Neutrinos et accélérateurs: vers la 3ème saveur

André Rubbia (ETH, Zürich)

Le neutrino dans tous ses états: Journée Jacques Bouchez

19 Novembre 2010

Back in 1997...

THE FUTURE OF NEUTRINO OSCILLATIONS AT ACCELERATORS

Jacques Bouchez
DAPNIA, CEA Saclay

Invited talk at the 32^{nd} rencontre de Moriond on electroweak interactions and unified theories

Les Arcs, France 15-22 march 1997

Abstract

The future neutrino oscillation experiments at accelerators are reviewed. Long baseline experiments will address the atmospheric neutrino anomaly. Intermediate baseline experiments will be sensitive to the LSND effect. Short baseline experiments will increase our sensitivity on mixing parameters by an order of magnitude in the domain of cosmologically relevant neutrino masses.

1 The present situation and strategies for the future

Presently, there exist several indications of neutrino oscillations, that is the possibility for neutrinos born in a given flavor to develop components in the other flavors, the probability of such an occurence showing an oscillatory pattern with time. Such a phenomenon implies neutrino masses and a mismatch between mass eigenstates and flavor eigenstates, leading to lepton number violation. More specifically, in the 3-family case, the conversion probability for a ν_α of energy E_ν to interact at a distance L as a ν_β is given by (assuming CP conservation, which implies that a real rotation matrix U links the flavor eigenstates to the mass eigenstates):

$$P_{\alpha\to\beta}(L) = \delta_{\alpha\beta} - a_{12}\sin^2\theta_{12} - a_{13}\sin^2\theta_{13} - a_{23}\sin^2\theta_{23}$$

with

$$a_{ij} = 4U_{\alpha i}U_{\alpha j}U_{\beta i}U_{\beta j}$$

and

$$\theta_{ij} = \frac{m_j^2 - m_i^2}{4} \times \frac{L}{E_\nu}$$

J. Bouchez, Moriond 1997

Three indications of ν oscillations

The 3 present indications of oscillations come from solar neutrino experiments [1], from atmospheric neutrinos [2], and from the Los Alamos experiment [3]. The explanations in terms of oscillations correspond to 3 very distinct mass scales, respectively 10^{-5}, 10^{-2} and 1 eV^2. It is clear that in a 3-family scheme, at least one of these experiments has to be either wrong or uncorrectly interpreted in terms of oscillations, since only two different mass scales should be present. To clarify the situation, it is crucial to check these results with other experiments, using if possible different techniques to decrease the chance of unidentified common systematic effects.

Finally, in front of the somewhat confused present situation, another totally legitimate strategy is to focuss on unexplored domains of oscillation parameters. In particular the domain of high neutrino masses (above a few eV) is of cosmological relevance as it could explain at least part of the dark matter in the Universe. Two accelerator experiments (CHORUS and NOMAD) are presently searching for ν_τ appearance with a sensitivity of a few 10^{-4} on the oscillation amplitude. These are short baseline experiments (L/E $\simeq$ 0.05 km/GeV). And projects are underway to gain an order of magnitude on the oscillation probability at high masses.

J. Bouchez, Moriond 1997

Jacques' conclusions in 1997

5 Conclusion

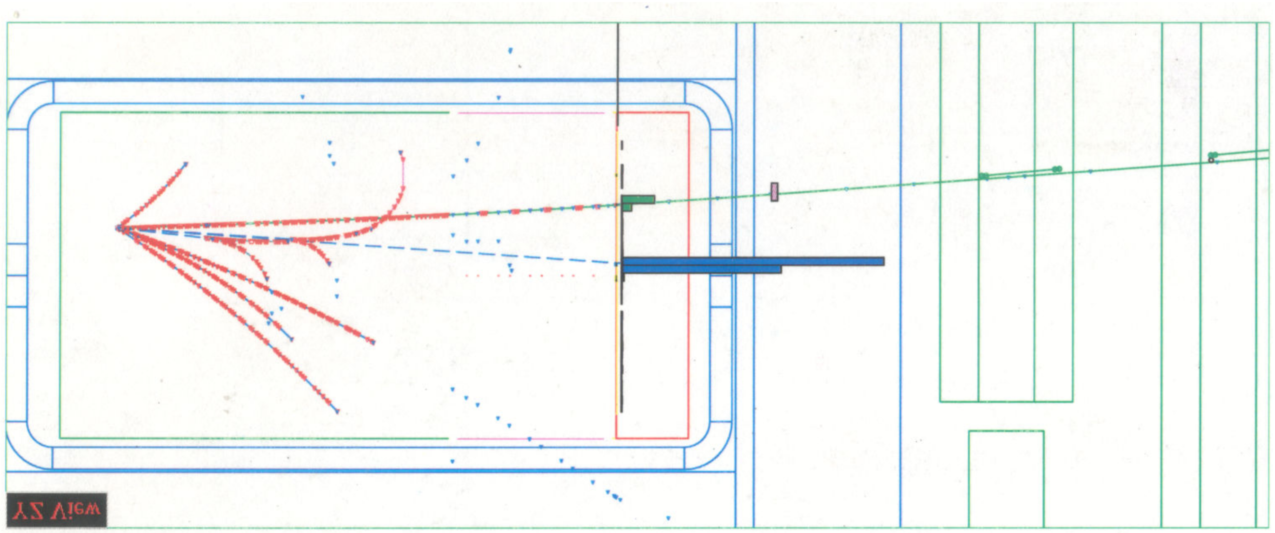
Although the present situation on neutrino oscillations is somewhat confused, the experimental efforts, present and future, will hopefully help in clarifying the situation. The first results to come, within a few months, are those of CHOOZ and SuperKamioka; they will have a big influence on the interest of long baseline experiments. On the other hand, the LSND result has to wait 2 or 3 years before being confirmed or disproved by KARMEN; a confirmation would give a considerable importance to the JURA experiment, the only one able to test ν_τ appearance. Of course, positive indications of oscillations in CHORUS and NOMAD would add to the confusion, and make the next generation of short baseline experiments absolutely mandatory.

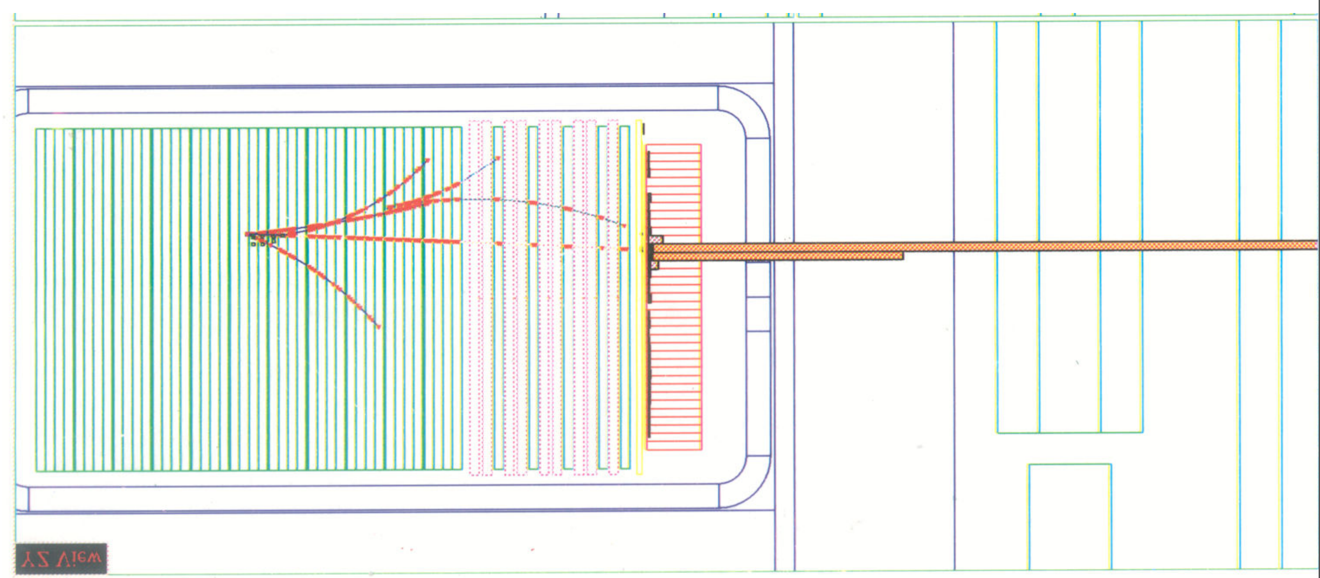
J. Bouchez, Moriond 1997

NOMAD and CHORUS at CERN WANF (1993-2000)

The NOMAD experiment (1993-2000)

Neutrino Oscillation MAgnetic Detector- WA96



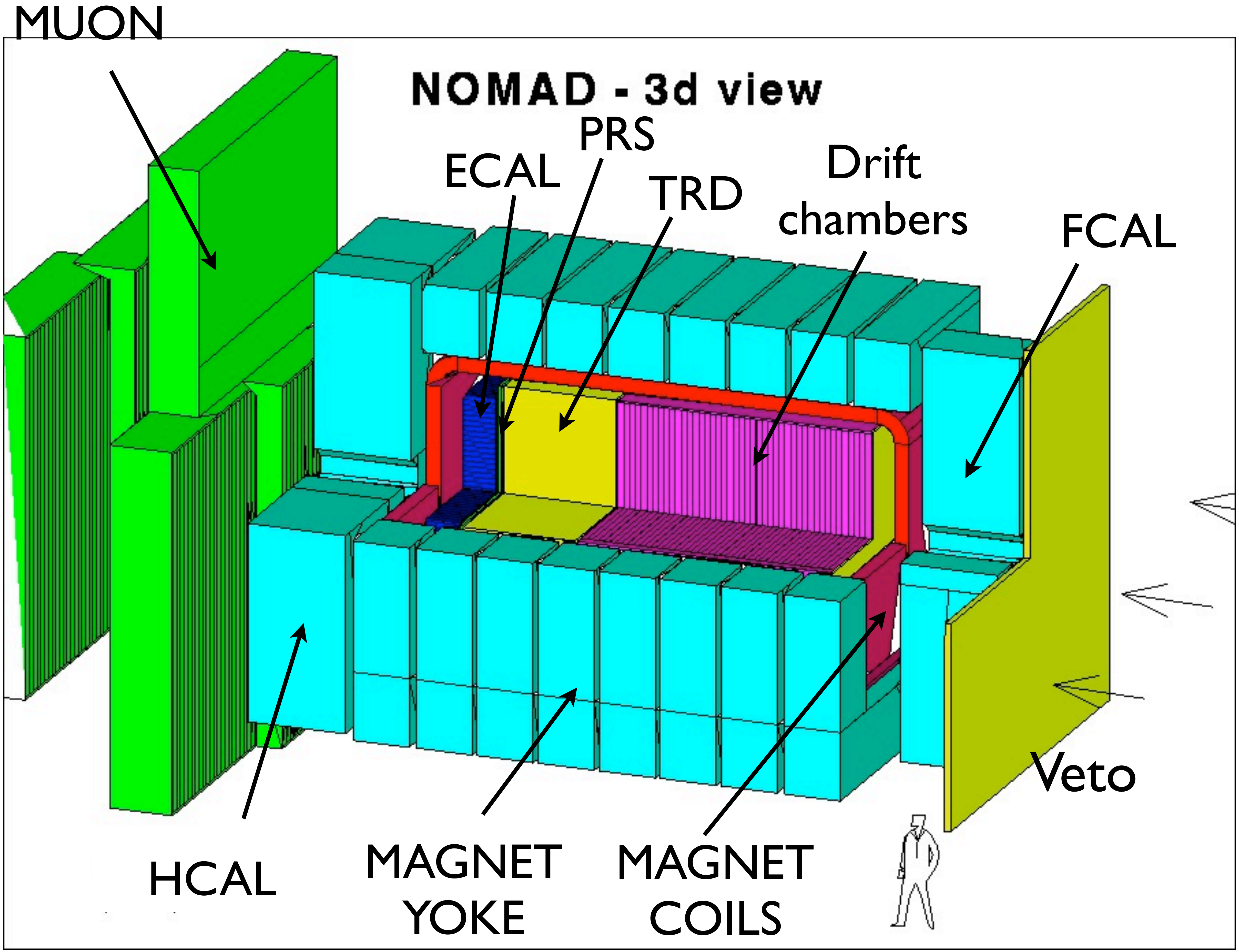


« Electronic bubble chamber »

Only 2-ton target, but very fine grain calorimeter

10^6 events obtained

Search for $\nu_\mu \rightarrow \nu_\tau$ (together with Chorus)


MUON
NOMAD - 3d view
PRS
ECAL
TRD
Drift
chambers
FCAL
Veto
HCAL
MAGNET
YOKE
MAGNET
COILS

◇ History

Beg 91	Proposal (SPS LC 91-11/91-21/91-48)
Sep 91	Approval
Aug 92	Status Report (SPS LC 92-51)
Summer 93	Magnet + Mu chambers ready X5 test beams
Fall 93	TRD, PS, CAL ready FIRST NEUTRINO RUN
23 Apr 94	First DC's NEUTRINO RUN 94

NOMAD Collaboration in 1994

Annecy LAPP
Bassompierre G. Fazio T. Gaillard J.M. Guoanère M. Mendiburu J.P. Nédélec P. Pessard H. Sillou D. Verkindt D.
Calabria Univ.
La Rotonda L.
California Univ. Los Angeles
Cardini A. Cousins R.
CERN
Bird I. Camilleri L. Di Lella L. Farthouat P. Ferrari R. Geiser A. Grant A. Huta W. Khomenko B. Linssen L. Placci A. Rubbia A. Sobczynski C. Tsesmelis E. Valdata M. Weber F.
Dortmund Univ.
Altegoer J. Goessling C. Plothow-Besch H. Pollmann D. Schmidt B. Weisse T.
Dubna JINR
Bunyatov S.A. Klimov O.L. Nefedov Yu.A. Popov B. Tereshenenko S. Valuev S.
Florence Univ./INFN
Conforto G. Iacopini E. Martelli F. Veltri M.
Harvard Univ.
Brome C. Dignan T. Feldman G. Hill M. Hubbard D. Hurst P. Mishra S.
Johns Hopkins Univ.
Blumenfeld B. Long J. Steele D.M.
Lausanne Univ.
Benslama K. Galumian P. Joseph C. Loude J.F. Nguyen Mau C. Steininger M. Tran T.-M. Vieira J.M. Werlen M.
Massachusetts Univ.
Ballocchi G. Bueno A. Gomez-Cadenas J. Hernando J.
Melbourne Univ.
Hyett N. Moorhead G. Poulsen C. Taylor G. Tovey S. Winton L.
Moscow, Inst. Nucl. Research (INR)
Gninenko S. Kovzelev A. Volkov S.
Padova Univ./INFN
Baldo-Ceolin M. Bobisut F. Gibin D. Guglielmi A. Laveder M. Mezzetto M.
Pavia Univ./INFN
Cattaneo P. Conta C. Goggi G.V. Fraternali M. Fumagalli G. Lanza A. Livan M. Orestano D. Pastore F. Pennacchio E. Petti R. Polesello G. Rimoldi A. Vercesi V.
Paris Univ. VI and VII
Astier P. Castera A. Dumarchez J. Letessier-Selvon A. Levy J.-M. Touchard A.M. Uros V. Vannucci F.
Pisa Univ./INFN
Autiero D. Cavasinni V. De Santo A. Delprete T. Flaminio V. Renzoni G. Roda C.
Saclay CEN DPhPe
Banner M. Baldisseri A. Bouchez J. Garretta D. Gosset J. Meyer J.P. Stolarczyk Th. Vo M. Zaccone H.
Sydney ANSTO
Donnelly I.J. Varvell K.
Sydney Univ.
Boyd S. Peak L. Soler P. Ulrichs J. Yabsley B.
Zagreb Rudjer Boskovic Inst.
Ljubicic A. Manola E. Stipcevic M. Tustonic T.

Spokesman: Vannucci F. Contactman: Camilleri L.

21 institutions   131 collaborators

The NOMAD drift chambers

Drift chambers are used to reconstruct the charged tracks and are the target.
They have to be massive enough to obtain an important number of neutrino interactions but light enough to minimize the multiple scattering.
The active target (3 tons) is composed of 44 chambers. 5 additional chambers are installed individually inside the TRD region and are used to improve the lever arm for tracking and for a better extrapolation of the tracks to the rest of subdetectors. Each chamber is composed of 3 planes of sensitive wires. The precision on the position of a hit in the chambers is <200 micrometers vertically and 2 millimeters horizontally (perpendicular to the beam). The drift chambers were build in CEA-Saclay by the DAPNIA.

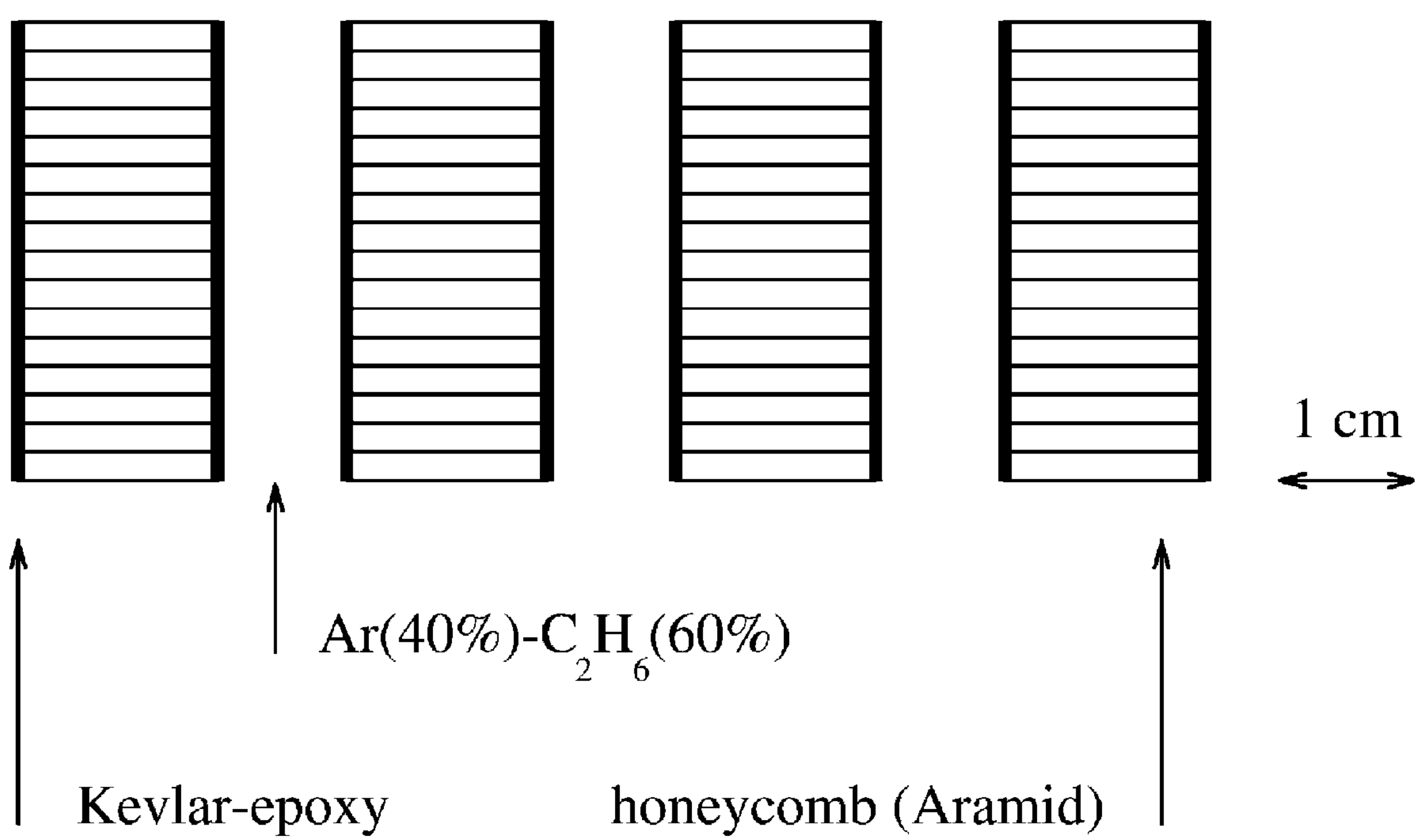


Fig. 2. A sideview of one NOMAD drift chamber cut by a plane orthogonal to the X axis.

