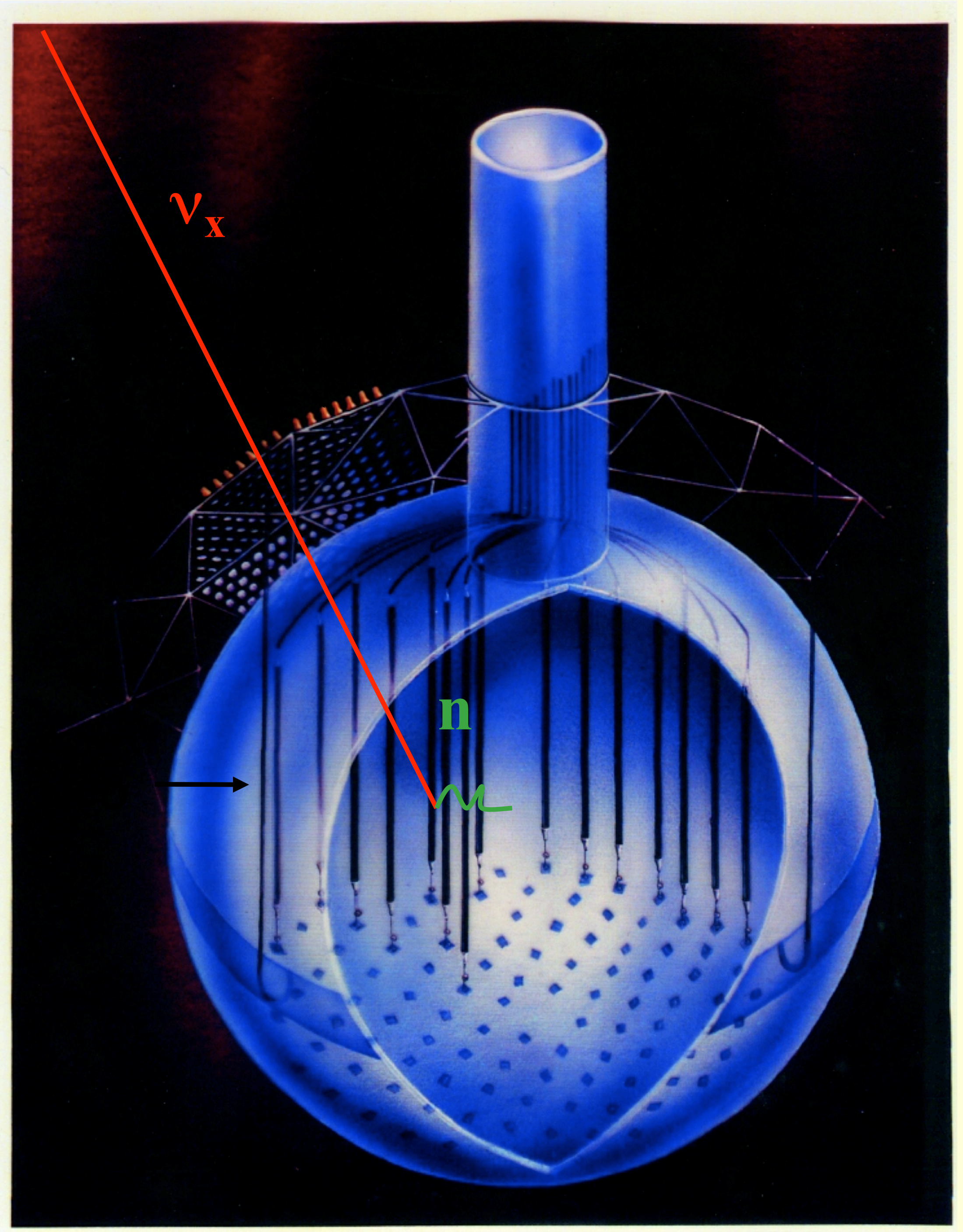
Event-by-event separation. Measure NC and CC in separate data streams.

Different systematic uncertainties than neutron capture on NaCl.

- ^{3}He Proportional Counters were installed (april 2004)

40 strings – 1m grid

→ 440 m total active length



Detection Principle

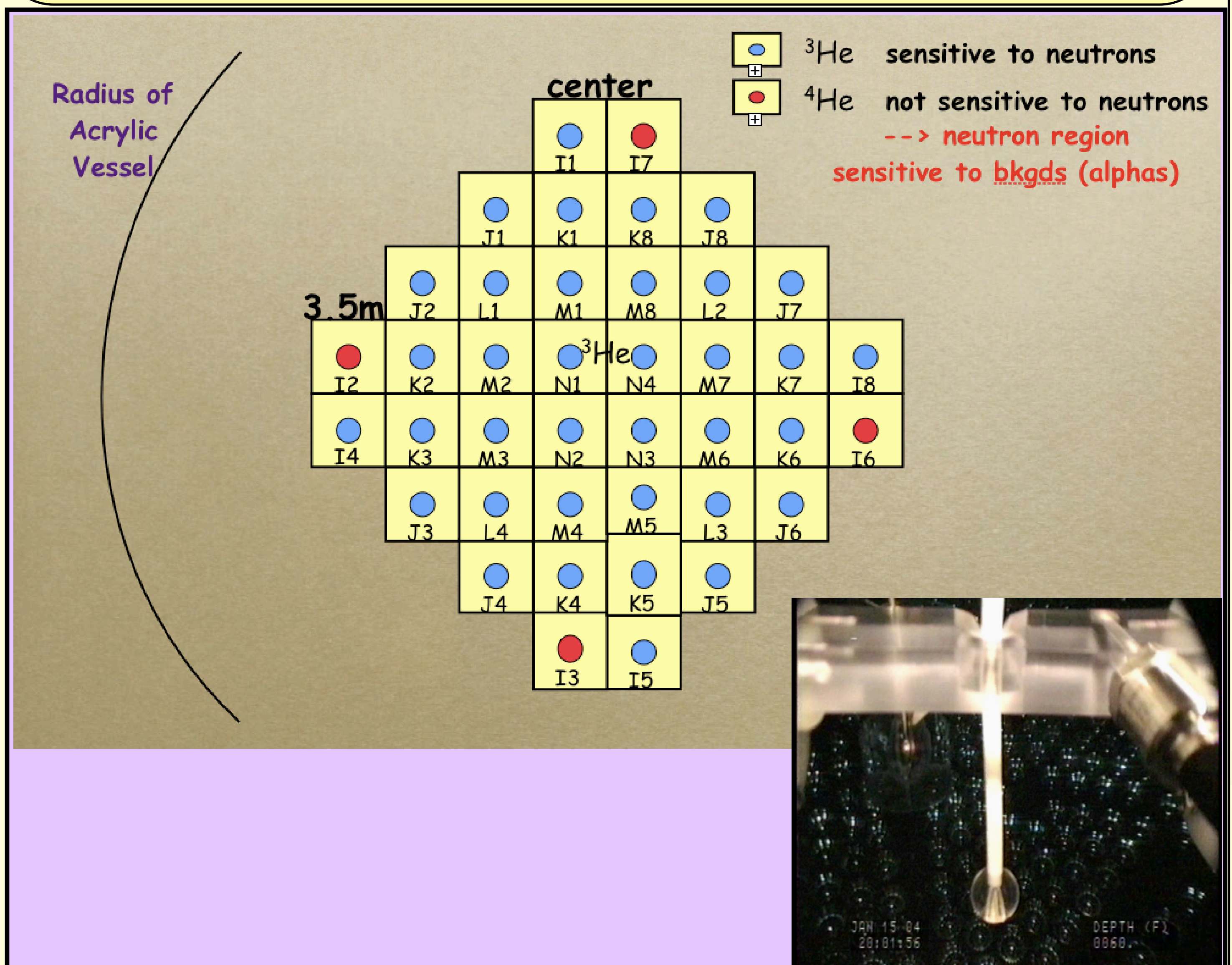
$^2H + \nu_x \rightarrow p + n + \nu_x - 2.22$ MeV (NC)

