PC Overview

Video CM, 21-22/Mar./2017

M. Komatsu

PC meetings since October

- We had four PC meetings since October CM @ Naples
- PC meeting 7/12/2016
  - https://indico.cern.ch/event/591841/
  - Final statistics for data analysis : Sato
  - Nue oscillation analysis : Matteo
  - Nue paper preparation status : Svetlana
  - Marginal event analysis : Giuliana
  - Multiplicity internal note status : Cagin
- PC meeting 13/1/2017
  - https://indico.cern.ch/event/597066/
  - Electron energy reconstruction : Frank
  - Nue oscillation analysis : Matteo
  - Nue paper preparation status : Svetlana
  - Numu disappearance analysis : Budimir
  - Marginal event analysis : Giuliana
  - Cosmic ray annual modulation : Nicoletta
  - Open data event set : Cagin

PC meetings since October

- PC meeting 17/2/2017
  - https://indico.cern.ch/event/612325/
  - Nue oscillation analysis : Matteo
  - Nue paper preparation status : Svetlana
  - Marginal event analysis : Giuliana
  - Cosmic ray annual modulation : Nicoletta
  - Materials provided offline
    - Double vertex event : Chiara
    - Multiplicity study : Cagin
- PC meeting 15/3/2017
  - https://indico.cern.ch/event/618894/
  - Nue analysis and paper status : Svetlana, Matteo
  - Marginal event analysis : Giuliana
  - numu disappearance analysis : Budimir
  - Cosmic ray annual modulation : Alessandro on behalf of Nicoletta
  - Event display for open data : Sergey

Final statistics for nue and marginal event analysis

Statistics frozen by the end of November 2016

SCANNING COORDINATION

Statistics at 5th Dec
same definition with 5th tau paper

Sato @ PC 7 Dec

Run year	0mu DS	1mu DS	0mu loc	1mu loc
2008	150	543	156	556
2009	255	1024	268	1042
2010	278	1001	296	1029
2011	291	1031	315	1093
2012	223	807	246	867
TOTAL	1197	4406	1281	4587

15 GeV cut for 1mu
1st and 2nd bricks
5603 TcauDecaySearched
5868 Located

Comparison with 5th tau paper

Sato @ PC 7 Dec

Run year	0mu DS		1mu DS		0mu loc		1mu loc	
2008	149	+1	542	+1	155	+1	555	+1
2009	253	+2	1020	+4	266	+2	1036	+6
2010	268	+10	968	+33	281	+15	989	+40
2011	270	+21	966	+65	293	+22	1016	+77
2012	204	+19	768	+39	228	+18	818	+49
TOTAL	1144	+53	4264	+142	1223	+58	4414	+173

DS done 5408(5th paper) + 195 → 3.6% increased.

Loc done 5637 + 231

Svetlana and Matteo

Updated in all PC meetings

NUE ANALYSIS

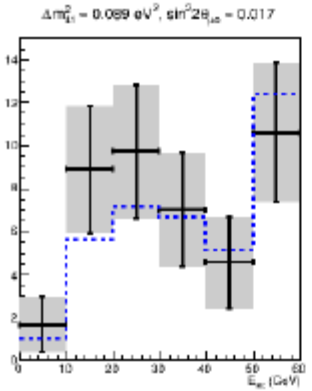
Key items for nue analysis

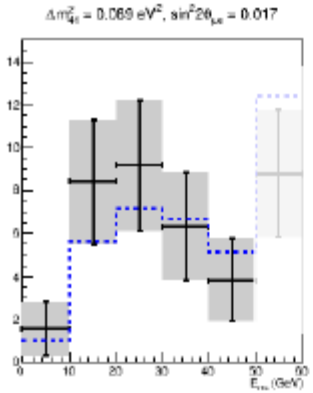
- 3+1 model with shape analysis (multi bin analysis) is baseline.
  - Big discussions and cross checks on “energy cut” or “no cut”
  - Concluded as “no cut” by February PC meeting and finalized
- Normalization
  - With a help of SC, normalization become more and more solid
  - Many cross checks been done.
- Model (mostly) independent $P_{\mu e}$ evaluation
  - Any interpretation can be applied on this $P_{\mu e}$ value
  - Counting method with energy cut (Best sensitivity)

Matteo @ PC 17 Feb

What happens there?

i.e. why that region are excluded in case of no energy cut?