Drift Chambers Problems:

- ☐ Very tight construction schedule (1 chamber/4 days)
  ~15 technicians , ~2500 m²
- ☐ 17 chambers currently inside magnet

Delays due to operation problems with the chambers at CERN

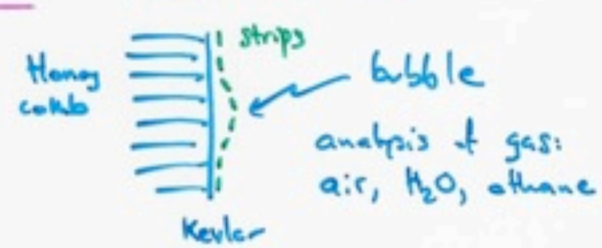
- ☐ A chronology

Aug 91 = Definition, Designs, Prototypes, Many tests
Nov 92 = Final structure with honeycomb structure
Apr 93 = Final choice of manufacturer
Apr 94 = 10 chambers at CERN

⚠ many broken wires ; Cure = better gluing of wires ⇒ no more broken wires

July 94 = 13 chambers at CERN

⚠ H.V. problems : on some reopened chambers, bubbles were seen on the strips



Outgassing from panel ?

Add a polyurethane film between the Kevlar and strips Mylar
⇒ indication that polyurethane prevents bubble formation

Sept 94 : 17 chambers

⚠ More studies are underway at Saclay and at CERN to understand more precisely the origin of problems.

Saclay has produced 24 new chambers and repaired 8 in 35 weeks !!

- ☐ Plan for 1995

end Feb 95 : 25 new chambers from Saclay
14 "old" chambers to be modified at CERN

→ Detector Complete in 1995

- ☐ Dummy 1.6t target in place of chambers

AR, TAUP 1994

SPSLC 95-61/M566
26 July 1995

MEMORANDUM
NOMAD COLLABORATION

Amherst, Annecy LAPP, Calabria, CERN, Dortmund, Dubna JINR, Florence, Harvard, John Hopkins, Lausanne, Melbourne, Moscow INR, Padova, Paris 6 & 7, Pavia, Pisa,, Saclay CEN, Sydney ANSTO, Sydney, UCLA, Zagreb.

As stated in the minutes of the Research Board 94-219, the West Area Neutrino facility will run until the end of 1997.

The NOMAD detector is now functioning well with an active target of about 3 tons. The performances of all the subdetectors are up to expectations. Neutrino interactions have been reconstructed (see the example of Fig. 1), and electrons and muons have been identified.

NOMAD is now steadily taking data and we wish to inform the Committee that we plan to continue data taking during the years 1996 and 1997 in order to reach the maximum sensitivity in the υ_μ - υ_τ oscillation search.

(actually NOMAD took data also in 1998)

DC performance

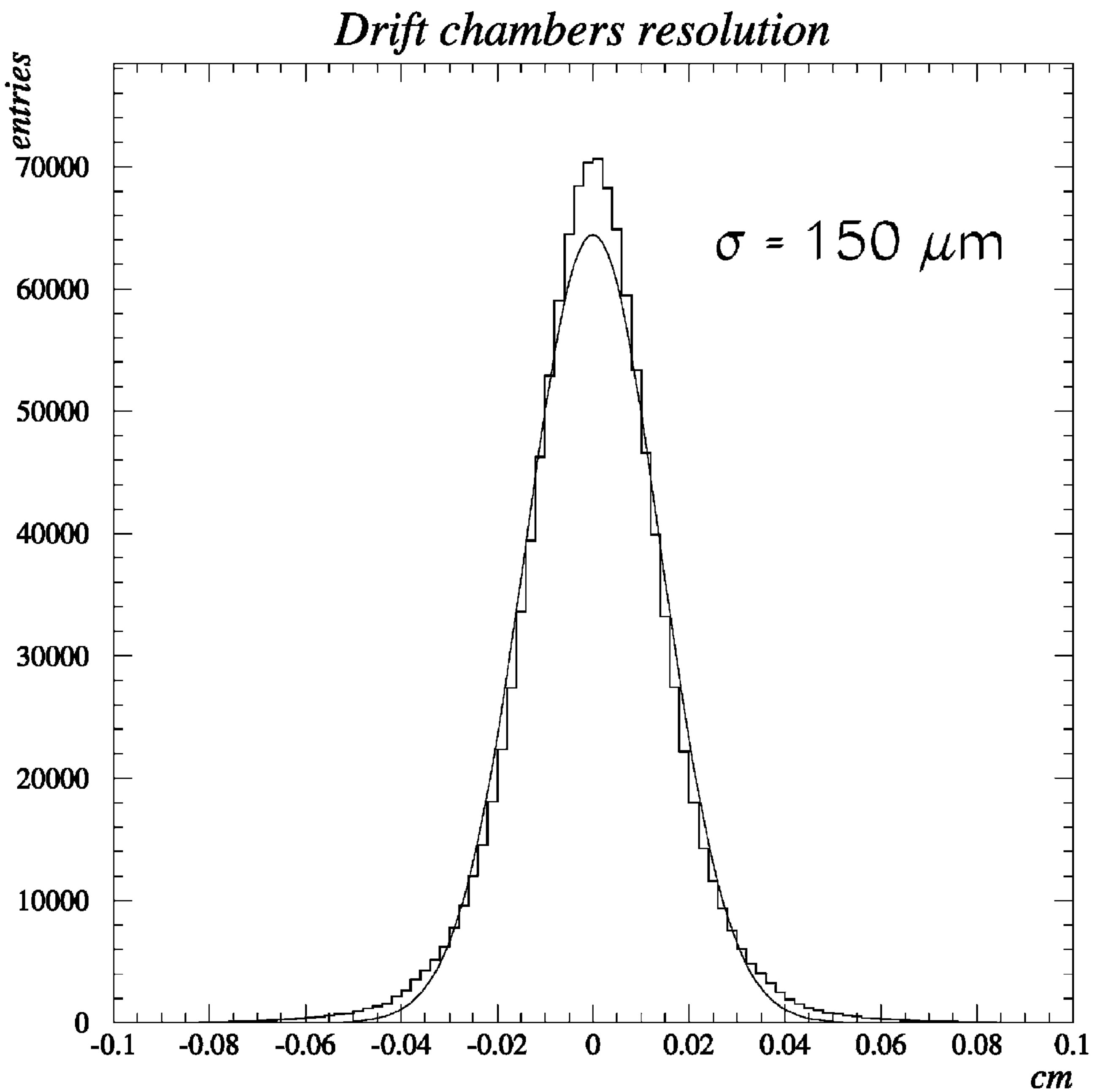


Fig. 11. Residuals for a sample of normal incidence tracks similar to the ones used for the alignment of the drift chambers.

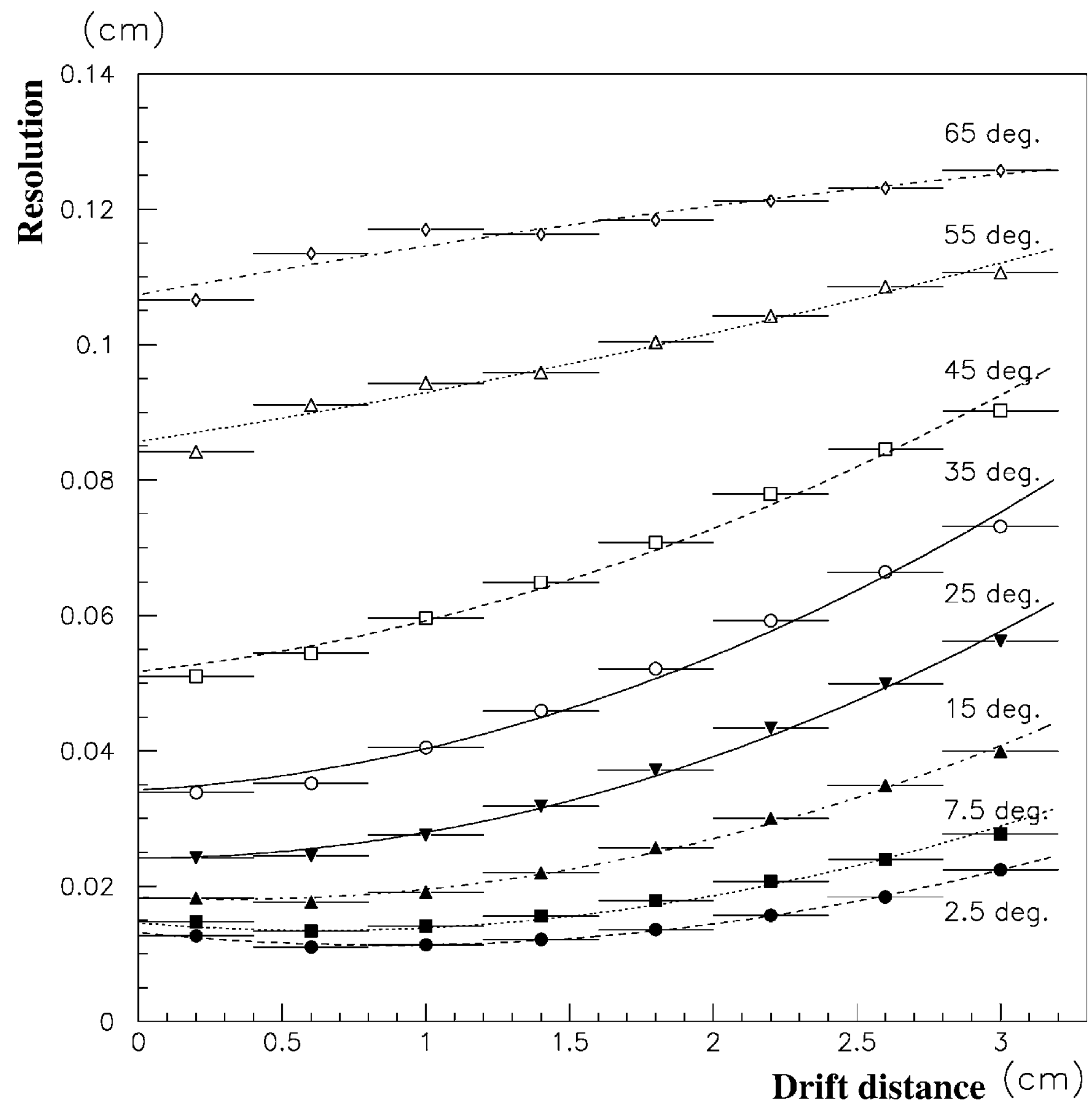


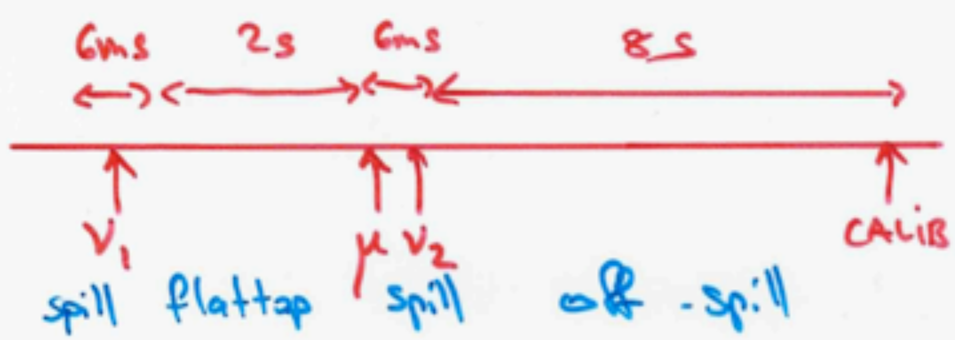
Fig. 12. The dependence of the track residuals on the drift distance for different crossing angles.

DAQ :

- entirely electronic detector
- # channels: 8000 TDC's
  3300 ADC's

  Front end electronic with digital buffer
  with multi event capability
  (dead - time $\lesssim$ 0.2% event)
  FASTBUS / VME implementation
  Backend = SUN workstations

- Readout cycle



SPS cycle
14.4 s

- High rate capability

  up to 90'000 evts / hour

  (alignment chamber, calibration, etc)

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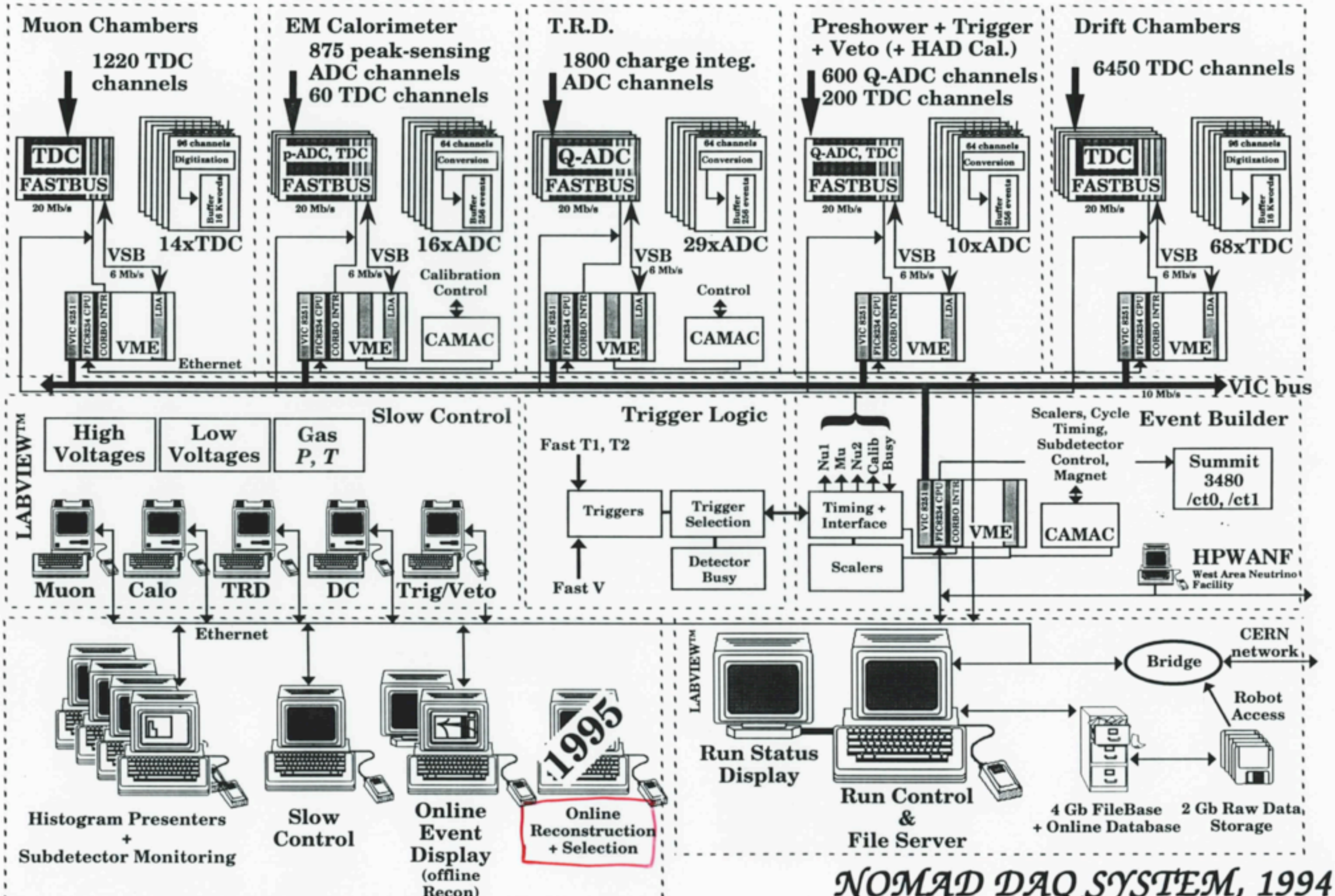
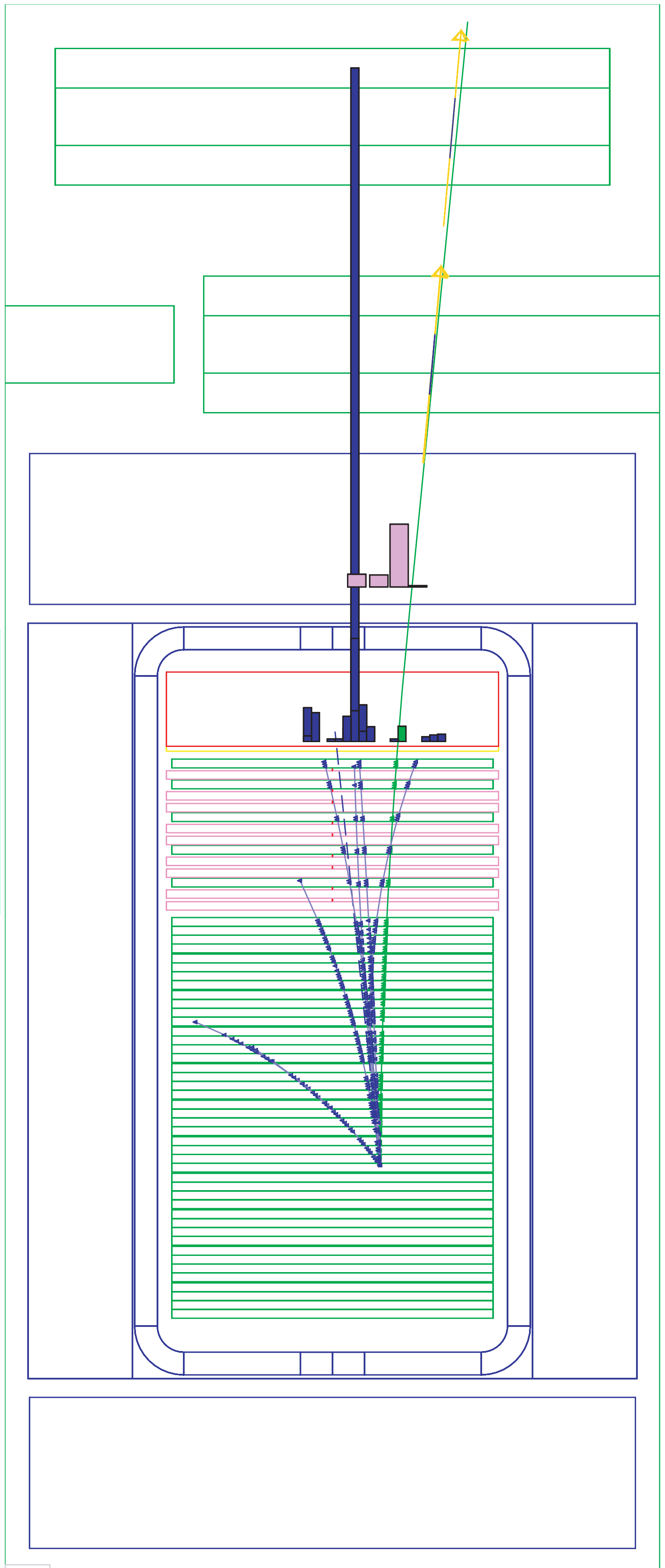
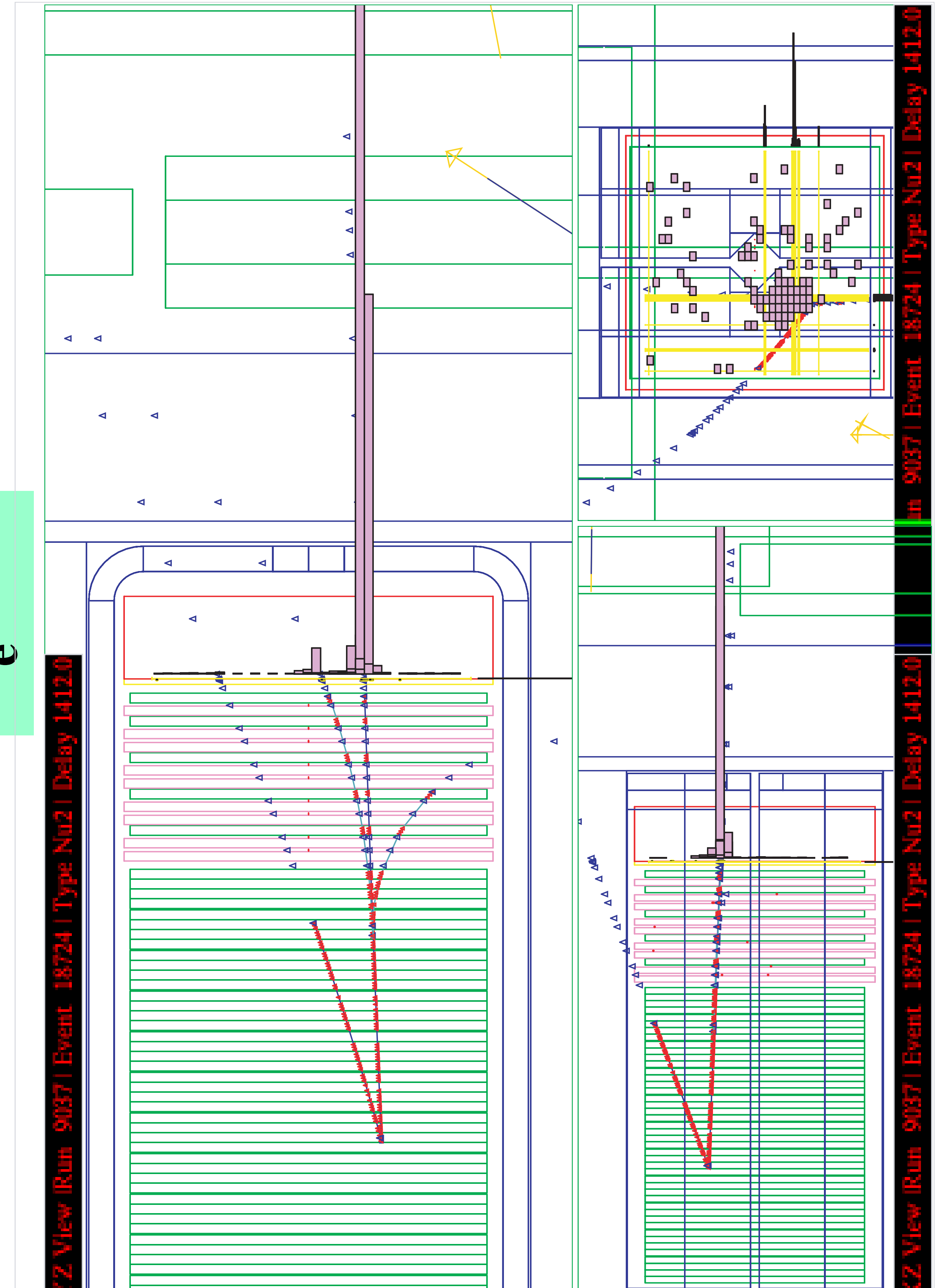