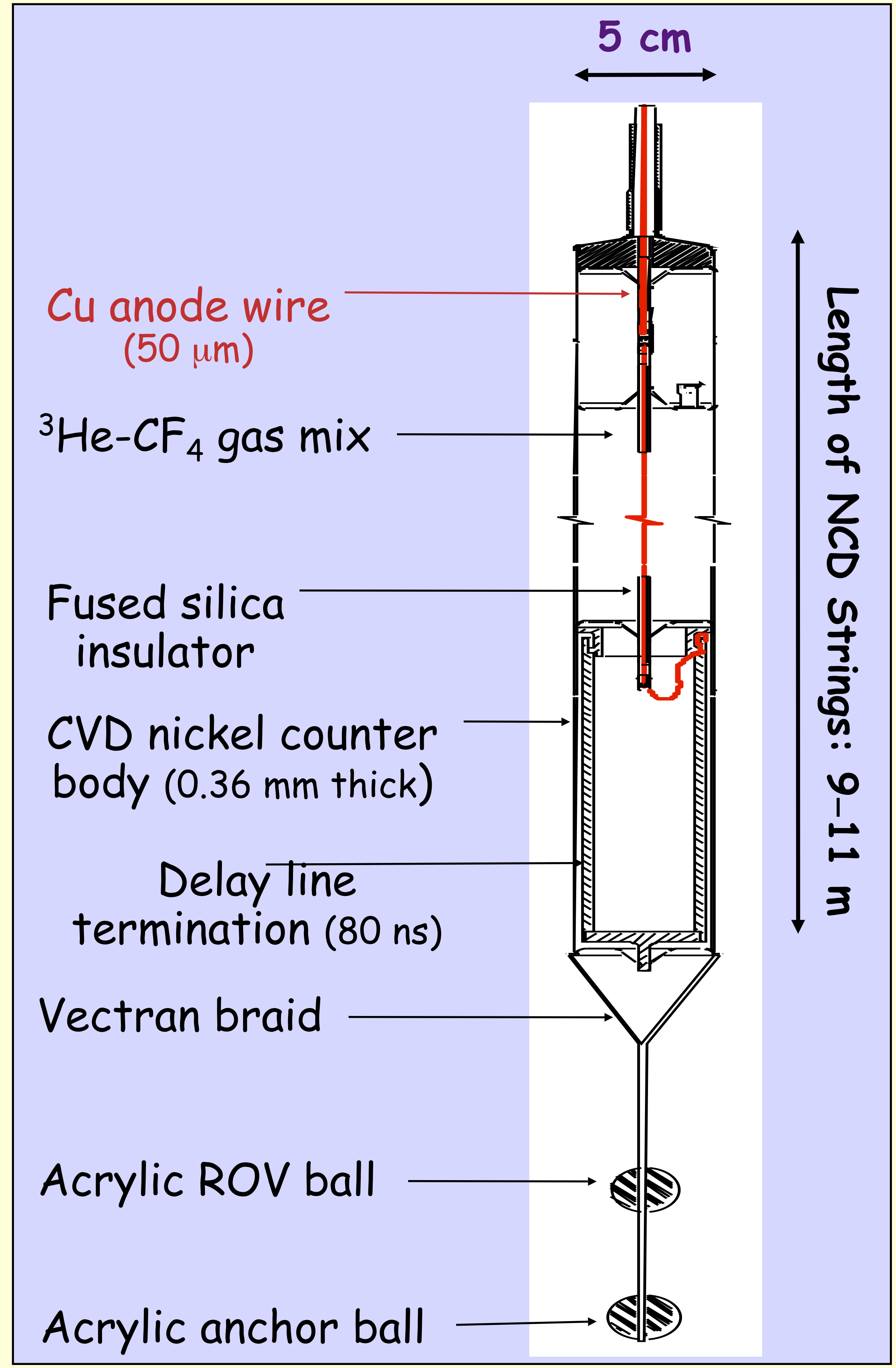
NCD: $^3He + n \rightarrow p + {}^3H + 0.76$ MeV

SNO neutral current detection array (NCDs)