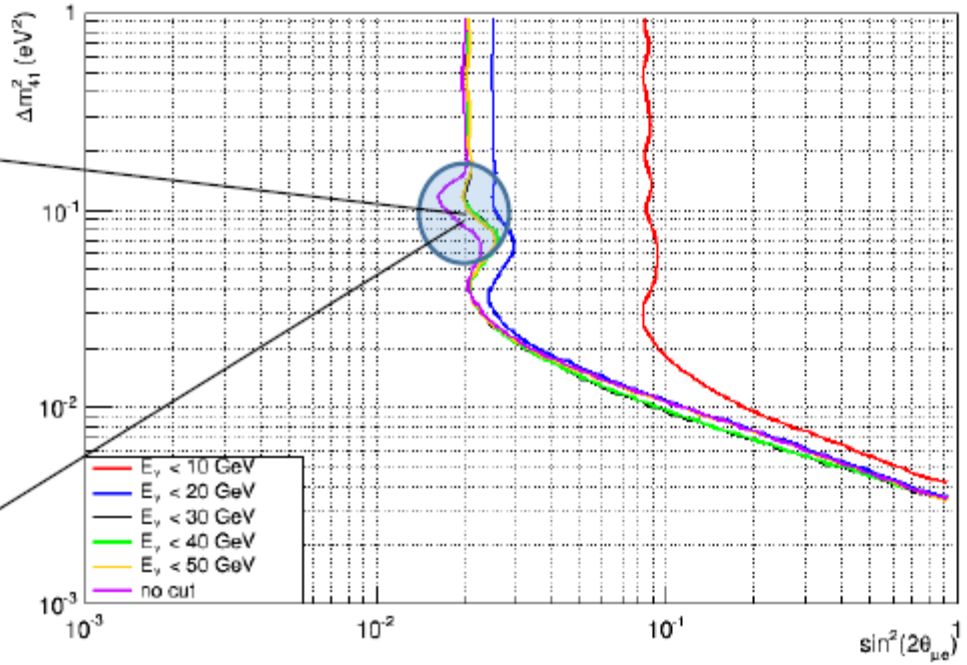




No energy cut

dotted line: expectation for null hypothesis

$E_{cut} = 50\ GeV$

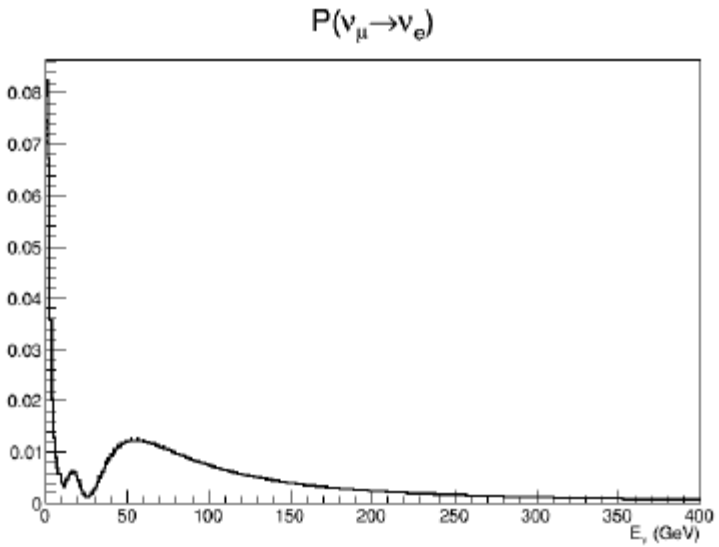


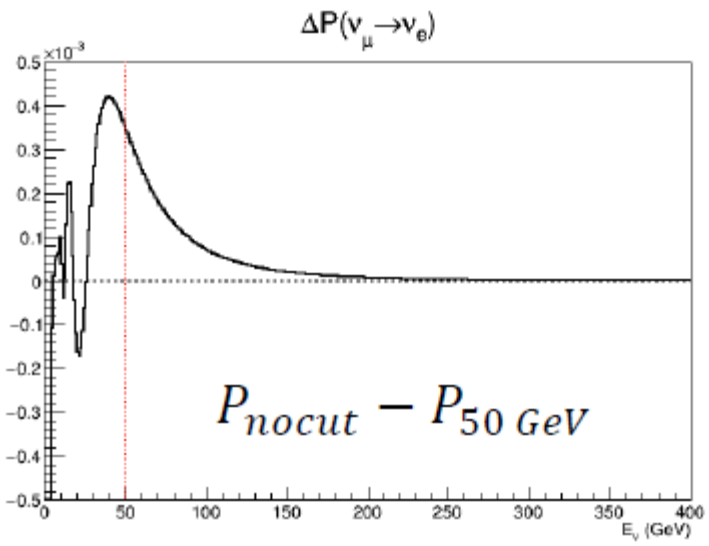
Roughly speaking last bin has greater weight due to its higher statistics and lead the best fit energy distribution to bigger values which are less compatible to null hypothesis

Matteo @ PC 17 Feb

Let's compare

continuous lines: $E_{cut} = 50\ GeV$