Muon Chambers
1220 TDC channels
TDC
FASTBUS
20 Mb/s
14xTDC
VSB
6 Mb/s
VME
Ethernet
EM Calorimeter
875 peak-sensing ADC channels
60 TDC channels
p-ADC, TDC
16xADC
Calibration Control
CAMAC
T.R.D.
1800 charge integ. ADC channels
Q-ADC
29xADC
Control
Preshower + Trigger + Veto (+ HAD Cal.)
600 Q-ADC channels
200 TDC channels
Q-ADC, TDC
10xADC
Drift Chambers
6450 TDC channels
68xTDC
VIC bus
10 Mb/s
LABVIEW™
Slow Control
High Voltages
Low Voltages
Gas P, T
Muon
Calo
TRD
DC
Trig/Veto
Trigger Logic
Fast T1, T2
Triggers
Trigger Selection
Detector Busy
Fast V
Nu1
Mu
Nu2
Calib
Busy
Timing + Interface
Scalers
Scalers, Cycle Timing, Subdetector Control, Magnet
Event Builder
Summit 3480 /ct0, /ct1
HPWANF
West Area Neutrino Facility
Ethernet
Histogram Presenters + Subdetector Monitoring
Slow Control
Online Event Display (offline Recon)
1995
Online Reconstruction + Selection
Run Status Display
Run Control & File Server
CERN network
Bridge
Robot Access
4 Gb FileBase + Online Database
2 Gb Raw Data Storage
NOMAD DAQ SYSTEM, 1994

Typical neutrino interactions

ν_μ CC



ν_e CC



The analysis strategy

Today we can safely say that the difficulty of the analysis had been largely underestimated in the NOMAD proposal. This "crisis" led to (forced us to) the development of new ideas, which are now commonly exploited in modern neutrino experiments.

1.- Likelihood technique

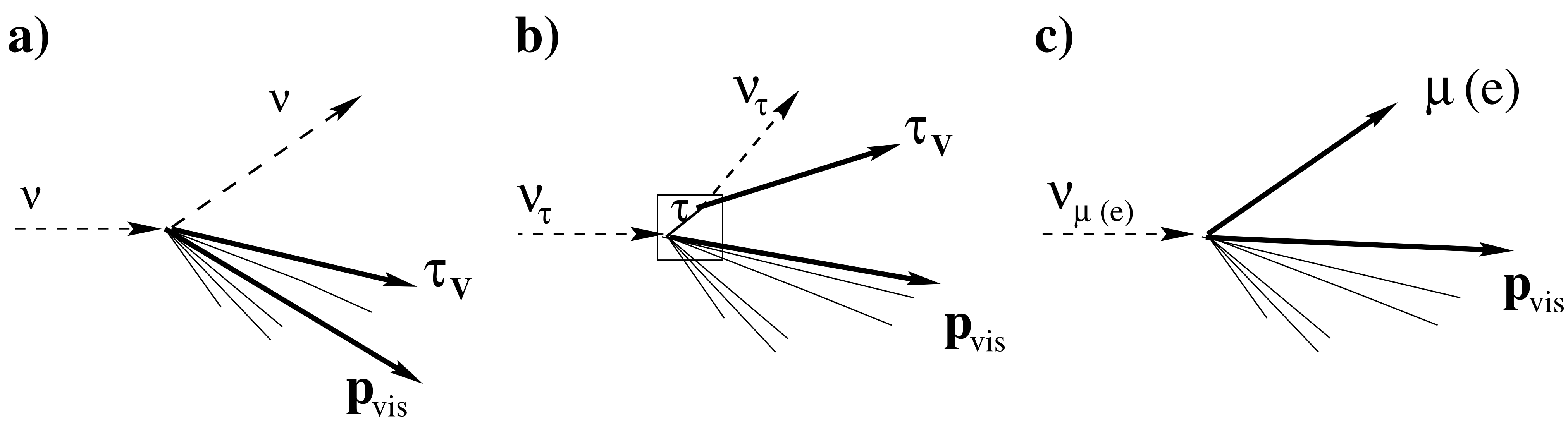
2.- Blind analysis: signal region (*box*) definition

3.- Data simulator corrections

4.- Background prediction for positive candidates and negative candidates outside the signal region

5.- *Box* opening

Tau decay channels analyzed



☑ **Electron channel:**

- ☺ Select prompt electron (no other prompt leptons allowed)
- ☹ Background sources:
  - ν_eCC natural beam contamination (~1%)
  - ν_μCC with unidentified muon
  - νNC

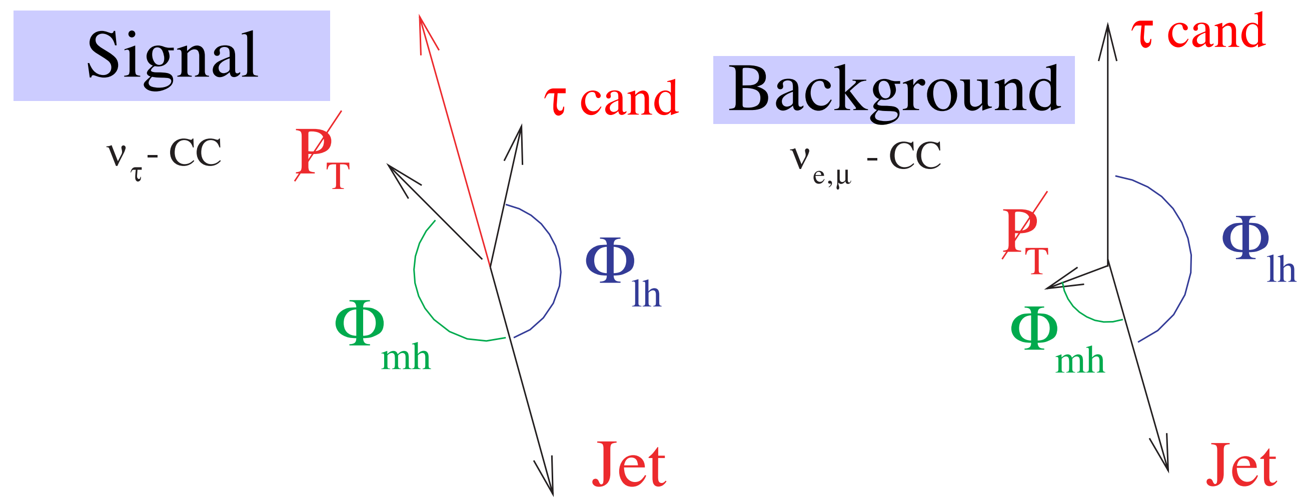
} γ conversions
Dalitz decays

☑ **Hadronic channels:**

- ☺ Select most isolated hadron(s)
- ☹ Background sources:
  - ν_e and ν_μCC with unidentified prompt lepton
  - νNC

Tau kinematical selection

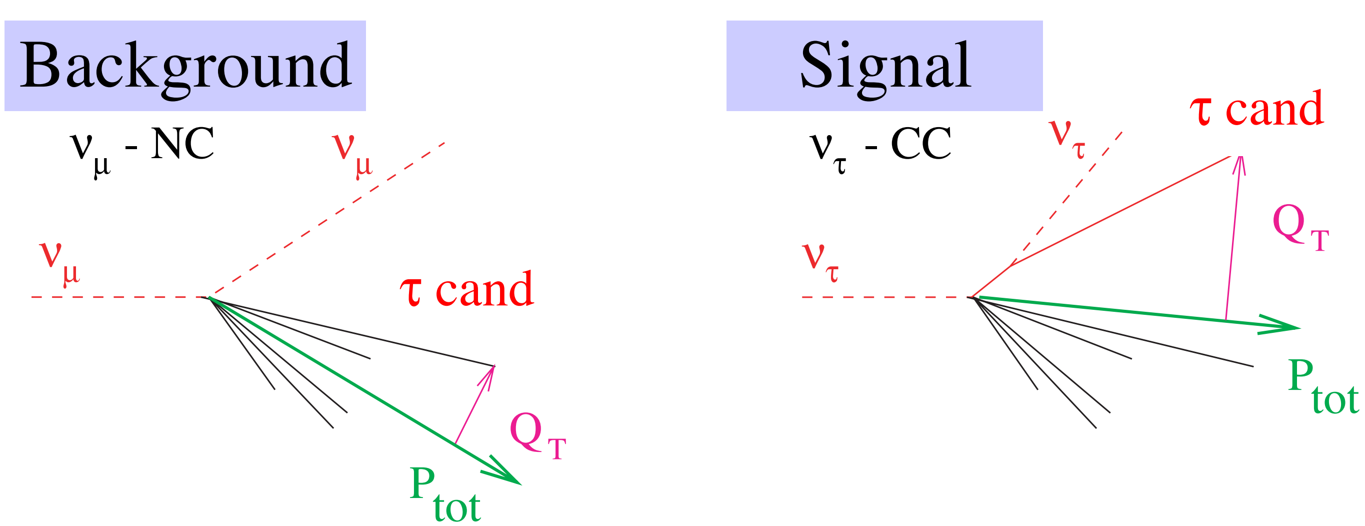
- **Charged Current Background rejection**: Kinematic configuration in the plane perpendicular to the incoming ν direction



Amount of imbalance: magnitude of the missing transverse momentum $\not{P}_T$

Direction of imbalance: angles Φ_{lh} and Φ_{mh}

- **Neutral Current Background rejection**: isolation of τ decay products from the hadronic jet



Q_T = component of the momentum of visible τ decay products perpendicular to the total visible momentum vector

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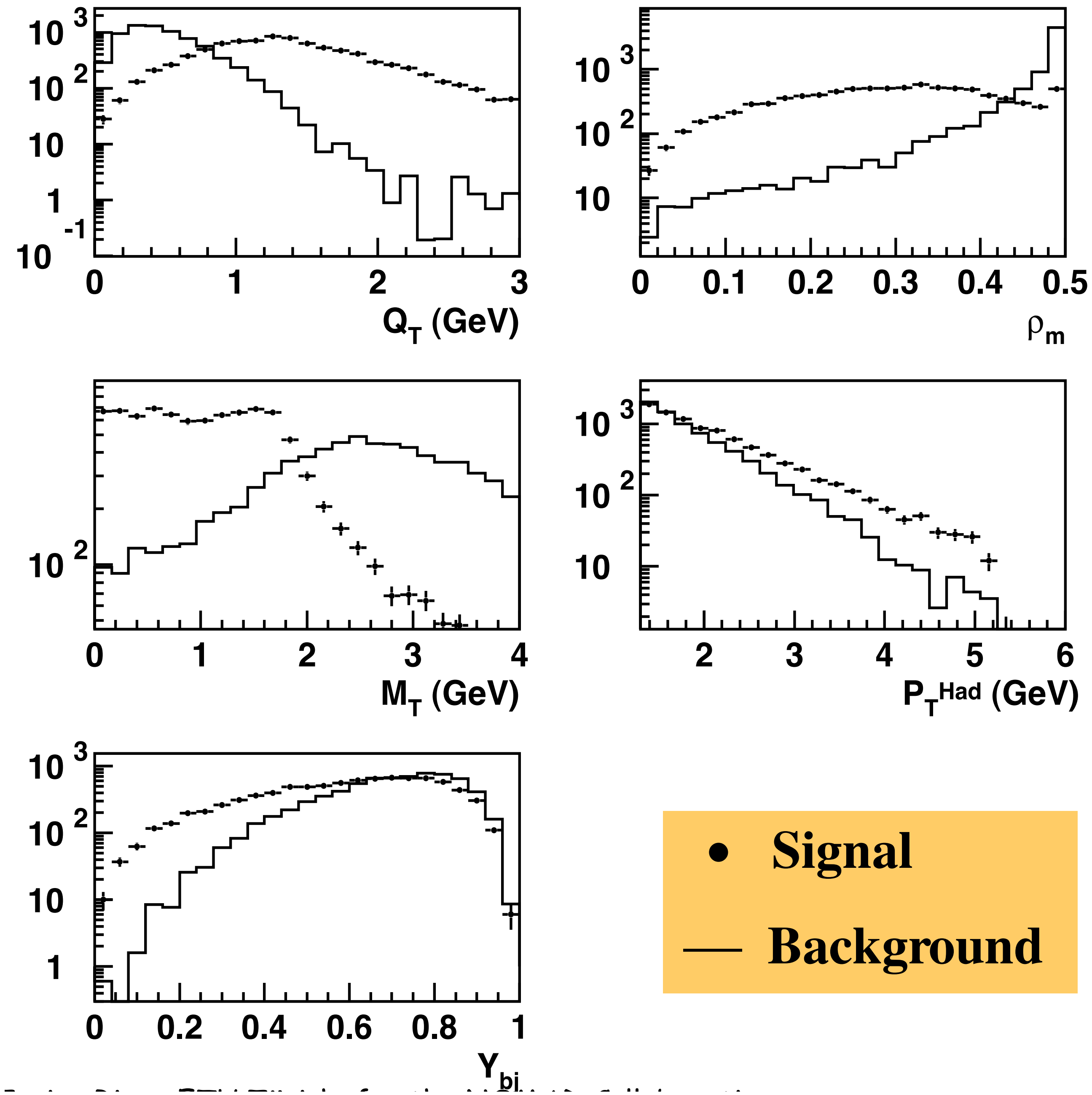
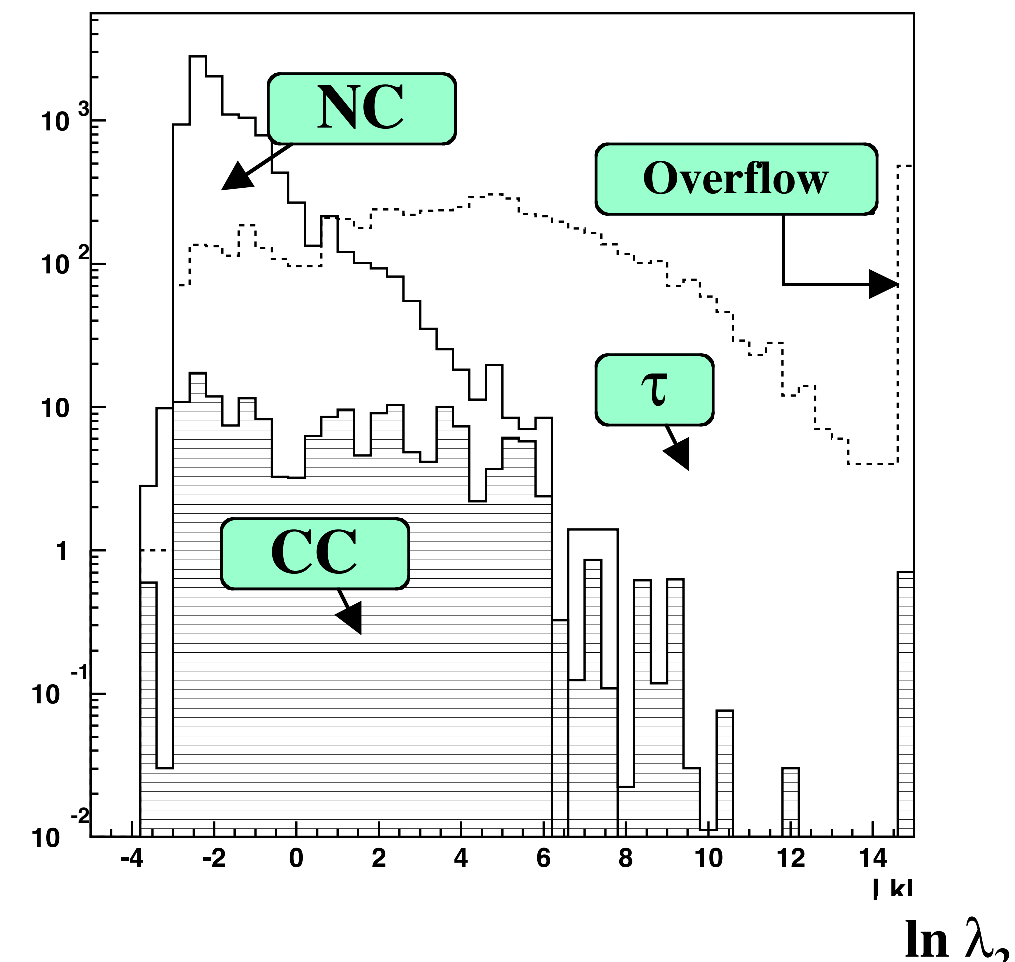
1. Rejection of NC interactions in $\tau^- \rightarrow h^-$

- Kinematics preselection: $M_T < 4$ GeV, $p_T^{had} > 1.3$ GeV, $\rho_H < 0.49$
- Rejection of NC (also some CC) backgrounds by means of likelihood function:

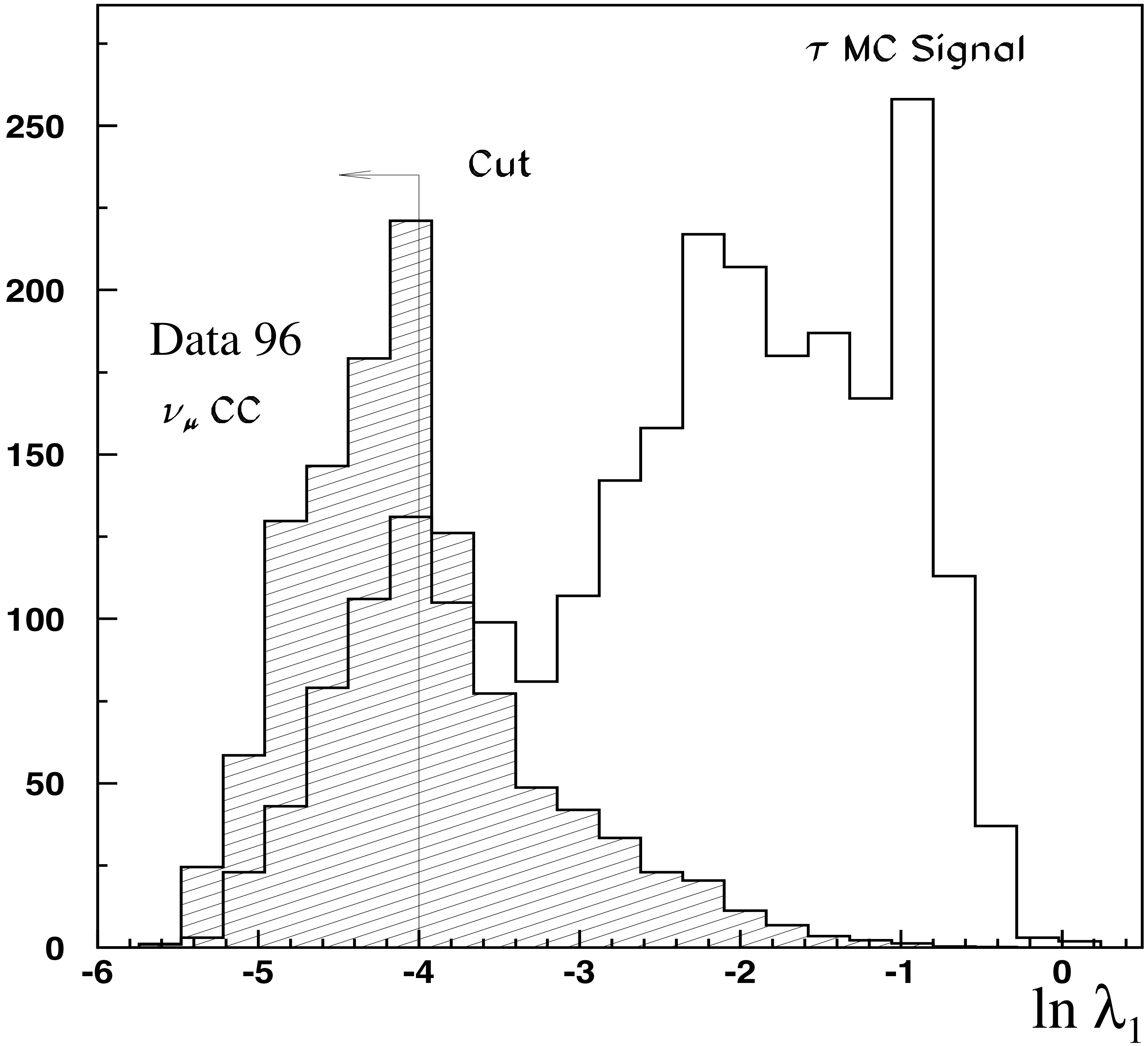
$$L_2^{NC} = [Q_T, M_T, \rho_m][y_{BJ}][p_T^H]$$





1. Rejection of CC interactions in $\tau^- \rightarrow h^-$

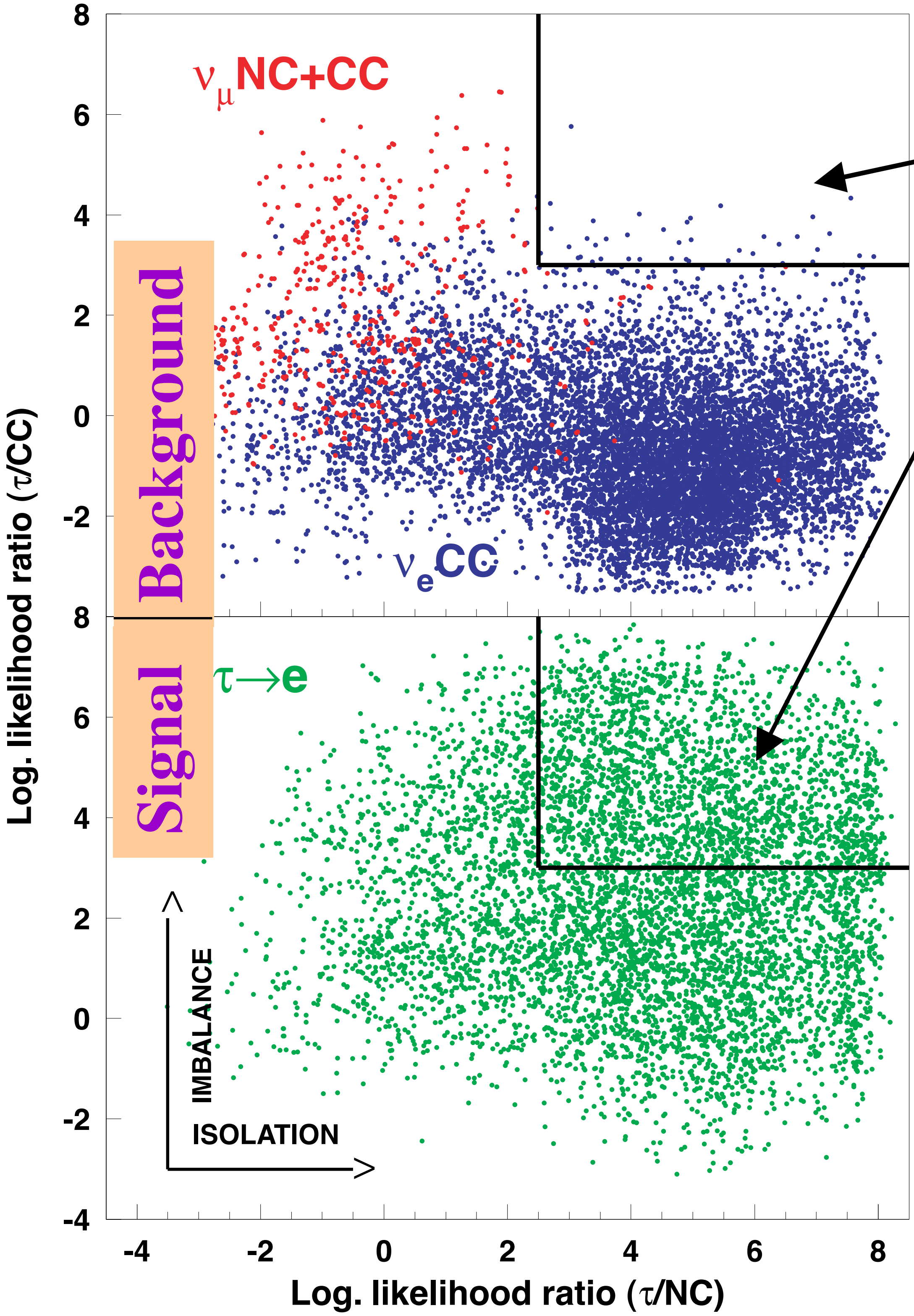
Background due to unidentified prompt μ taken as the hadron candidate



Likelihood built using data events with an identified muon, which is considered to be the hadron candidate

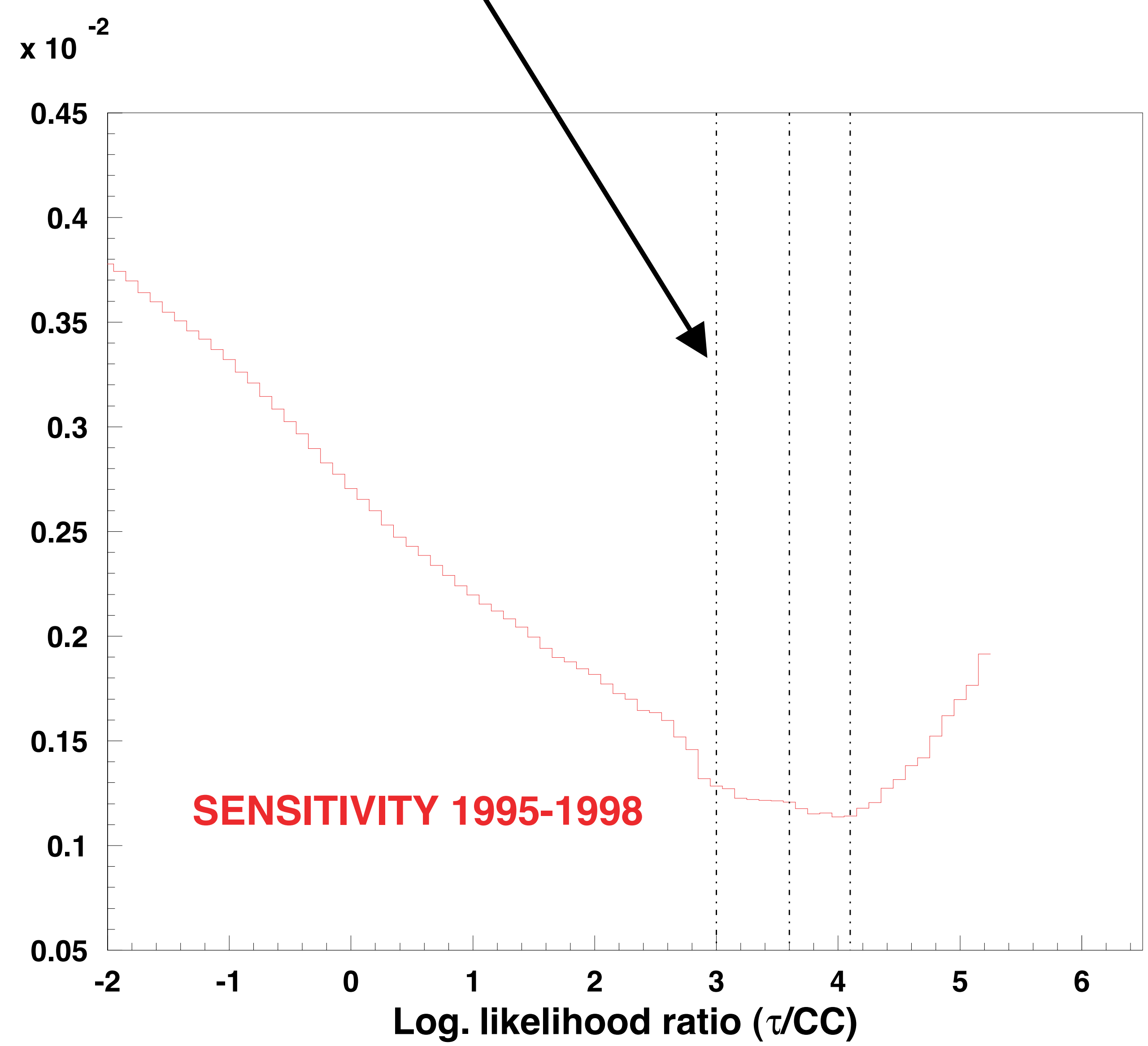
$$L_1^{\mu\rightarrow\pi} = [Q_T, \rho_1, \rho_H]$$

2. Blind analysis: Box concept



Blind region

Defined as the region of best sensitivity



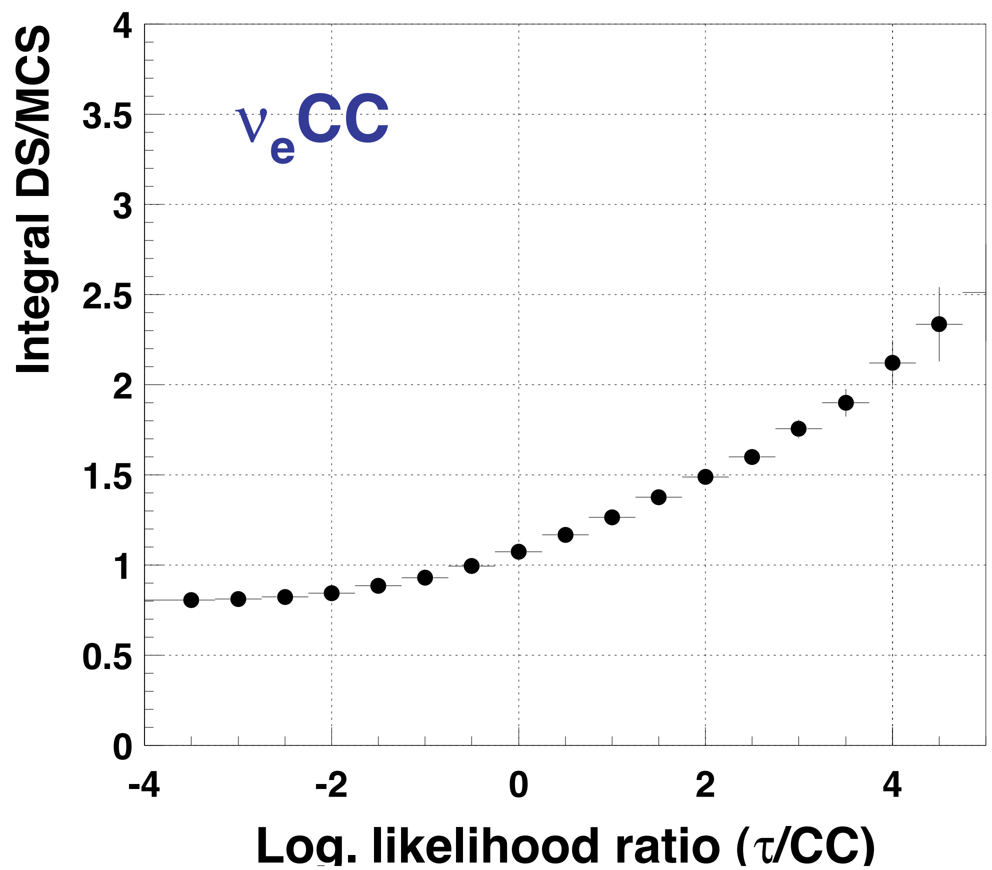
3. Data Simulator

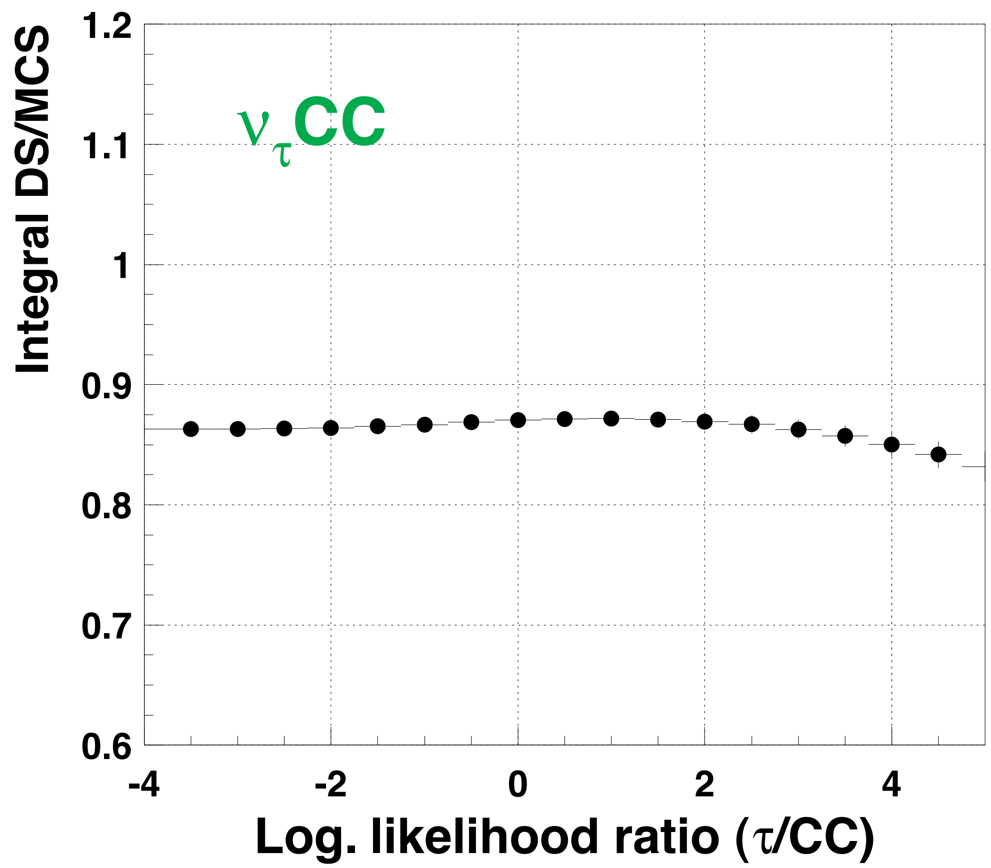
Data control sample used to correct for the discrepancies observed between Monte-Carlo and real data events

THE METHOD

- Identified ν_μ CC $\Rightarrow$ remove the μ $\Rightarrow$ replace it by another lepton
- Do it for DATA (DS) and MC events (MCS)
- Backgrounds and signal efficiencies are corrected:

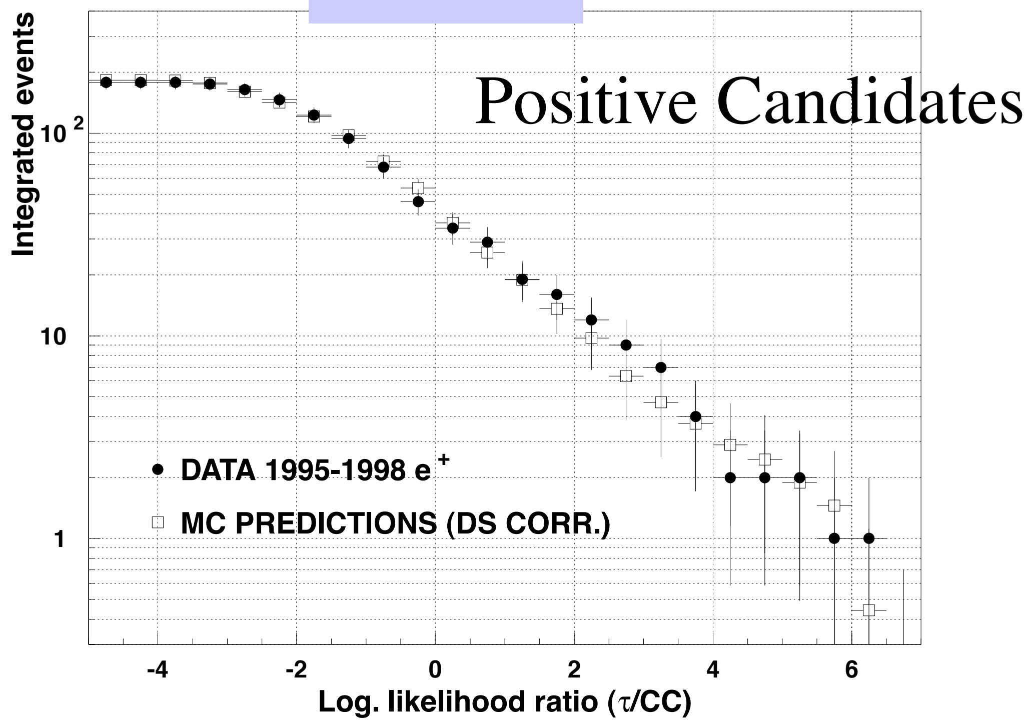
$$\varepsilon = \varepsilon_{MC} \times \varepsilon_{DS} / \varepsilon_{MCS}$$