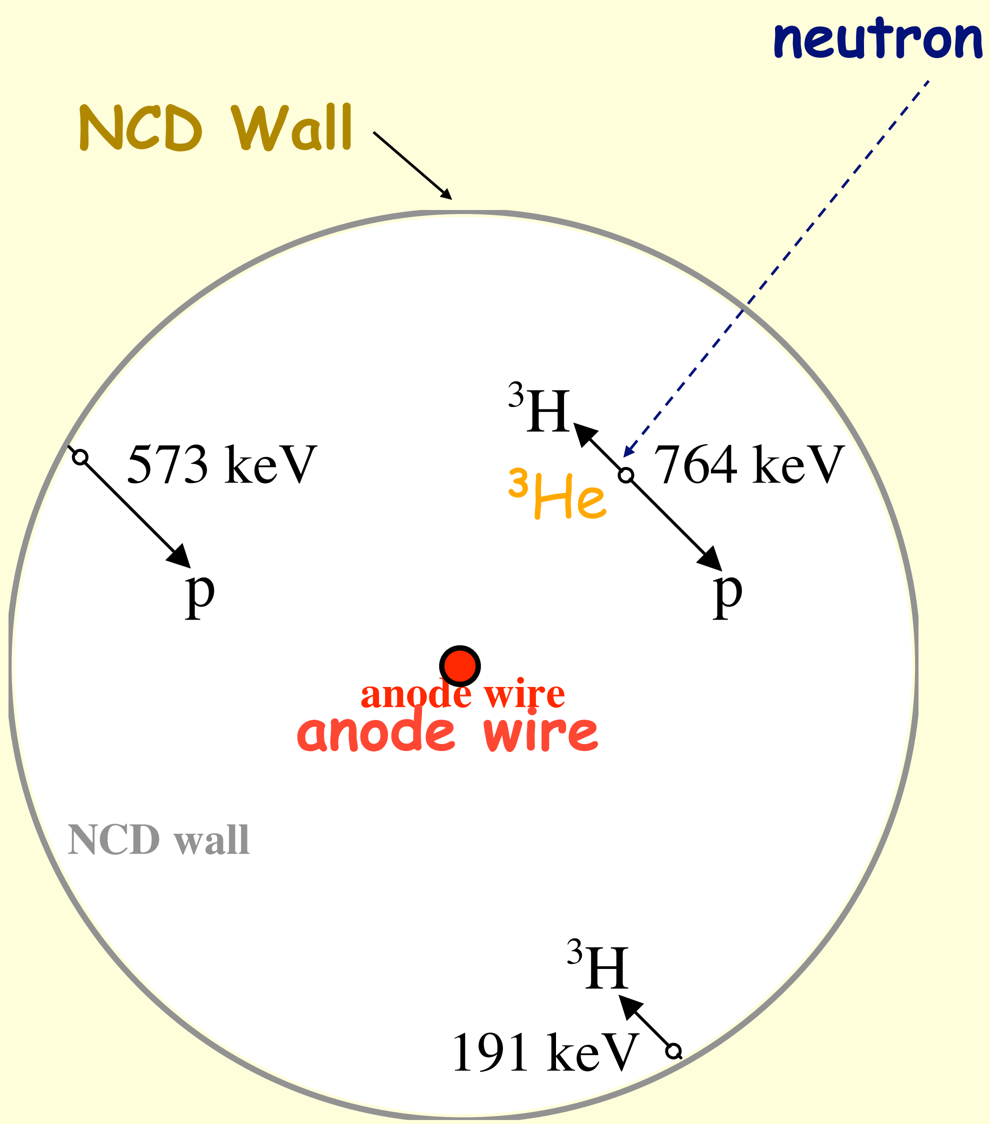
NCD Specifications:

- neutron detection: $^3He + \mathbf{n} \rightarrow {}^3H + p$
- active Gas: ^3He-CF_4 [85:15] at 2.5 atm.
- operating voltage: 1950 V (gain ~200)
- radiopurity: <10 ppt U,Th (<4% SSM)