dotted line: no cut





Last bin leads to higher probability, consequently the expectations for the other bins increase leading to a less compatible distribution with respect to null hypothesis resulting in the exclusion of these parameter values

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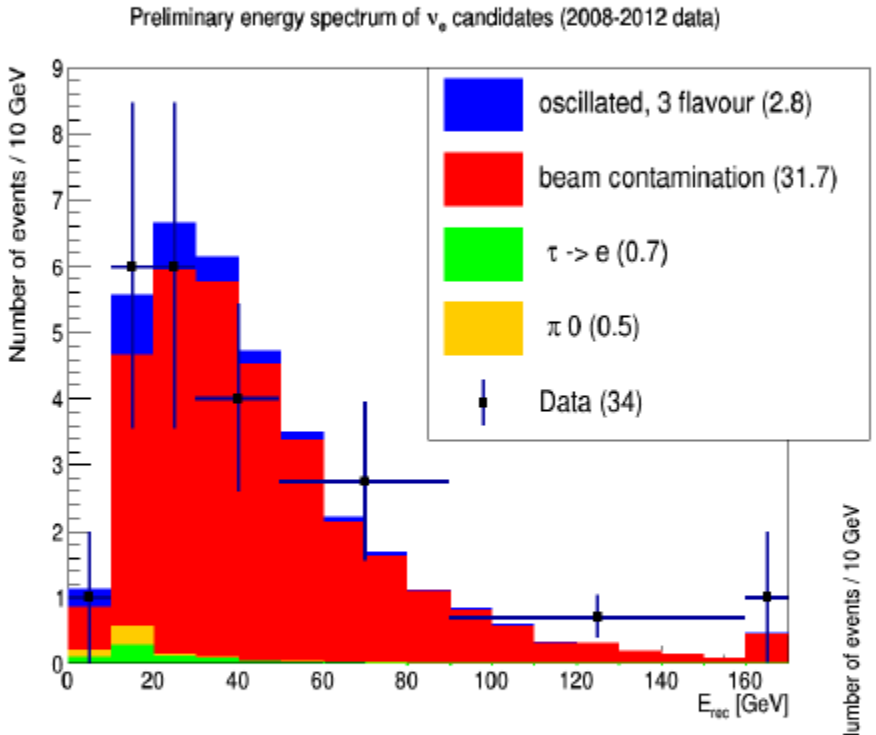
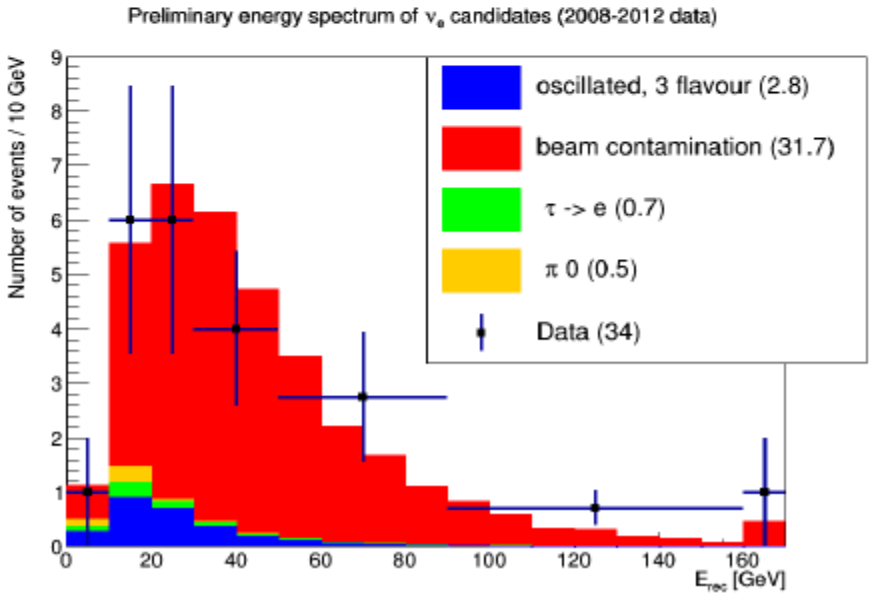
The expected energy spectra (normalized on 1185)