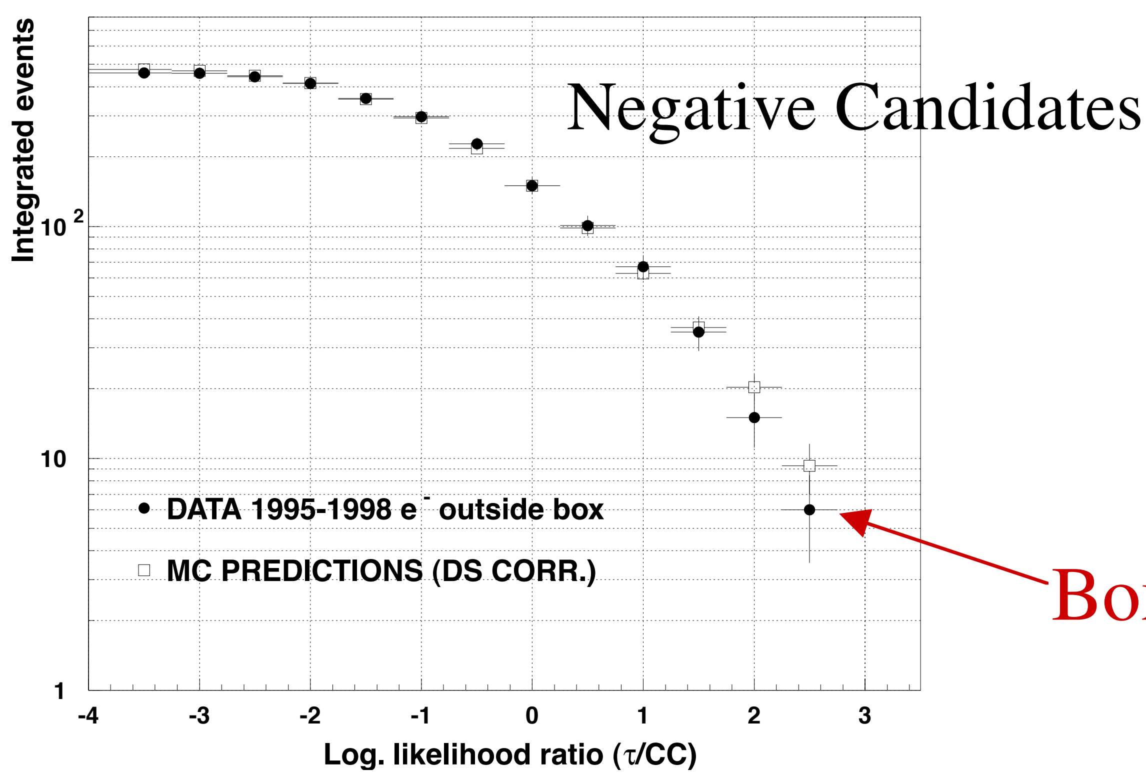




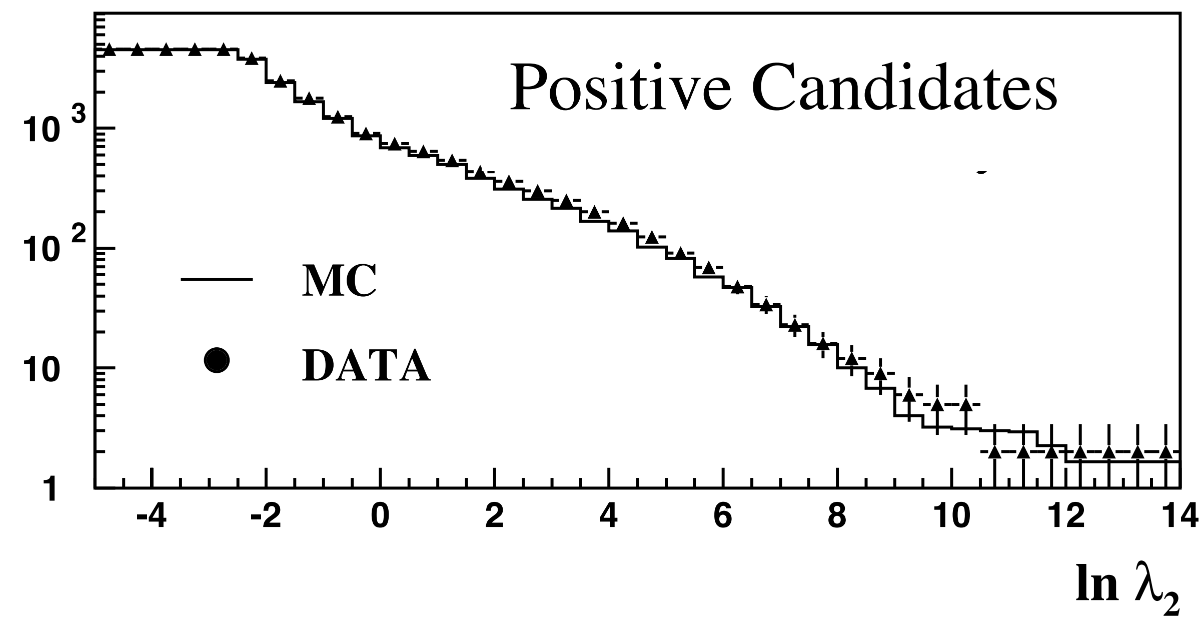
4. Background Prediction

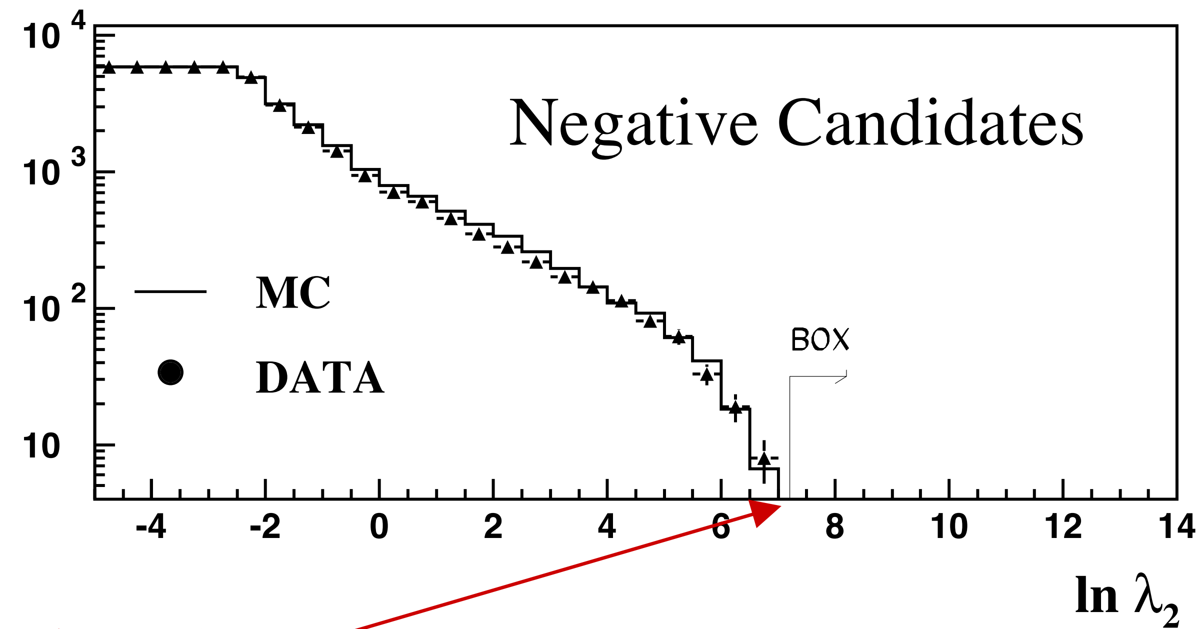
$\tau \to e$





$\tau \to h$





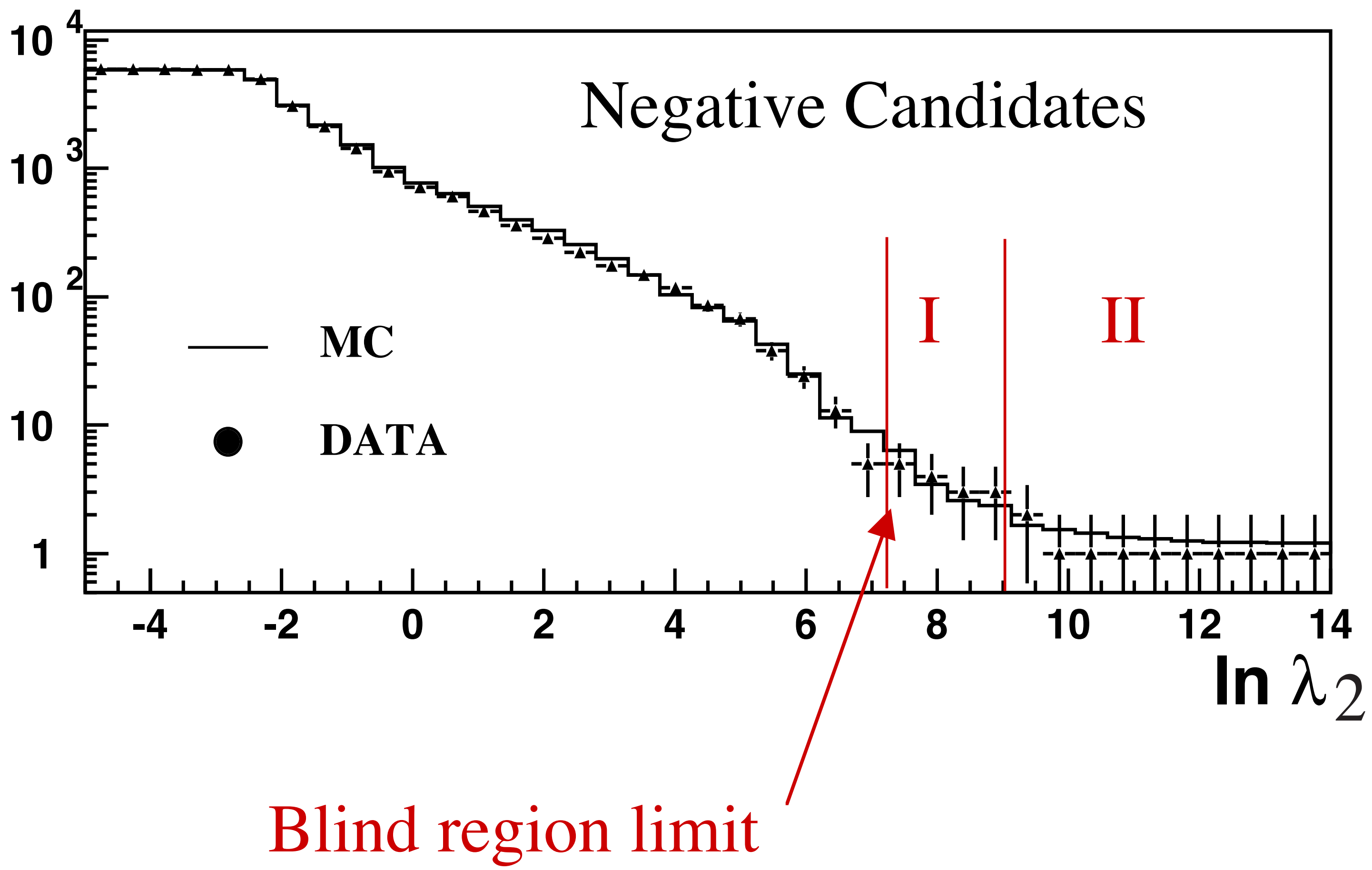
Box closed

Good agreement demonstrated

25

5. $\tau^- \rightarrow h^-$ box opening

Likelihood integral distribution



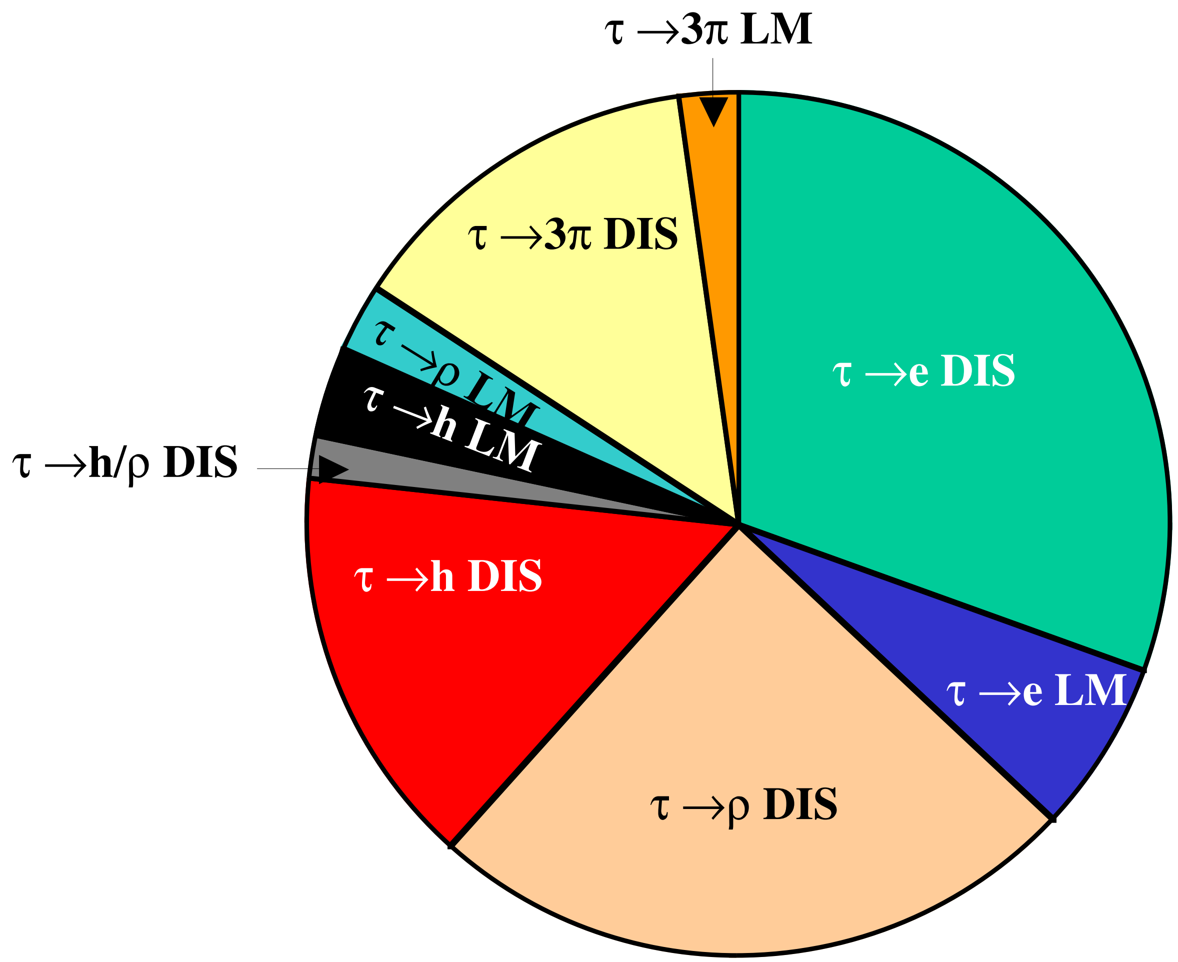
Bin	N_τ	Exp. Bckgnd	Data
I	817	4.4 ± 1.9	3
II	1205	2.4 ± 0.8	2
Tot	2022	6.8 ± 2.1	5

$\varepsilon_\tau = 0.6\ \%$

No oscillation evidence

NOMAD analysis summary

Channel	*Est. Backg.*	N_{obs}	N_τ	ε (%)
$\tau \to e^- \nu_\tau \bar{\nu}_e$ DIS	$5.3\ ^{+0.08}_{-0.06}$	5	4110	3.6
$\tau \to e^- \nu_\tau \bar{\nu}_e$ LM	5.4 ± 0.4	6	859	6.3
$\tau \to \rho^- \nu_\tau$ DIS	9.5 ± 2.5	7	3307	1.04
$\tau \to h^- (+n\ \pi^0)\ \nu_\tau$ DIS	6.8 ± 2.1	5	2022	0.70
$\tau \to h^-/\rho^- \nu_\tau$ DIS	0 ± 0.74	1	210	0.07
$\tau \to \rho^- \nu_\tau$ LM	5.2 ± 1.8	7	458	2.0
$\tau \to h^- (+n\ \pi^0)\ \nu_\tau$ LM	6.7 ± 2.3	5	357	0.84
$\tau \to \pi^- \pi^- \pi^+ \nu_\tau$ DIS	9.6 ± 2.4	9	1820	1.9
$\tau \to \pi^- \pi^- \pi^+ \nu_\tau$ LM	3.5 ± 1.2	5	288	1.8



$$P(\nu_\mu \to \nu_\tau) < 2.2 \times 10^{-4},\ \mathbf{90\%\ C.L.}$$

$$\text{Sensitivity} = (4.3 \pm 2.7) \times 10^{-4}$$

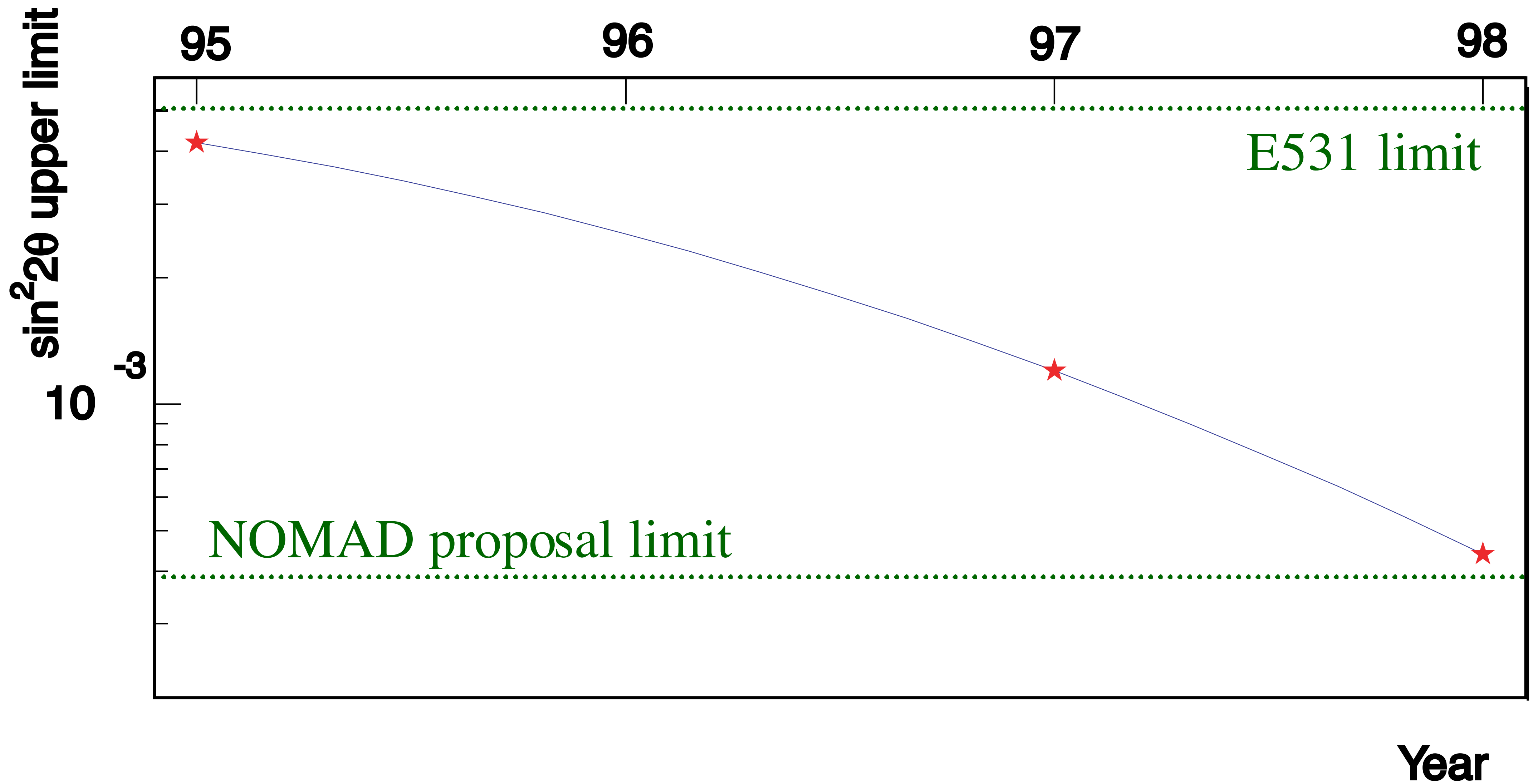
Using prescription of G. J. Feldman and R. D. Cousins
Phys. Rev. **D57** (1998) 3873