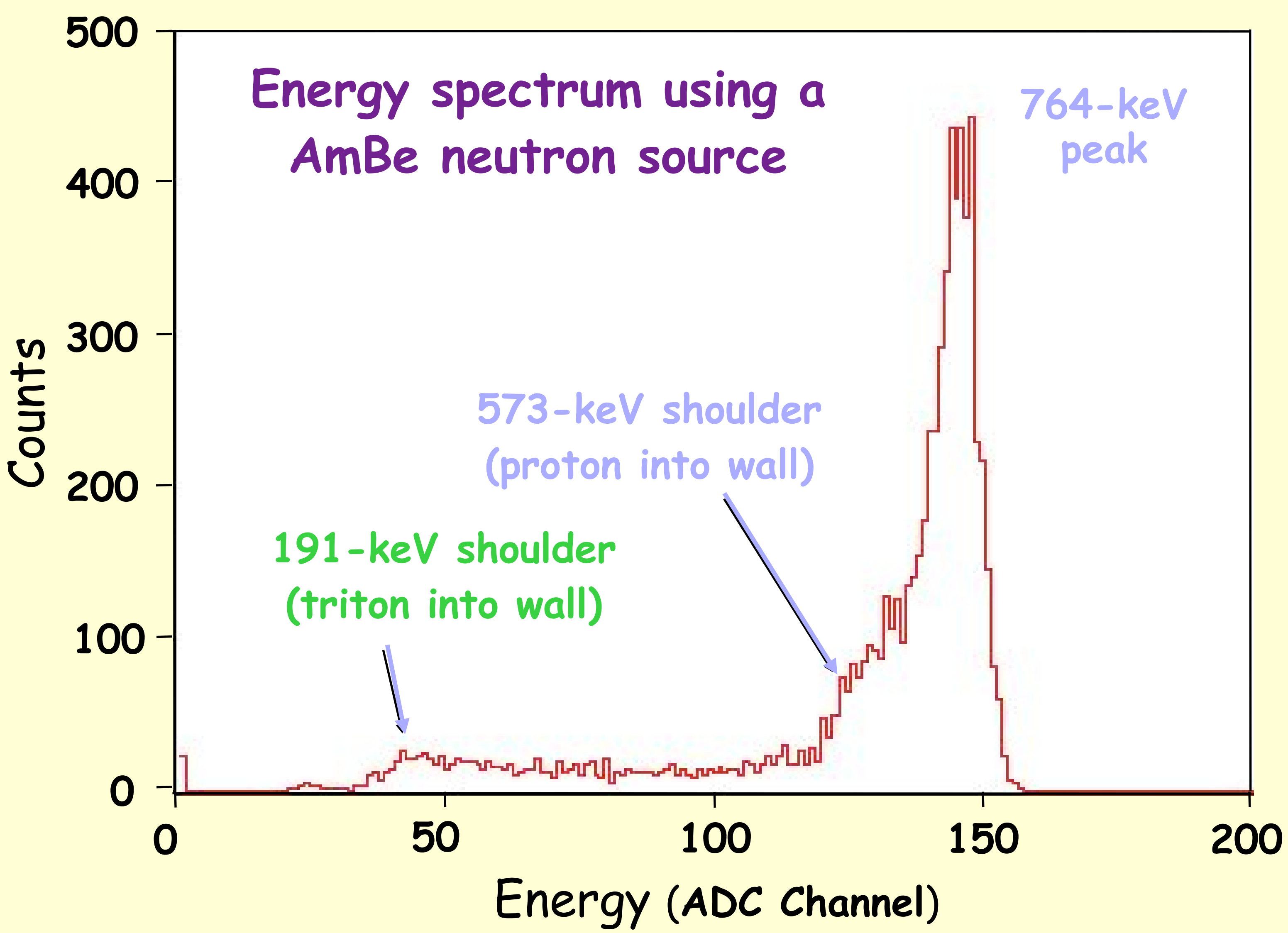




NCD spectrum



End view of an NCD with representative ionization tracks

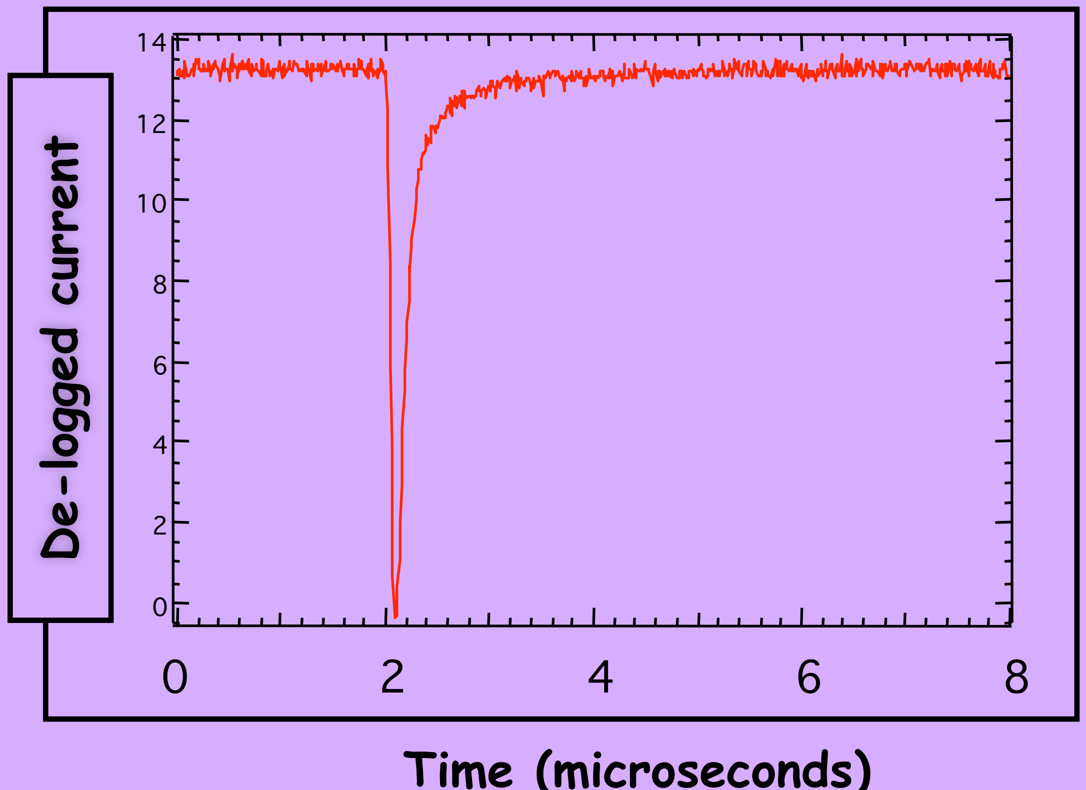


Energy spectrum from a single deployed ^{3}He proportional counter. The main peak corresponds to the 764-keV Q-value of the ^{3}He(n, p)^{3}H reaction.