Svetlana @ PC 15 Mar



(the same data on both plots, the difference is the oscillated events are on top and on the bottom of the stack)



Number of expected events in the different energy intervals (normalized on 1185)

Svetlana @ PC 15 Mar

Energy region [GeV]	0-10	0-20	0-30	0-40	0-50	all
Beam contamination	0.6±0.12	4.7±0.53	10.5±1.11	16.2±1.68	20.7±2.13	31.7±3.23
τ -> e	0.1±0.02	0.4±0.05	0.5±0.06	0.6±0.07	0.6±0.07	0.7±0.08
π0	0.1±0.02	0.4±0.05	0.4±0.05	0.5±0.06	0.5±0.06	0.5±0.06
Total BG to 3 flavour	0.8±0.12	5.5±0.53	11.4±1.11	17.3±1.68	21.8±2.13	32.9±3.23
3 flavour scenario (osc)	0.3±0.06	1.2±0.15	1.9±0.22	2.3±0.26	2.5±0.28	2.8±0.31
3 flavour scenario+BG	1.1±1.37	6.7±0.56	13.3±1.13	19.6±1.70	24.3±2.15	35.7±3.25
νe found	1+2.29-0.83	7+3.75-2.57	13+4.67-3.54	19+5.41-4.30	21+5.63-4.52	34+6.85-5.77
Signal to BG ratio (3 flavour)	0.38	0.22	0.17	0.13	0.11	0.09

Svetlana @ PC 15 Mar

Upper limits and sensitivities for N oscillated events (normalized on 1138)