NOMAD final tau appearance result

95 DATA: $\sin^2 2\theta < 4.2 \times 10^{-3}$ [*Phys. Lett.* **B431** (1998) 219]

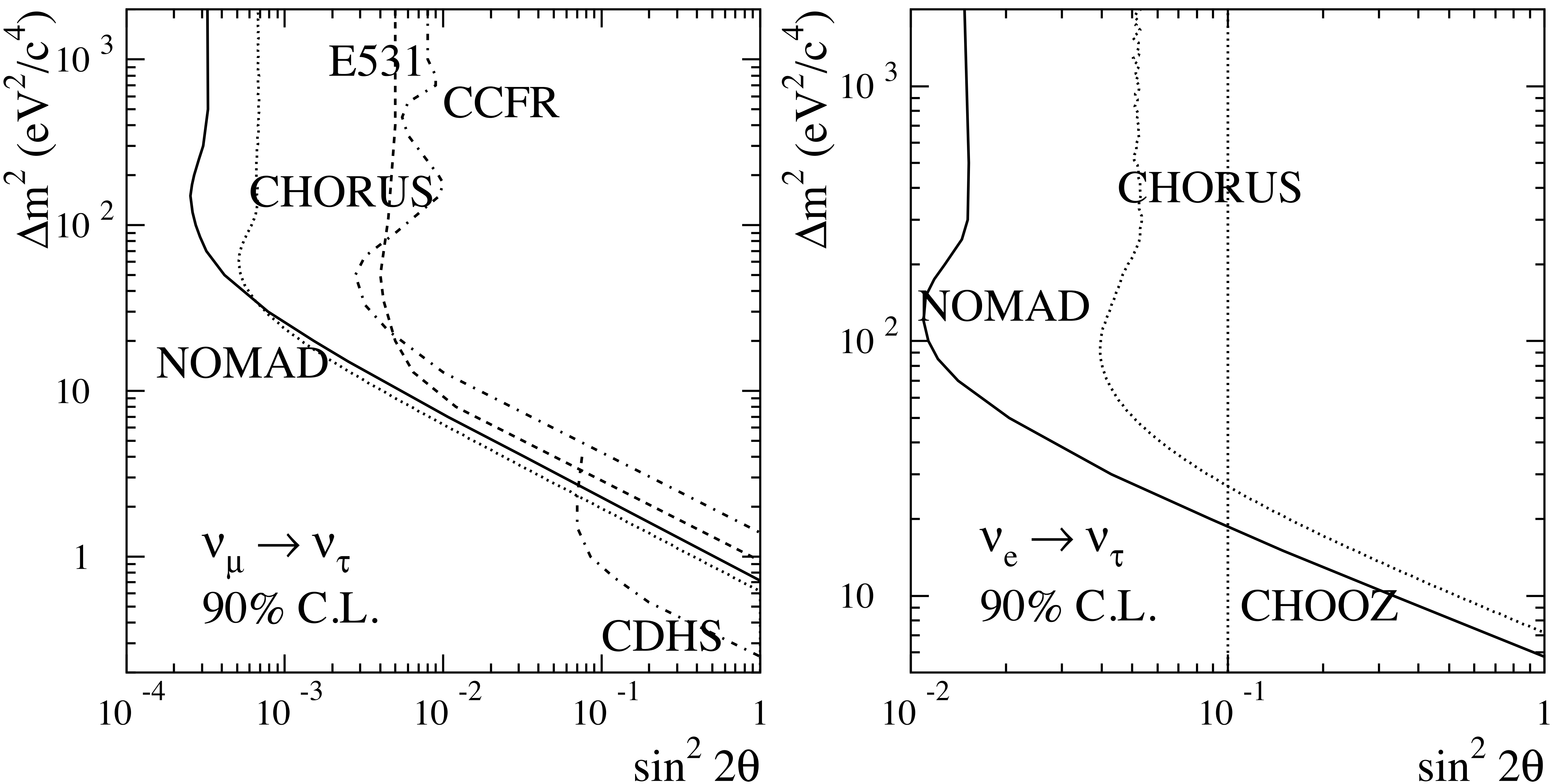
95-97 DATA: $\sin^2 2\theta < 1.2 \times 10^{-3}$ [*Phys. Lett.* **B453** (1999) 169]

95-98 DATA: $\sin^2 2\theta < 4.4 \times 10^{-4}$ [**Phys.Lett. B483 (2000) 387-404]**



NOMAD final tau appearance result

NOMAD Collab., Nucl.Phys. B611 (2001) 3-39



No evidence for oscillations

NOMAD results (SPIRES)

- 35 published papers
- Some examples:
  - Final NOMAD results on muon-neutrino ---> tau-neutrino and electron-neutrino ---> tau-neutrino oscillations including a new search for tau-neutrino appearance using hadronic tau decays. NOMAD Collaboration (P. Astier et al.). CERN-EP-2001-043. Jun 2001. 46 pp. Published in Nucl.Phys. B611 (2001) 3-39
  - Search for nu(mu) ---> nu(e) oscillations in the NOMAD experiment. NOMAD Collaboration (P. Astier et al.). CERN-EP-2003-038. Jun 2003. 19 pp. Published in Phys.Lett. B570 (2003) 19-31
  - Measurement of the Lambda polarization in nu/mu charged current interactions in the NOMAD experiment. NOMAD Collaboration (P. Astier et al.). CERN-EP-2000-111. Jul 2000. 31 pp. Published in Nucl.Phys. B588 (2000) 3-36

Jacques' addendum in 1997

Note added (july 1997)

After this report was written, new informations have become available:

- SuperKamioka has given first preliminary results on atmospheric neutrinos, confirming the global deficit of ν_μ's relative to ν_e's. But the azimuthal dependance for multi-GeV events, although not incompatible with Kamioka, looks much less pronounced and is compatible with a flat distribution. More precise results are eagerly awaited.

- The CERN committee SPSLC has recommended the construction of a neutrino beam aiming at Gran Sasso. It seems now possible to complete this beam in 2001. Furthermore, a new scheme for the SPS supercycle (after LEP is stopped) would give a factor 3 improvement in neutrino flux. A sooner start with higher intensity makes ICARUS at Gran Sasso more competitive with respect to the KEK and FNAL projects. As a consequence of this scenario, the JURA project is compromised and TOSCA (also recommended by the SPSLC) would have to move to an underground hall in the new beam, 1 km away from the source. It is conceivable however that a totally flat azimuthal distribution in SuperKamioka would lead to reconsider this scenario.

J. Bouchez, Moriond 1997

A few years later... in 2000

Status of present neutrino experiments at accelerators and reactors

J. Bouchez[a]

[a]DAPNIA/SPP, CEA Saclay,
F91191 Gif-sur-Yvette Cedex, France

5. CONCLUSIONS

Most experiments described above have reached or are near completion, so that the overall picture for neutrino oscillations is not expected to change in the near future.

At high energy accelerators, no $\nu_\mu \to \nu_\tau$ oscillation has been observed, and the final limit on oscillation probability will be near 10^{-4}, an improvement of more than a factor 20 over previous limits. The expertise acquired in both detection techniques, and in particular the tremendous improvements done by CHORUS on automated emulsion processing, will be very useful to the future long baseline experiments at Gran Sasso such as OPERA and ICANOE in their search for ν_τ interactions.

The LSND effect will need new experiments, such as BooNE, for a definite cross check (see F.Bobisut's contribution).

For reactor experiments, the future is to even higher distances with deep underground detectors, with the prospect of testing by a terrestrial experiment one of the oscillation scenarios (MSW at large angle) which can explain the solar neutrino deficit.

Four-Seas-Conference, Thessaloniki (2002)

From: bouchez@hep.saclay.cea.fr (Jacques Bouchez)
Subject: **thessalonique**
Date: February 19, 2002 1:33:22 PM GMT+01:00
To: ANDRE.RUBBIA@cern.ch, DANIEL.DENEGRI@cern.ch

---

je suis d'accord avec la proposition d'Andre pour le partage entre neutrinos atmospheriques pour lui et neutrinos solaires (+KamLand) pour moi.

ciao,

Jacques Bouchez
DAPNIA/SPP
CEA Saclay
91191 Gif-sur-Yvette Cedex
France
tel: 33-1-69-08-44-69
fax: 33-1-69-08-64-28
email: bouchez@hep.saclay.cea.fr

"small or large mixing angles ?"

Oscillation map - "allowed regions"

Two-neutrino oscillation

$\bar{\nu}_\mu \rightarrow \bar{\nu}_e$

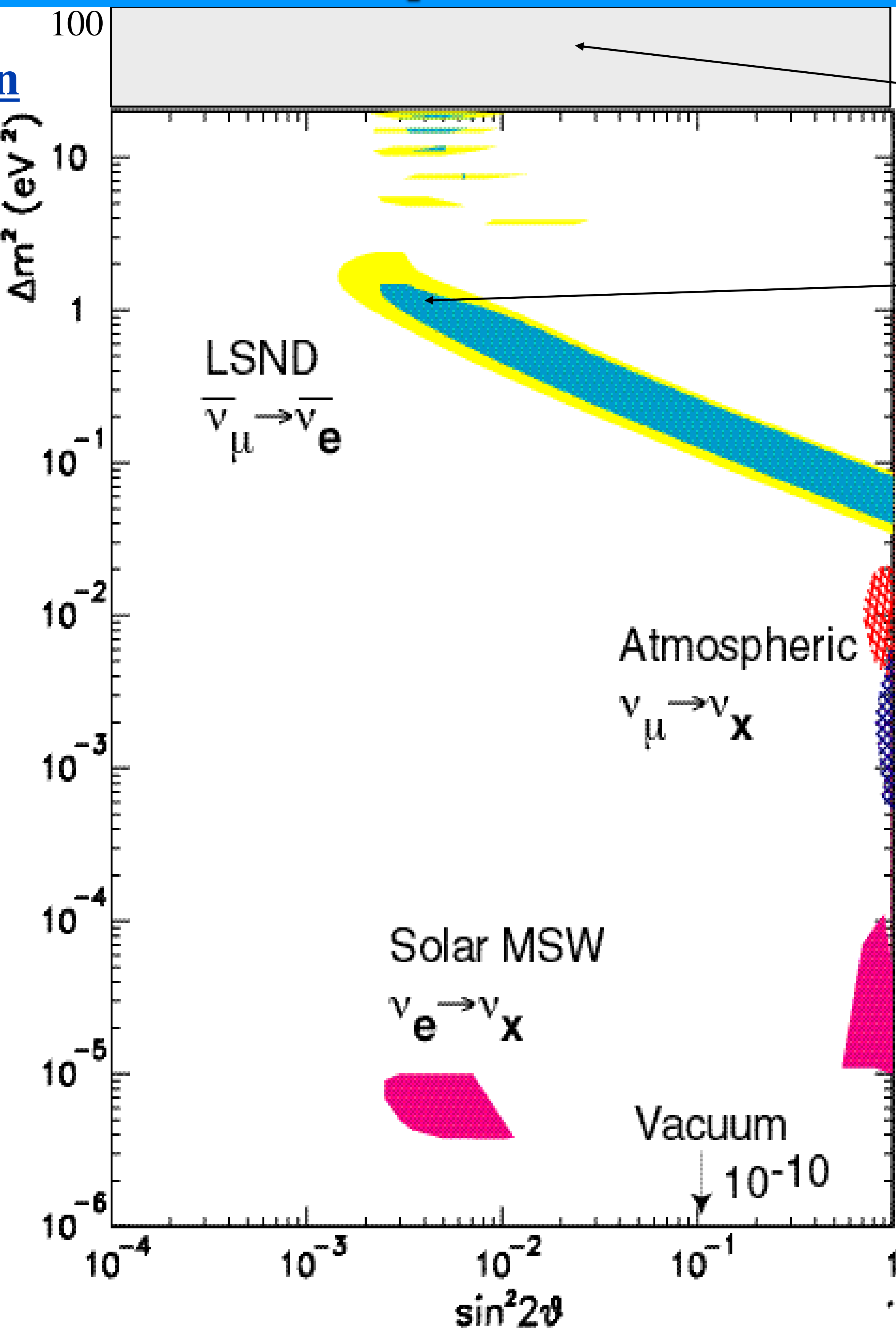
Electron excess

$\nu_\mu \rightarrow \nu_x$

Muon deficit

$\nu_e \rightarrow \nu_x$

Electron deficit



cosmological $\nu_\mu \rightarrow \nu_\tau$

$\Delta m^2_{LSND} \approx 1$ eV^2
$\sin^2 2\theta \approx 0.003$

$\Delta m^2_{atm} \approx 10^{-3}$–$10^{-2}$ eV^2
$\sin^2 2\theta \approx 1$

$\Delta m^2_{solar} \approx 10^{-5}$ eV^2
$\sin^2 2\theta \approx 0.8$ or 0.008

Matter enhanced (MSW effect)

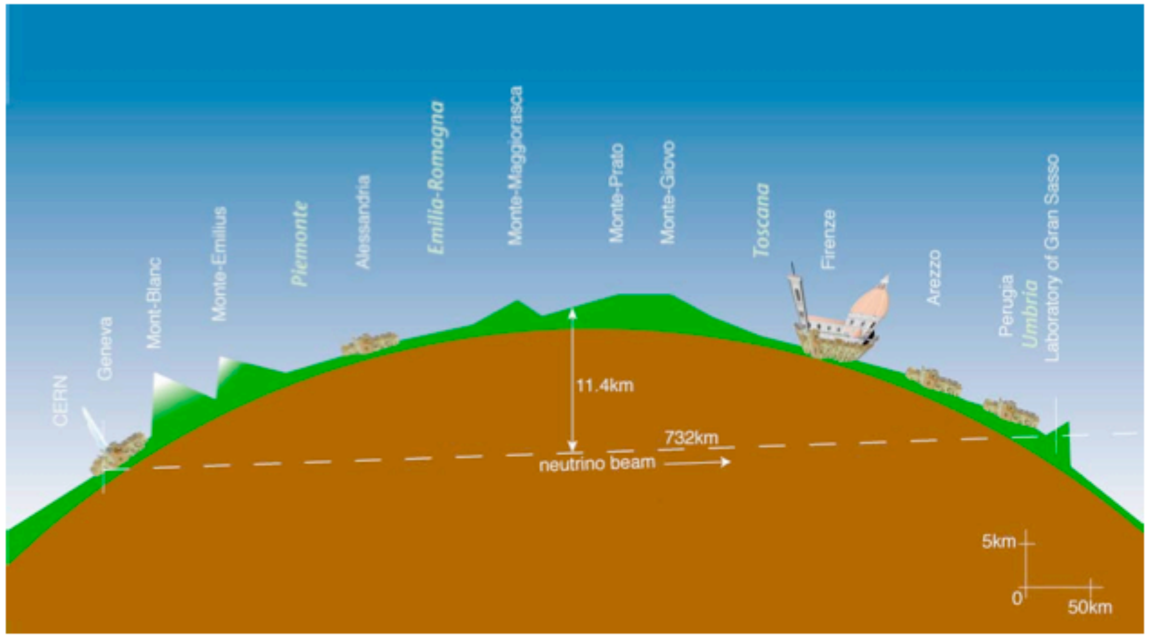
$\Delta m^2_{solar} \approx 10^{-10}$ eV^2
$\sin^2 2\theta \approx 0.8$

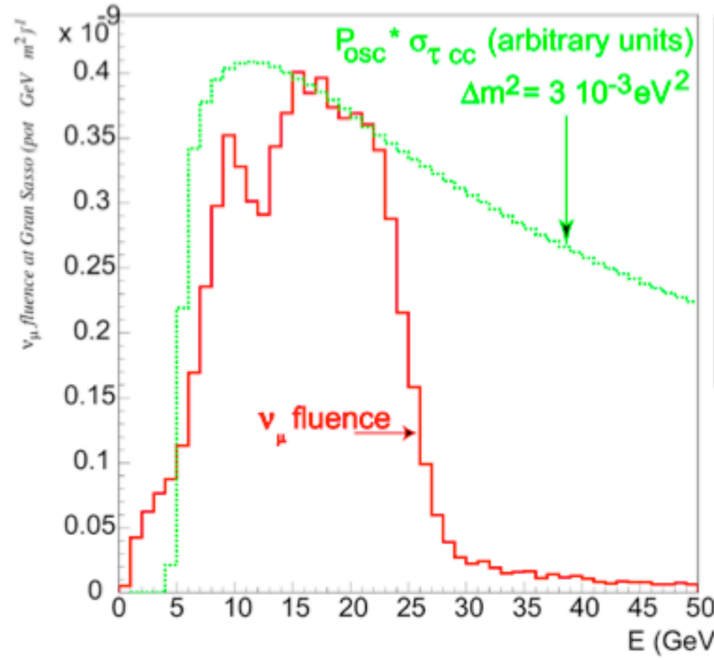
Vacuum oscillation

André Rubbia, ETH/Zürich 2002, Four Seas Conference

CERN-Gran Sasso and OPERA (2006-)

CERN to Gran Sasso Long Baseline Neutrinos



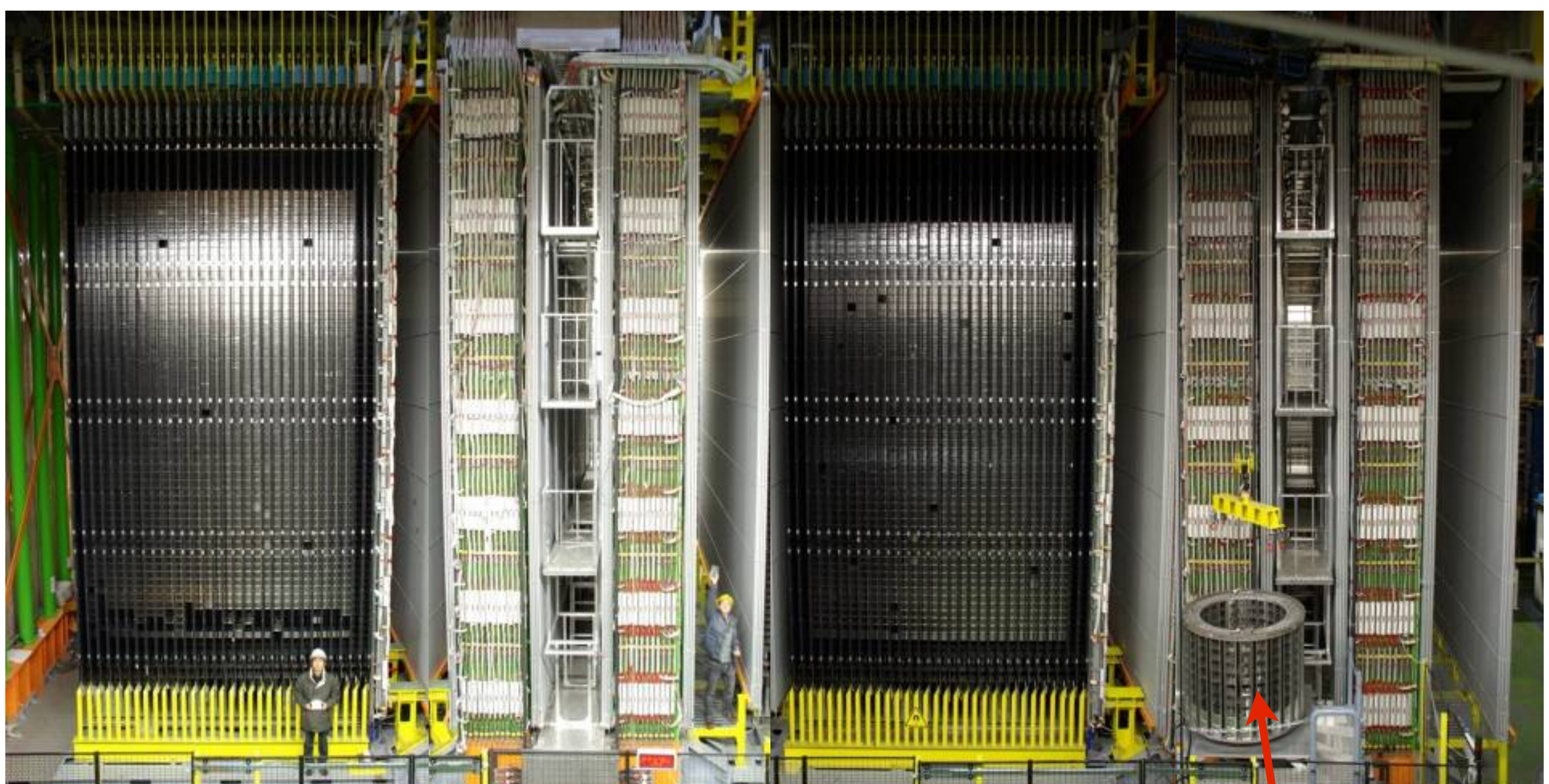


Decay channel	Detection efficiency(%)	Branching ratio(%)	Signal (Δm^2=2.5x10^{-3})	Background
$\tau \to \mu$	17.5	17.7	2.9	0.17
$\tau \to e$	20.8	17.8	3.5	0.17
$\tau \to h$	5.8	49.5	3.1	0.24
$\tau \to 3h$	6.3	15	0.9	0.17
ALL	effxBR=10.6%		**10.4**	**0.75**

5 year exposure @4.5x10^{19} POT/year

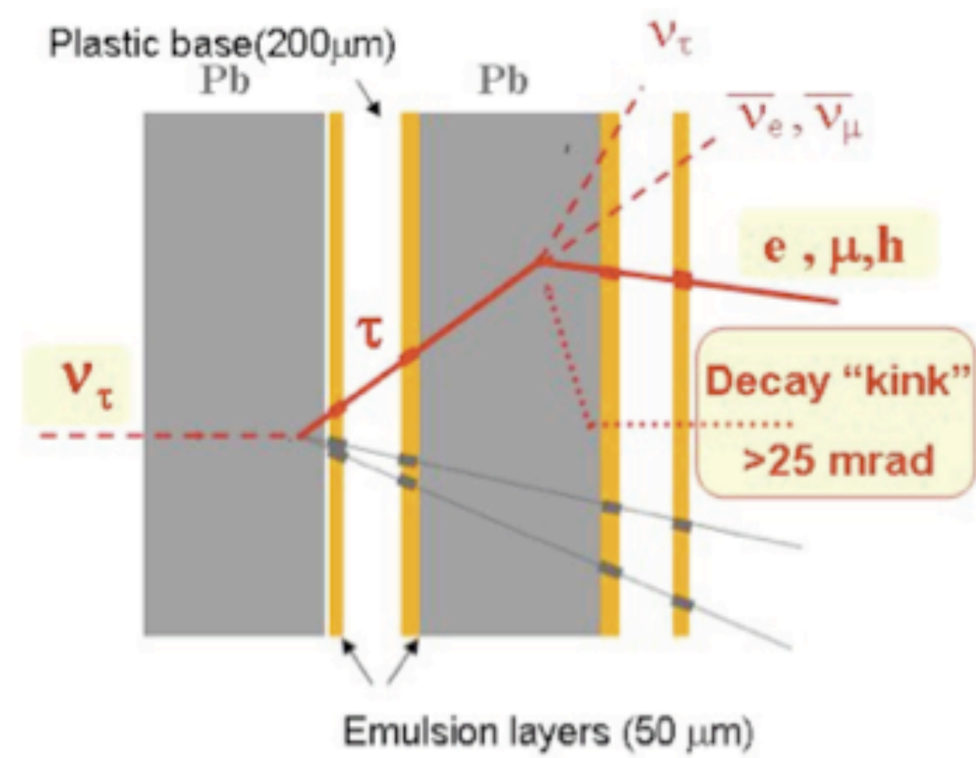
Difficult experiment, and can only expect a handful of events...