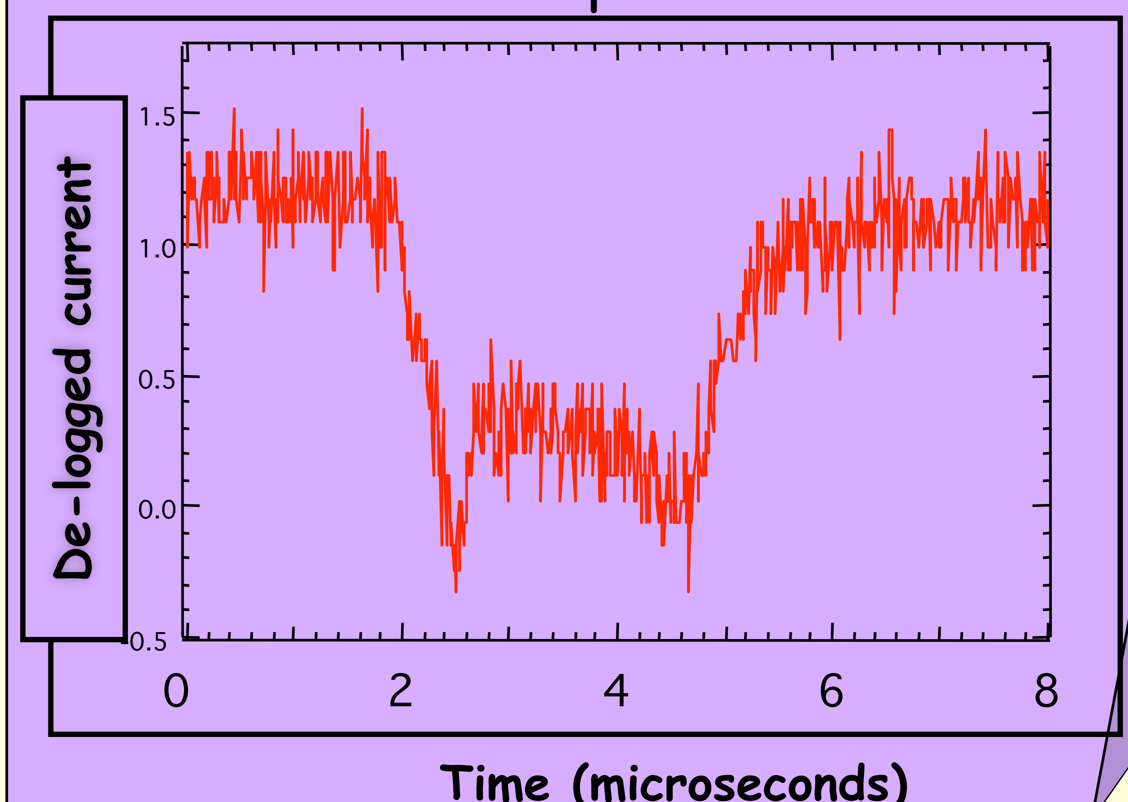
NCD pulse shapes

Pre-amplifiers digitize pulse shapes for particle identification

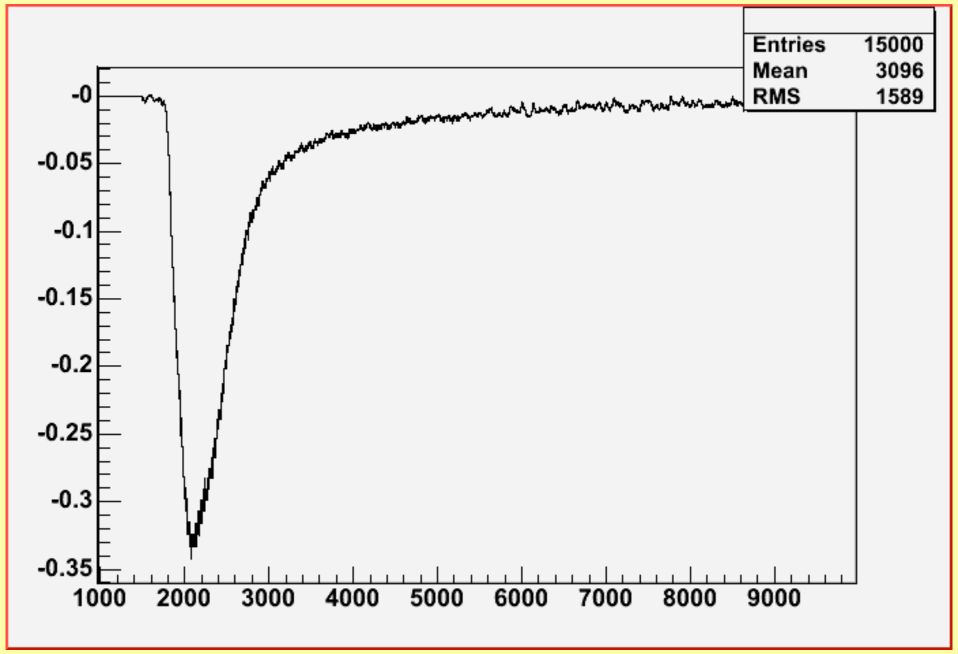
neutron with p-t track || wire