SM1 **SM2**



Target area (ECC + CS + TT)
Muon spectrometer (Magnet+RPC+PT)
Brick Manipulator System

Extract Brick and CS, scan CS.
Confirm the event in the ECC brick.
Develop brick and send to scanning labs.



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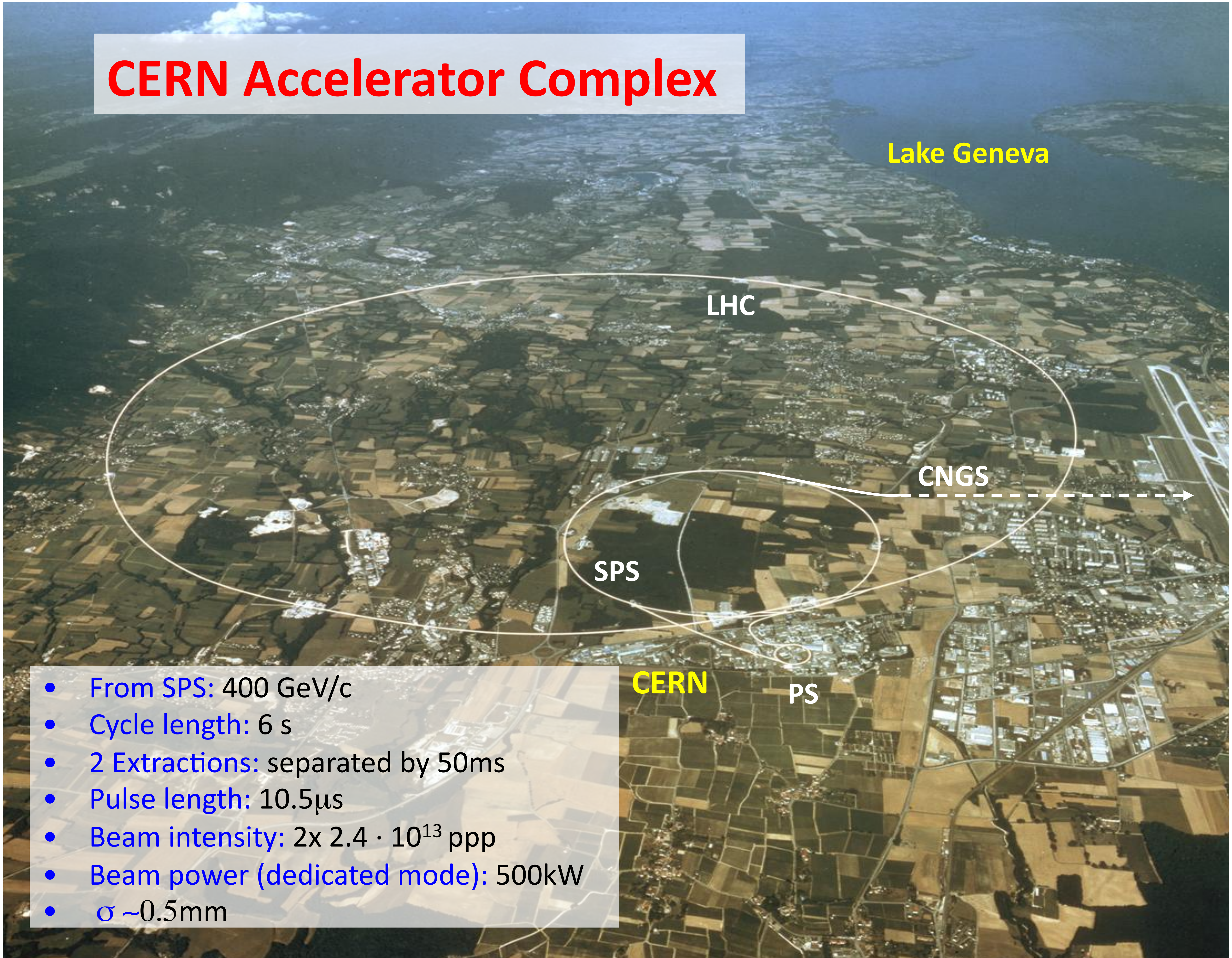
CERN Accelerator Complex

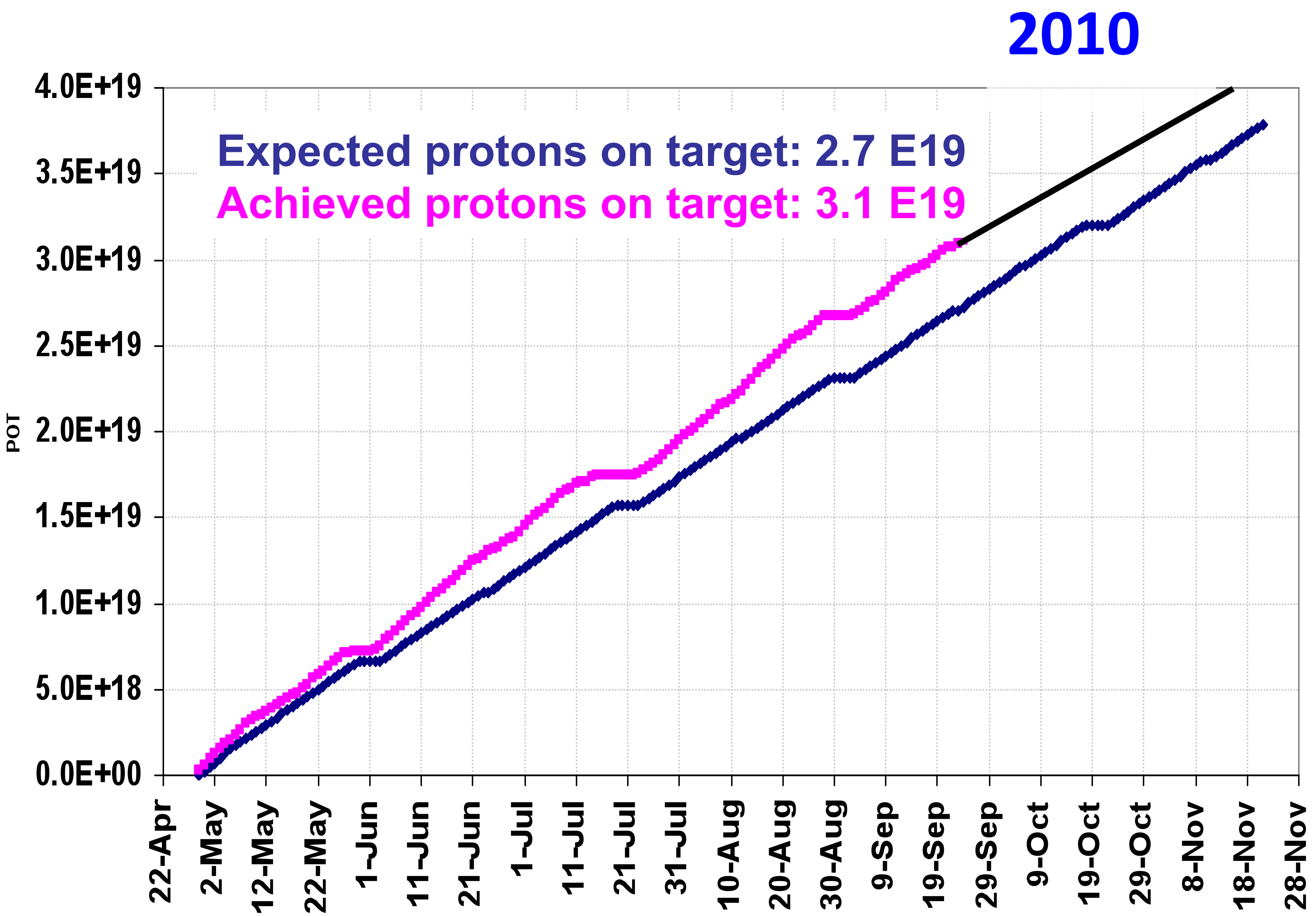


- From SPS: 400 GeV/c
- Cycle length: 6 s
- 2 Extractions: separated by 50ms
- Pulse length: 10.5μs
- Beam intensity: 2x $2.4 \cdot 10^{13}$ ppp
- Beam power (dedicated mode): 500kW
- $\sigma \sim 0.5$mm

Total Integrated Intensity since CNGS Start in 2006

Protons on target/year

2006	0.08 E19
2007	0.08 E19
2008	1.78 E19
2009	3.52 E19
2010 (today)	3.10 E19
Total	8.56 E19



Dear all,
we broke another symbolic record: the total number of pot accumulated so far (Monday 15 November at 7:00) is 4.008E19 corresponding to 25286 on-time events and 4206 candidate interactions in the target.
Congratulations to you all for keeping excellent OPERA running conditions...and the run is not over!

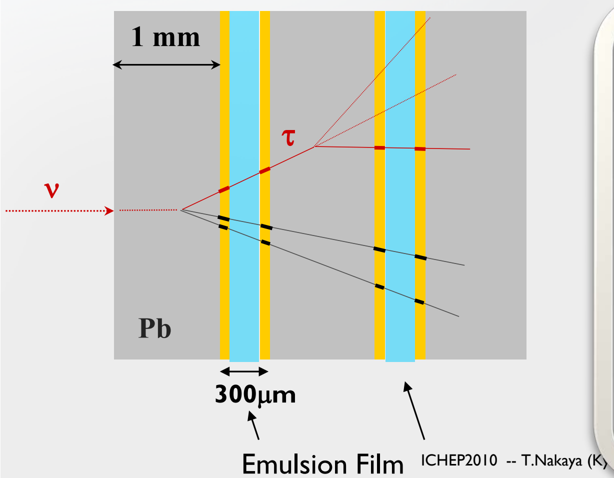
Kind regards,
Antonio

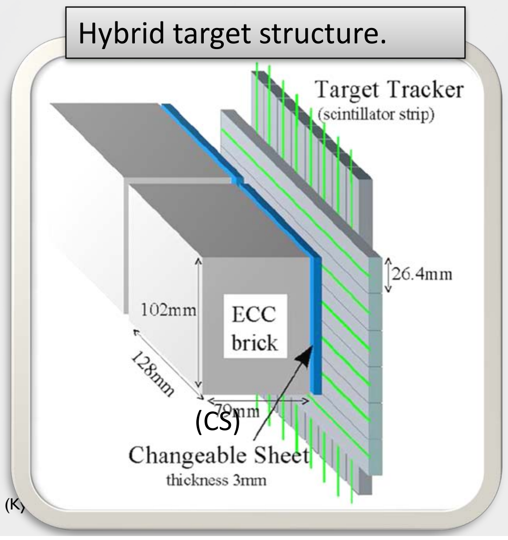
Prof. Dr. Antonio Ereditato

OPERA - direct evidence for $\nu_\mu \rightarrow \nu_\tau$!

emulsion cloud chamber technique

- The micron-resolution with one kilo-ton mass scale.
  - $c\tau_\tau$ = 87μm



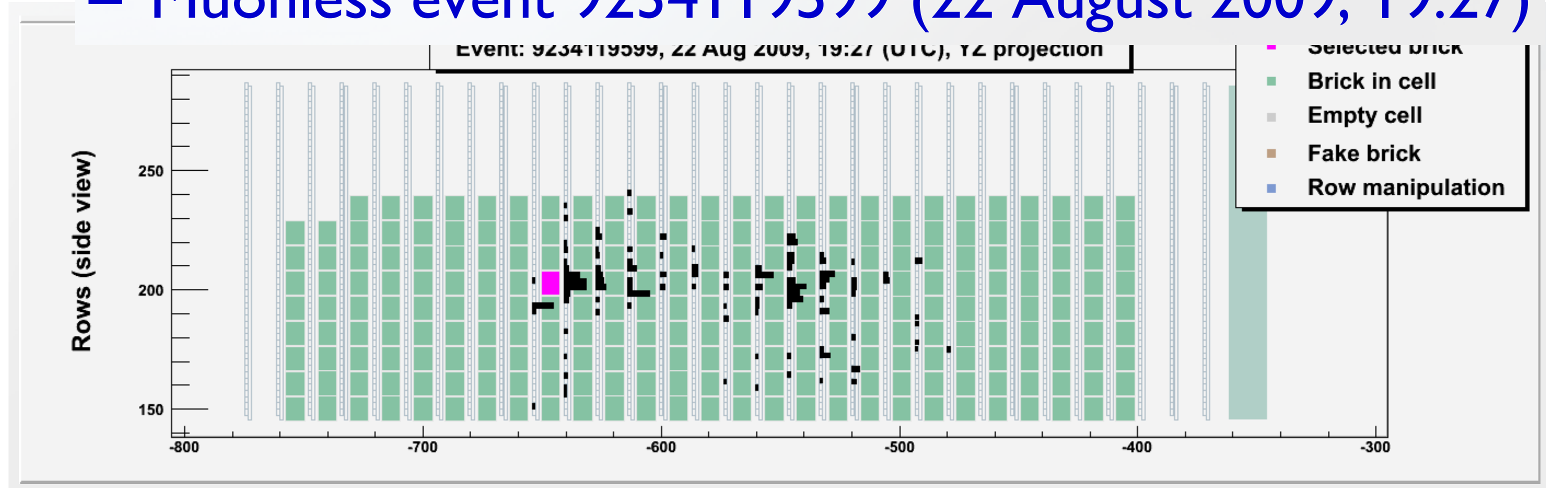


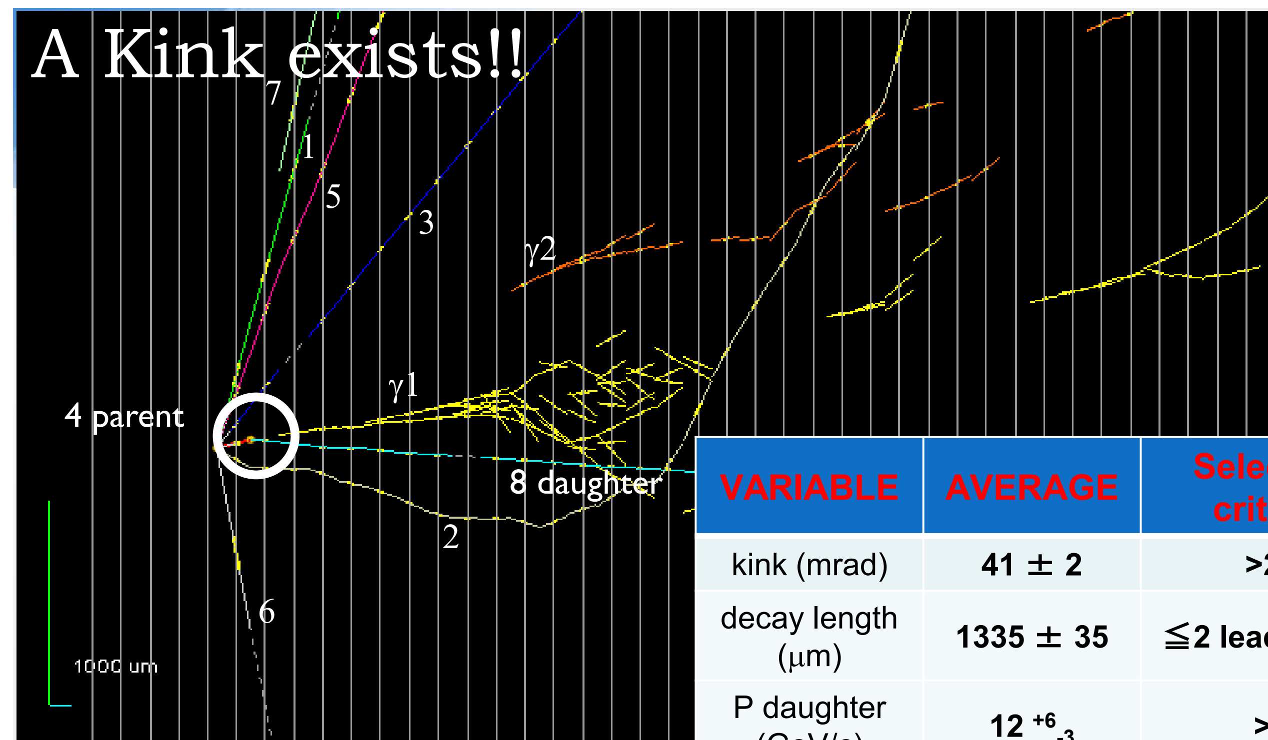
- The Expected Number of BG
  - 0.018 ± 0.007 for the 1 prong tau selection
  - 0.045 ± 0.020 for all kinds of tau selections
- The expected Signal events
  - 0.54 ± 0.13 (syst.) @ $\sin^2 2\theta_{23}=1.0$, $\Delta m_{23}^2=2.5\times10^{-3}$eV^2

- The statistical Significance
  - 2.36 σ with 0.018 ± 0.007 BG events
  - 2.01 σ with 0.045 ± 0.020 BG events

OPERA to take data at least until ≈2013

– Muonless event 9234119599 (22 August 2009, 19:27)





- $\tau \rightarrow \rho \nu_\tau$ candidate
  - $\rho \rightarrow \pi\pi^0 (\pi^0 \rightarrow \gamma\gamma)$

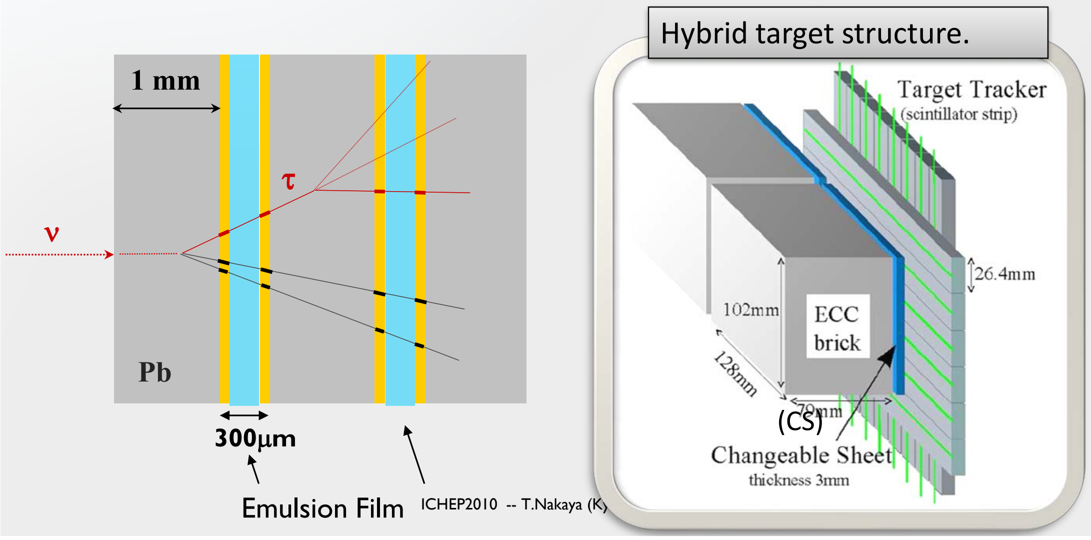
ICHEP2010 -- T.I

VARIABLE	AVERAGE	Selection criteria
kink (mrad)	41 ± 2	>20
decay length (μm)	1335 ± 35	≦2 lead plates
P daughter (GeV/c)	12^{+6}_{-3}	>2
Pt (MeV/c)	470^{+230}_{-120}	>300
missing Pt (MeV/c)	570^{+320}_{-170}	<1000
Azimuth angle (deg)	173 ± 2	>90

OPERA - direct evidence for $\nu_\mu \rightarrow \nu_\tau$!