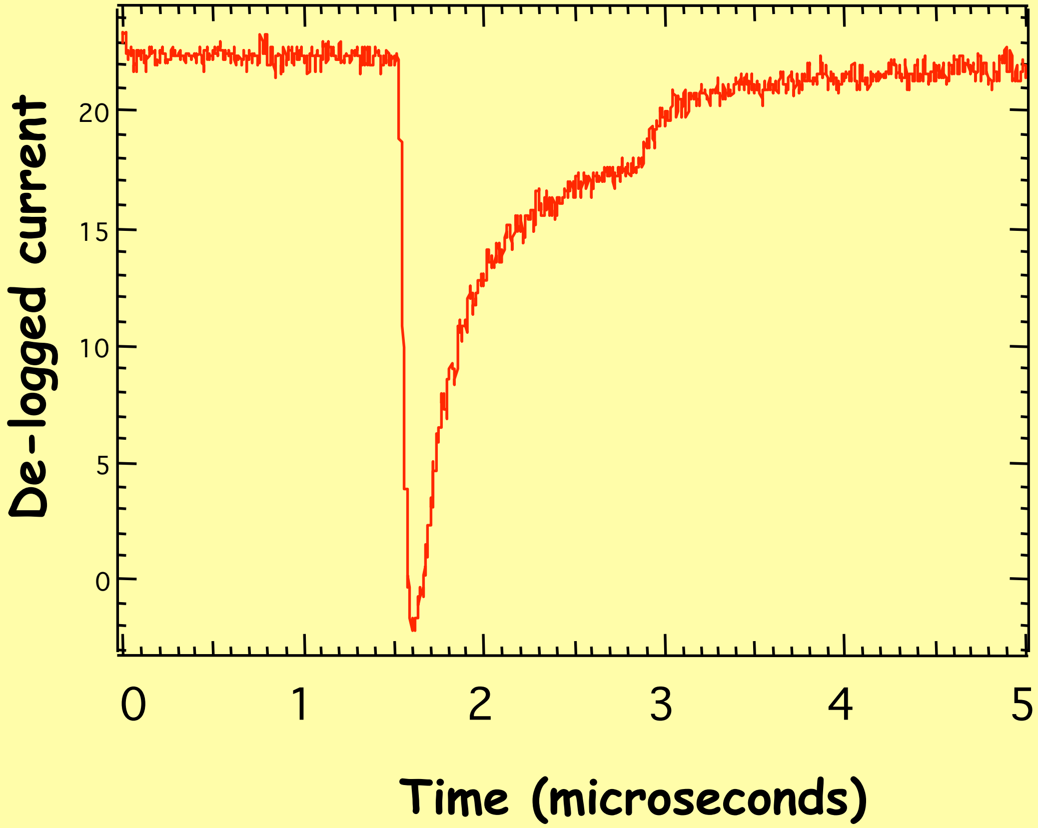
neutron with p-t track ⊥ wire



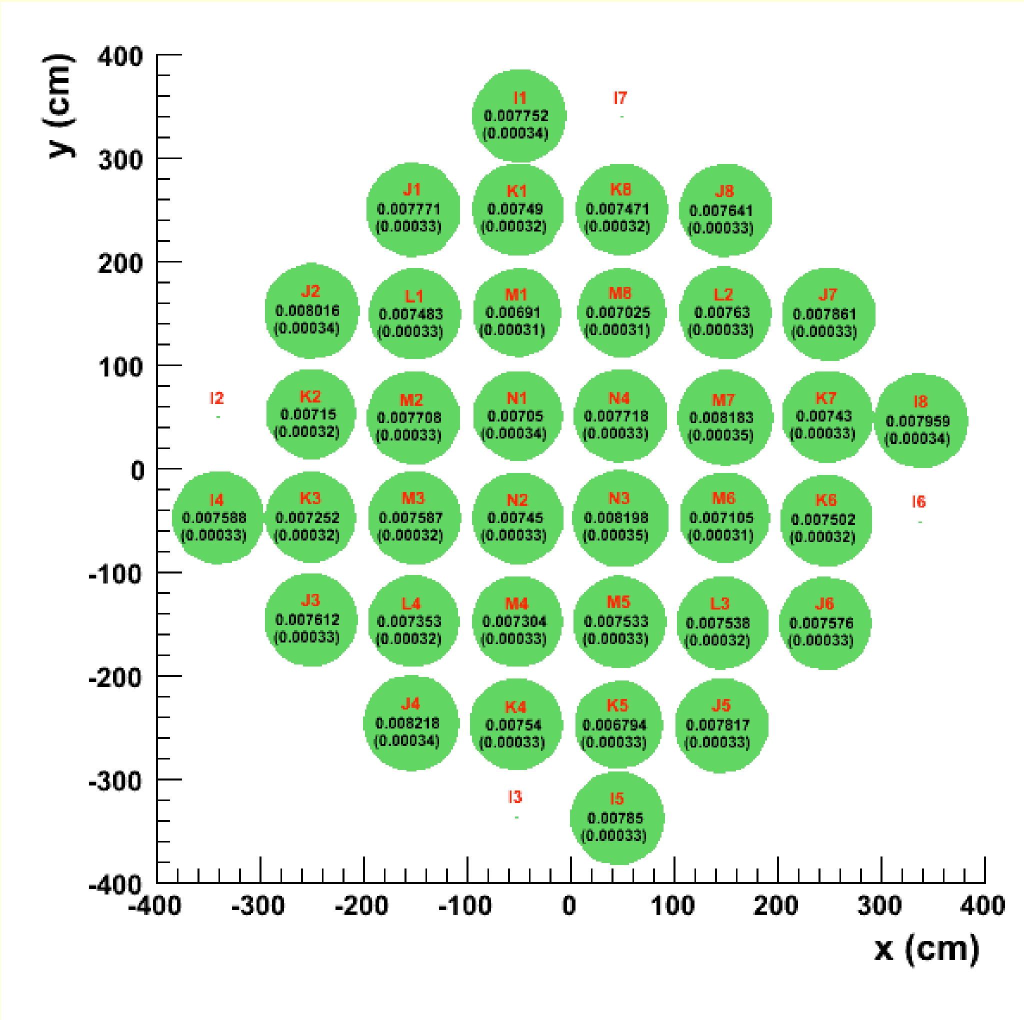
α track || wire

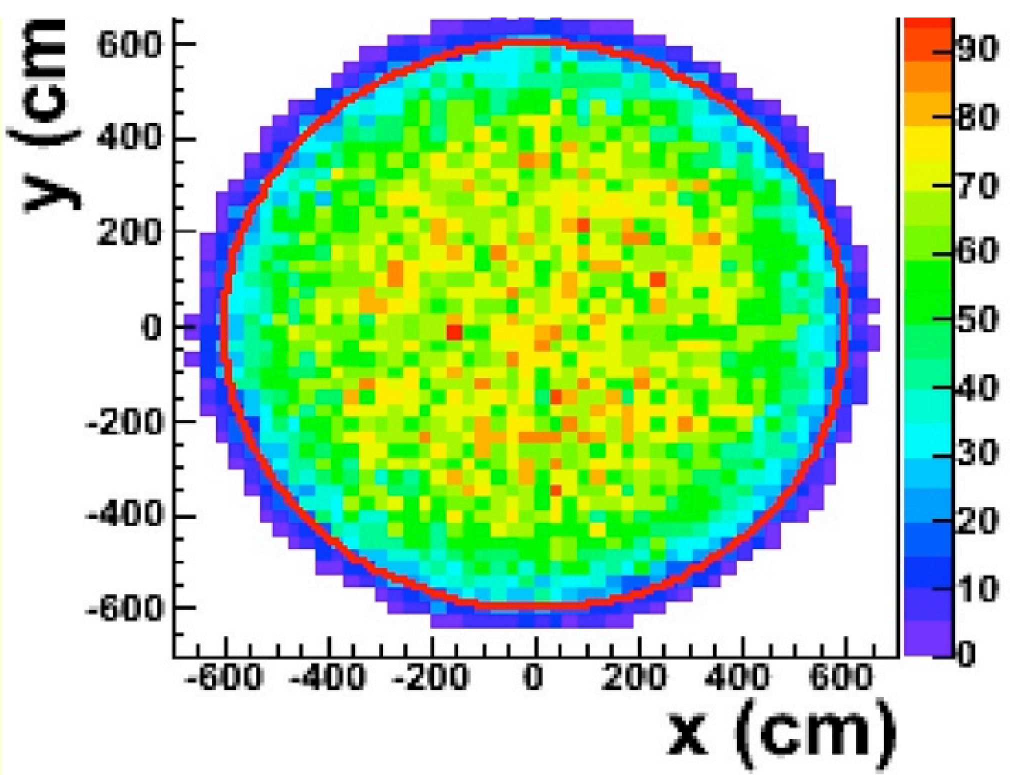


α track ⊥ wire



Calibration - neutrons - 24Na (example)