emulsion cloud chamber technique

- The micron-resolution with one kilo-ton mass scale.
  - $c\tau_\tau$ = 87μm



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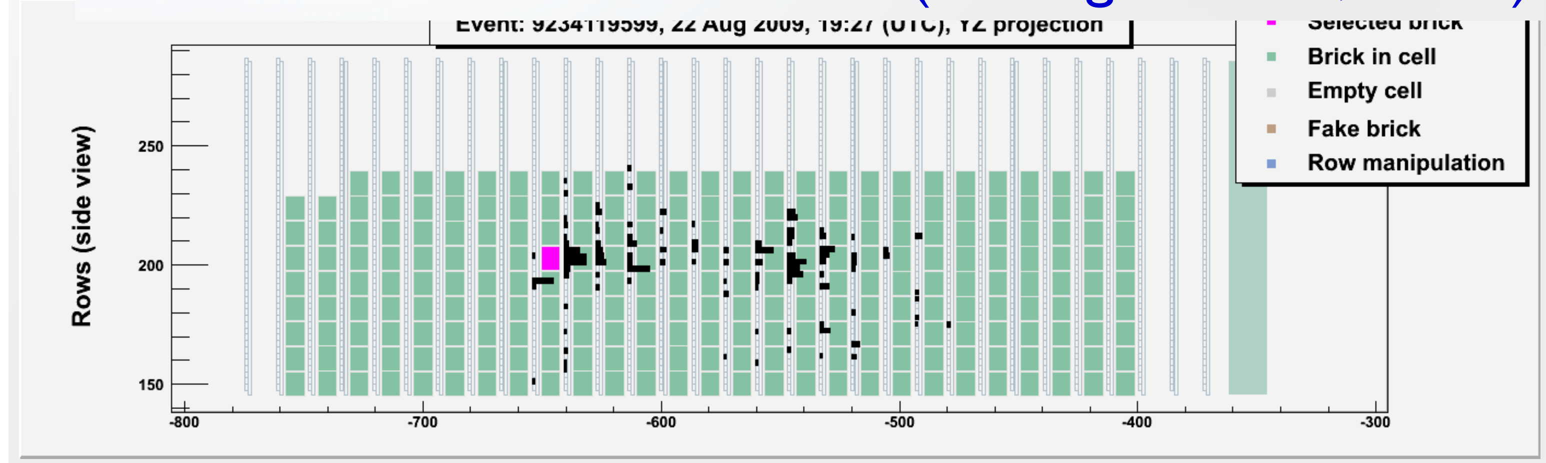

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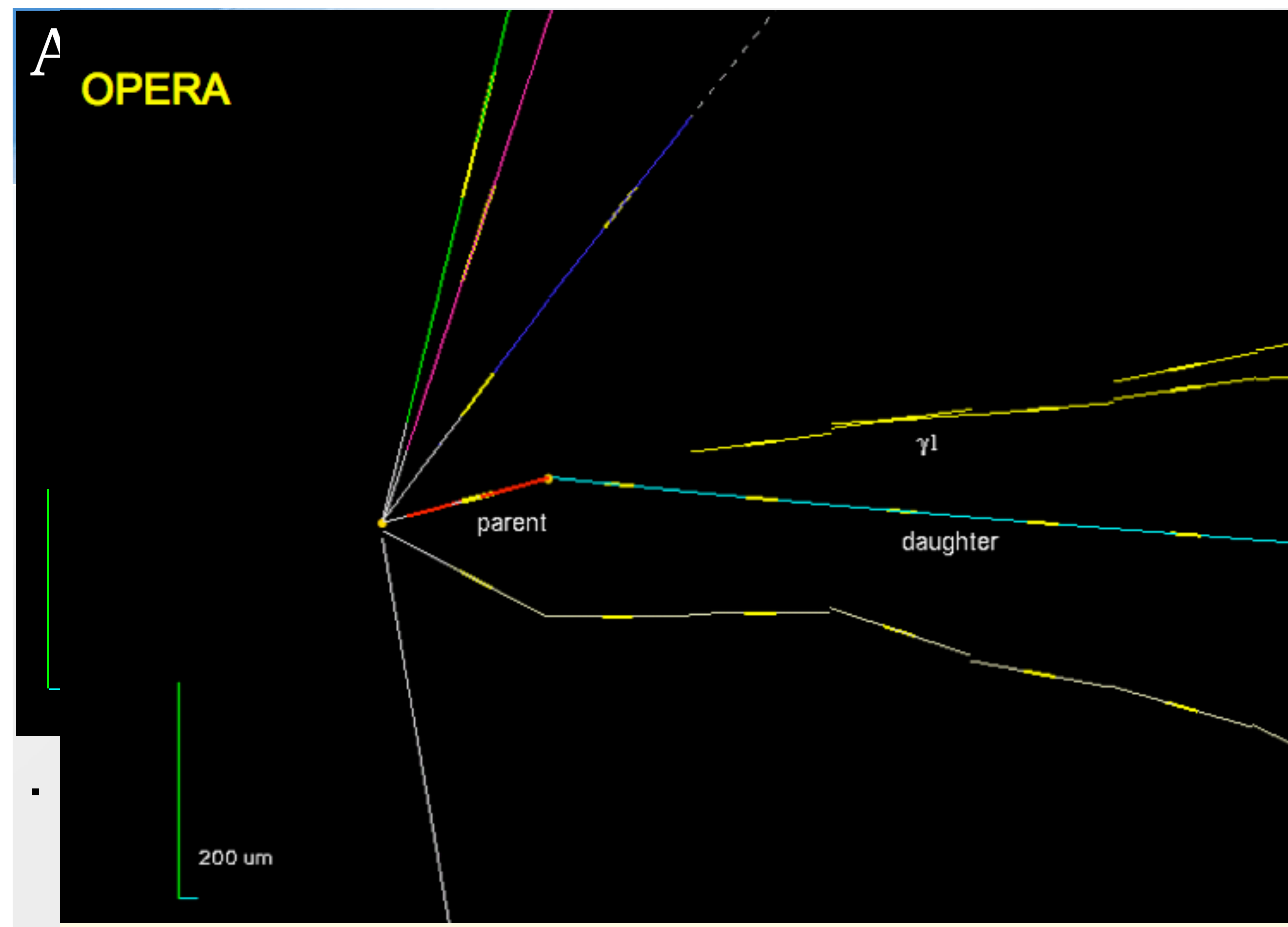


First candidate $\nu_\mu \rightarrow \nu_\tau$ $\tau^- \rightarrow \pi^- + \pi^0$

- The statistical Significance
  - 2.36 σ with 0.018 ± 0.007 BG events
  - 2.01 σ with 0.045 ± 0.020 BG events

OPERA to take data at least until ≈2013

Instead of LBL tau appearance...

- Jacques decided to join the Japanese efforts to look for the "third flavor" of a different kind. He played a fundamental role in setting up the France-Japan Collaboration in K2K, and then contributed to the initial phases of T2K

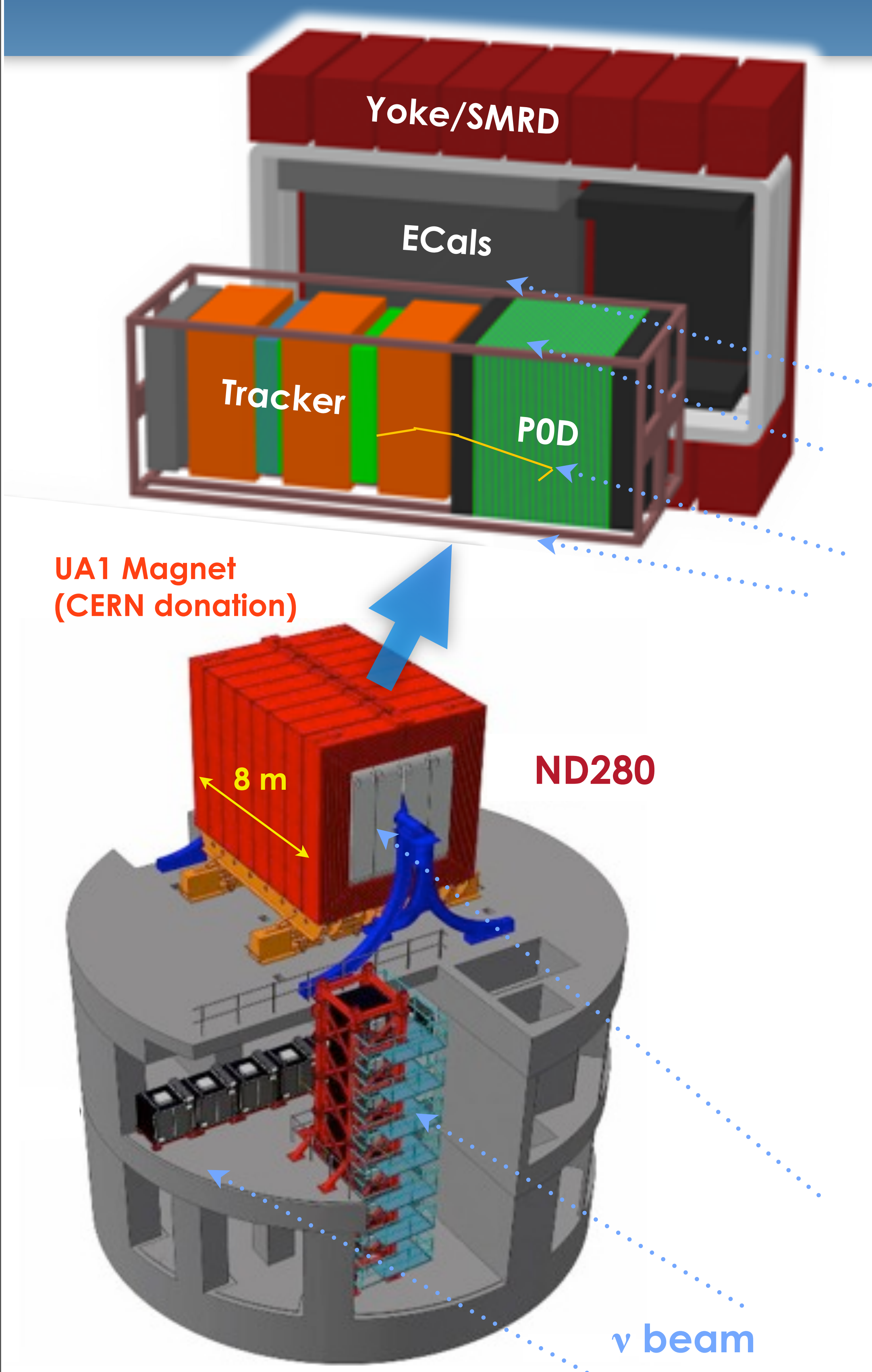
PRL **96,** 181801 (2006) PHYSICAL REVIEW LETTERS week ending 12 MAY 2006

Improved Search for $\nu_\mu \rightarrow \nu_e$ Oscillation in a Long-Baseline Accelerator Experiment

S. Yamamoto,[16] J. Zalipska,[25] E. Aliu,[1] S. Andringa,[1] S. Aoki,[14] J. Argyriades,[5] K. Asakura,[14] R. Ashie,[29] F. Berghaus,[3] H. Berns,[33] H. Bhang,[24] A. Blondel,[9] S. Borghi,[9] J. Bouchez,[5] J. Burguet-Castell,[32] D. Casper,[4] J. Catala,[32] C. Cavata,[5] A. Cervera,[9] S. M. Chen,[31] K. O. Cho,[6] J. H. Choi,[6] U. Dore,[23] X. Espinal,[1] M. Fechner,[5] E. Fernandez,[1] Y. Fukuda,[19] J. Gomez-Cadenas,[32] R. Gran,[33] T. Hara,[14] M. Hasegawa,[16] T. Hasegawa,[26] K. Hayashi,[16] Y. Hayato,[29] R. L. Helmer,[31] K. Hiraide,[16] J. Hosaka,[29] A. K. Ichikawa,[11] M. Iinuma,[12] A. Ikeda,[21] T. Inagaki,[16] T. Ishida,[11] K. Ishihara,[29] T. Ishii,[11] M. Ishitsuka,[30] Y. Itow,[29] T. Iwashita,[11] H. I. Jang,[6] E. J. Jeon,[24] I. S. Jeong,[6] K. K. Joo,[24] G. Jover,[1] C. K. Jung,[27] T. Kajita,[30] J. Kameda,[29] K. Kaneyuki,[30] I. Kato,[31] E. Kearns,[2] D. Kerr,[27] C. O. Kim,[15] M. Khabibullin,[13] A. Khotjantsev,[13] D. Kielczewska,[34,25] J. Y. Kim,[6] S. B. Kim,[24] P. Kitching,[31] K. Kobayashi,[27] T. Kobayashi,[11] A. Konaka,[31] Y. Koshio,[29] W. Kropp,[4] J. Kubota,[16] Yu. Kudenko,[13] Y. Kuno,[22] Y. Kurimoto,[16] T. Kutter,[17,3] J. Learned,[10] S. Likhoded,[2] I. T. Lim,[6] P. F. Loverre,[23] L. Ludovici,[23] H. Maesaka,[16] J. Mallet,[5] C. Mariani,[23] S. Matsuno,[10] V. Matveev,[13] K. McConnel,[18] C. McGrew,[27] S. Mikheyev,[13] A. Minamino,[29] S. Mine,[4] O. Mineev,[13] C. Mitsuda,[29] M. Miura,[29] Y. Moriguchi,[14] T. Morita,[16] S. Moriyama,[29] T. Nakadaira,[11] M. Nakahata,[29] K. Nakamura,[11] I. Nakano,[21] T. Nakaya,[16] S. Nakayama,[30] T. Namba,[29] R. Nambu,[29] S. Nawang,[12] K. Nishikawa,[16] K. Nitta,[11] F. Nova,[1] P. Novella,[32] Y. Obayashi,[29] A. Okada,[30] K. Okumura,[30] S. M. Oser,[3] Y. Oyama,[11] M. Y. Pac,[7] F. Pierre,[5] A. Rodriguez,[1] C. Saji,[30] M. Sakuda,[21] F. Sanchez,[1] A. Sarrat,[27] T. Sasaki,[16] H. Sato,[16] K. Scholberg,[8,18] R. Schroeter,[9] M. Sekiguchi,[14] M. Shiozawa,[29] K. Shiraishi,[33] G. Sitjes,[32] M. Smy,[4] H. Sobel,[4] M. Sorel,[32] J. Stone,[2] L. Sulak,[2] A. Suzuki,[14] Y. Suzuki,[29] T. Takahashi,[12] Y. Takenaga,[30] Y. Takeuchi,[29] K. Taki,[29] Y. Takubo,[22] N. Tamura,[20] M. Tanaka,[11] R. Terri,[27] S. T'Jampens,[5] A. Tornero-Lopez,[32] Y. Totsuka,[11] S. Ueda,[16] M. Vagins,[4] L. Whitehead,[27] C. W. Walter,[8] W. Wang,[2] R. J. Wilkes,[33] S. Yamada,[29] C. Yanagisawa,[27] N. Yershov,[13] H. Yokoyama,[28] M. Yokoyama,[16] J. Yoo,[24] and M. Yoshida[22]

(K2K Collaboration)

T2K off-axis detector



The Off-axis near detector (ND280) provides

- Off axis beam measurement based on CCQE
- beam nue contamination
- Super-K background measurements (NCπ^0)

Two target regions :

- The P0D (Brass/Plastic segmented) : π^0 detector
- The tracker region : Fined grained plastic detector and TPC
- Both region have passive water planes

Large Calorimeter coverage (Plastic/Pb segmented)

- Additional NCπ^0 production measurement in tracker and PID, hermicity, active veto

Side Muon ranging detector

- Neutrino Rate, Side muons, cosmics trigger

Precise cross-section measurements with very large statistics !!!

T2K ND280 off-axis detector

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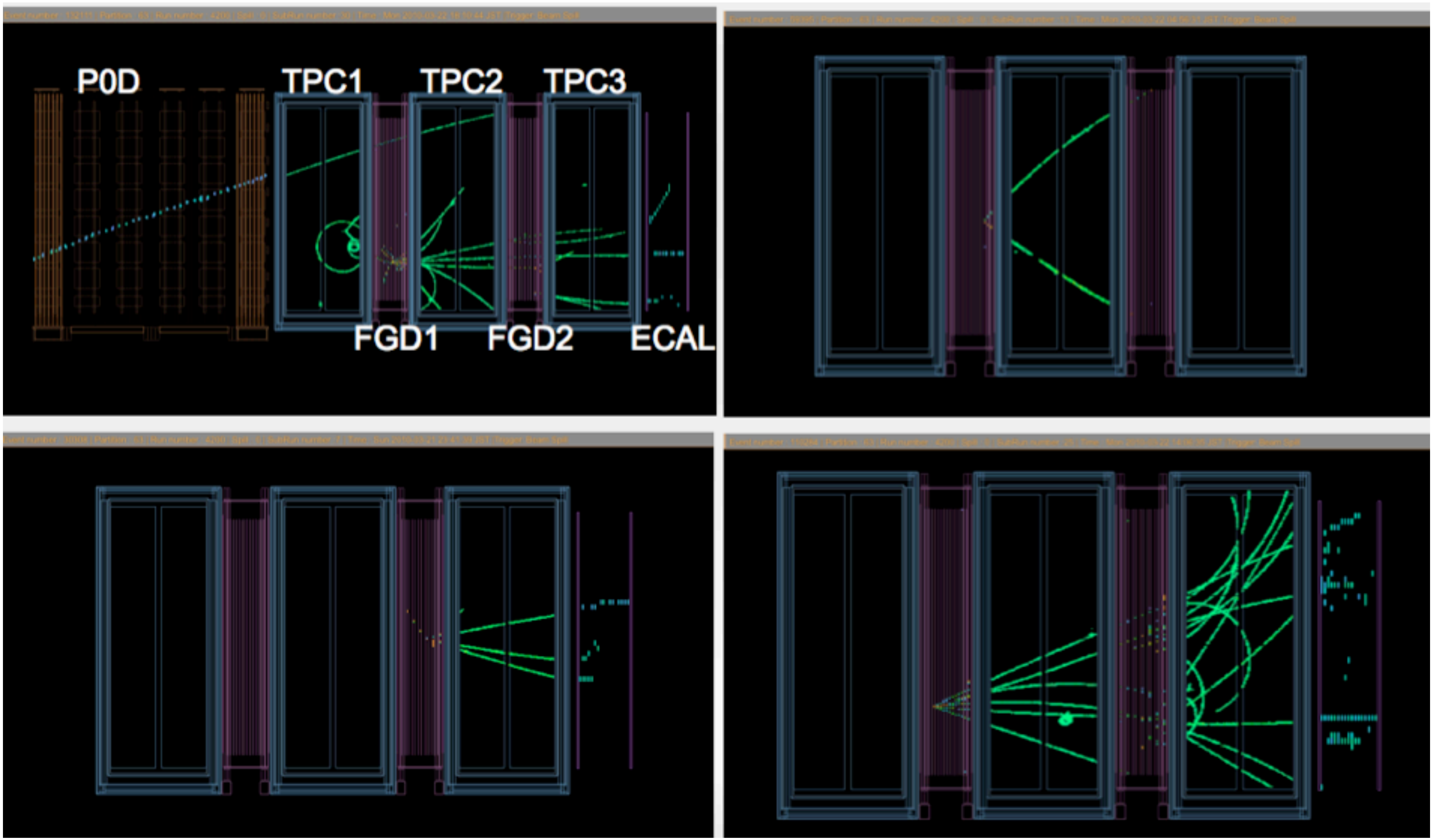
T2K ND280 off-axis detector



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LAGUNA "name" vote

From: "bouchez" <bouchez@hep.saclay.cea.fr>
Subject: **RE: Vote for the name of the three liquids project**
Date: June 12, 2006 7:31:15 PM GMT+02:00
To: "Andre Rubbia" <andre.rubbia@cern.ch>

Mon cher Andre,

Je reconnais bien la ton souci de la precision!
Ton mail m'a rappele que je devais te demander si tu as essaye de te faire rembourser ton voyage a Paris pour la these de Maximilien en envoyant ton billet. Je n'en ai pas entendu parler. Qu'en est-ilexactement?

Amicalement,

Jacques Bouchez
DAPNIA/SPP
CEA-Saclay
91191 Gif-sur-Yvette cedex
France
Tel: (+)33-1-69-08-44-69
Fax: (+) 33-1-69-08-64-28
E-mail: bouchez@hep.saclay.cea.fr

The last email I received from Jacques

Thank you very much for your attention !

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