determine total neutron efficiency of array

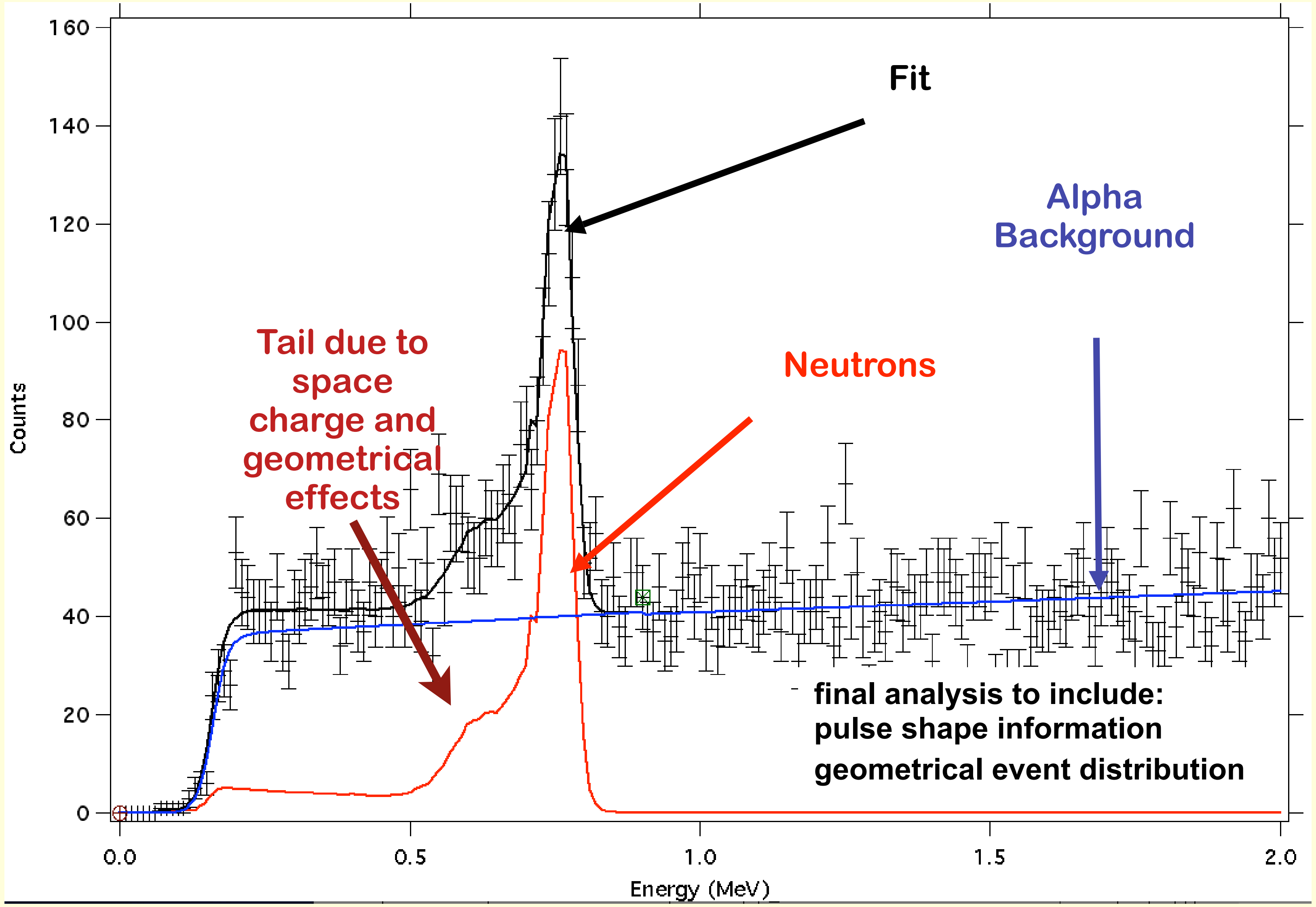
add 2l of activated 24NaCl-D2O brine into SNO and mix until uniformly distributed

several methods used for source strength determination

NCD neutron capture efficiency: (26.7 +/- 0.7)%

array eff.: 64% (2.5% rel. err.)

Analysis scheme for NCD data

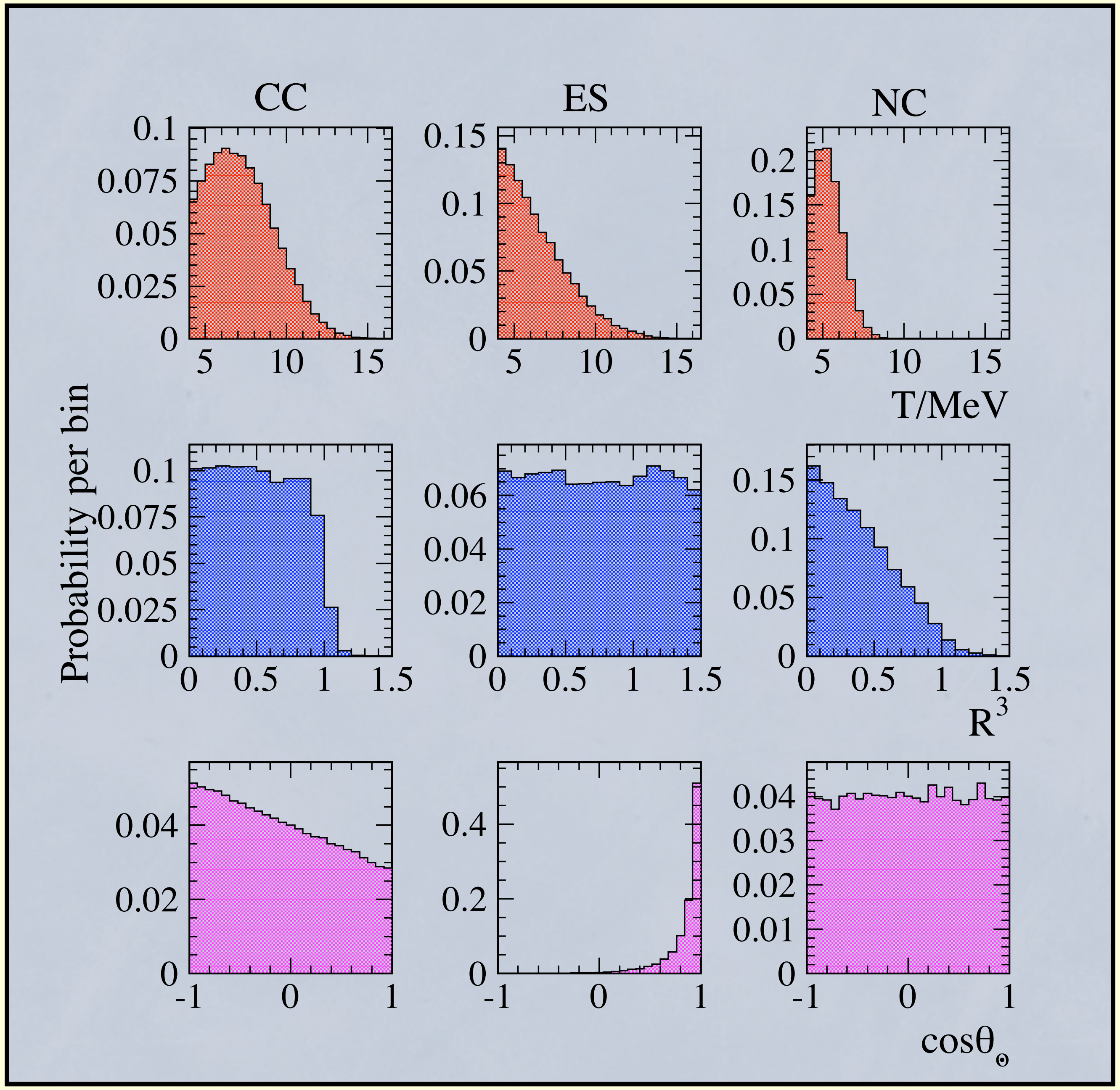


- do energy fit
- subtract background
- use pulse shape discrimination
- use neutron calibration data to determine eff. and capture and neutron shape

Collaboration has developed 4 pulse shape discrimination methods
Determination of systematic uncertainties well under way
MC efforts for NCD pulse shapes well under way
Fit of final spectral form will determine number of neutrons detected in the NCD array, after all corrections (measured with help of calibration data) have been applied.

SNO pdf* fit method

- Each physics process has typical signature in energy, radial profile and angle towards the sun
- This allows statistical separation of events
- in third phase the NC events in D_2O are largely suppressed by ^{3}He neutron capture. That allows charged current measurement with lower uncertainty (goal 3.3% instead of 5.3% phase I and 4.5% phase II)



*probability density function

NCD phase PRL: SOON

- including: NCD NC flux measurement
- including: CC flux (PMTs)
- including: ES (PMTs)
- including: external backgrounds
- very close to projected systematic uncertainties (~ 5-6% for NC, ~3-4% in CC)

complete data set processed (close), systematic studies well under way

Other ongoing analysis: LETA

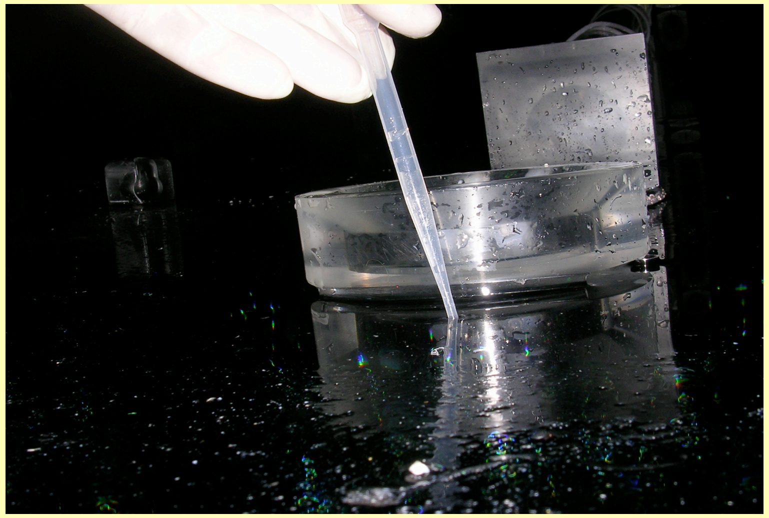
LETA = Low Energy Threshold Analysis

- Combining phase I and II (D2O and SALT)
- Pushing energy threshold as low as possible (3.5 MeV instead of 5.5 MeV before)
- Increase statistics, improve analysis, include background PDFs, decrease systematic uncertainty
- Final systematic uncertainty studies ongoing (substantial improvement), expect publication in the next few months

Since end of data taking

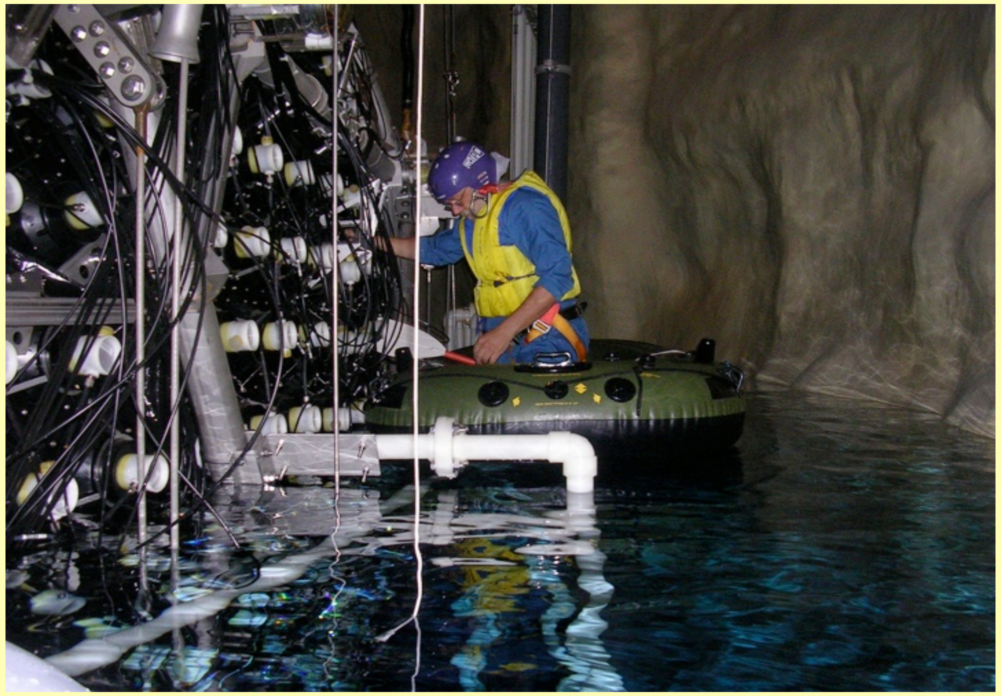
data taking ended Nov. 28th, 2006

40 NCD's removed

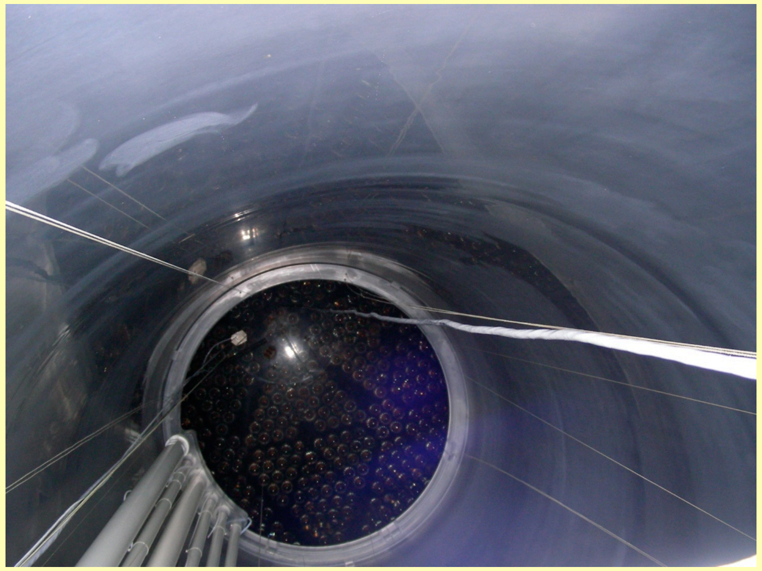


D2O removed

D2O shipped



boating expeditions



empty vessel

H2O removed

systematic studies:
determine radioactivity (NCDs, AV), ...