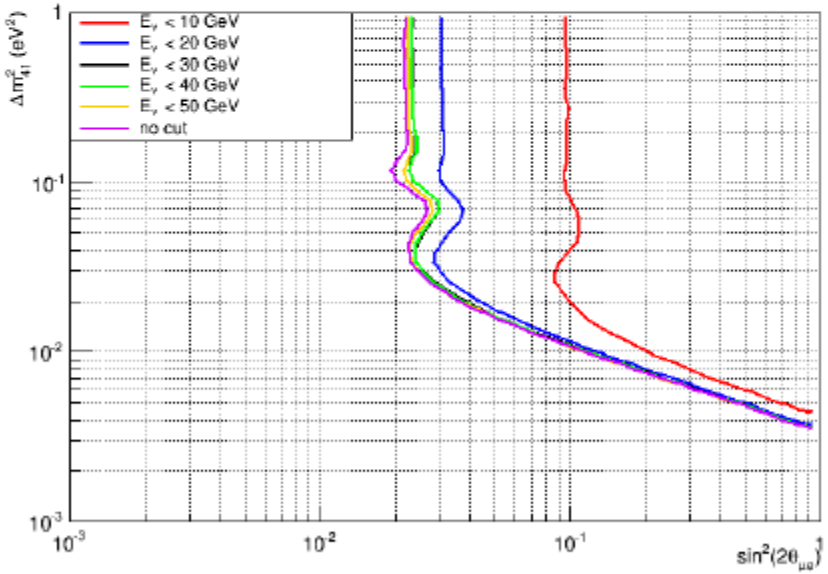
Energy interval [GeV]	Upper limits Nosc (Pμe, Pee=1)		Sensitivity Nosc (Pμe, Pee=1)	
	Bayesian	F&C	Bayesian	F&C
0-10	3.37 (0.0281)	3.56 (0.0296)	3.37(0.0281)	3.57 (0.0297)
0-20	6.76 (0.0060)	7.28 (0.0065)	5.81 (0.0051)	5.98 (0.0053)
0-30	8.51 (0.0033)	9.11 (0.0035)	6.86 (0.0027)	6.62 (0.0026)
0-40	9.98 (0.0036)	10.70 (0.0035)	8.41 (0.0030)	8.22 (0.0027)
0-50	9.08 (0.0031)	8.74 (0.0030)	9.82 (0.0034)	9.74 (0.0034)
all	11.84 (0.0037)	13.57(0.0042)	10.37 (0.0032)	11.31(0.0035)

Svetlana @ PC 15 Mar

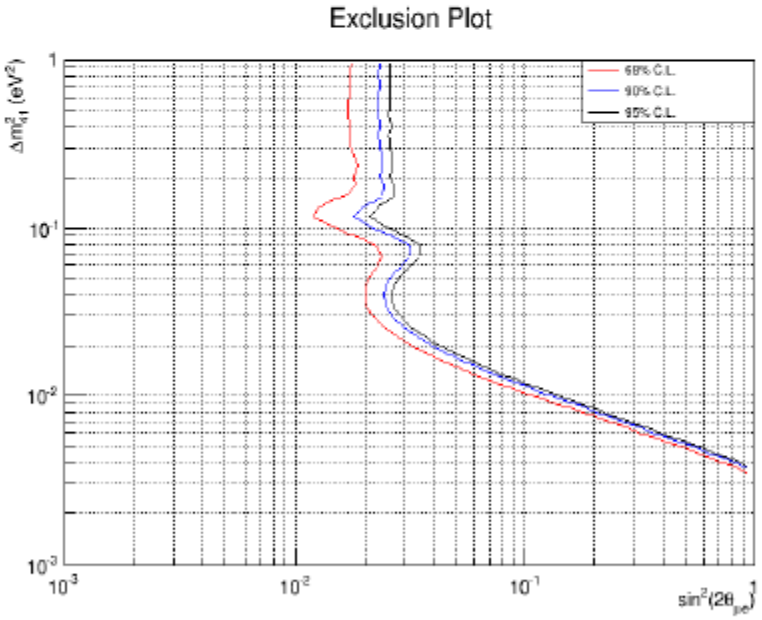
νe analysis: Matteo's plots for March Conference

Sensitivity (with syst. Uncert.)

The best result is obtained with no cut



Exclusion plot
(no E cut and with syst. uncert.)



Giuliana

Updated in all PC meetings

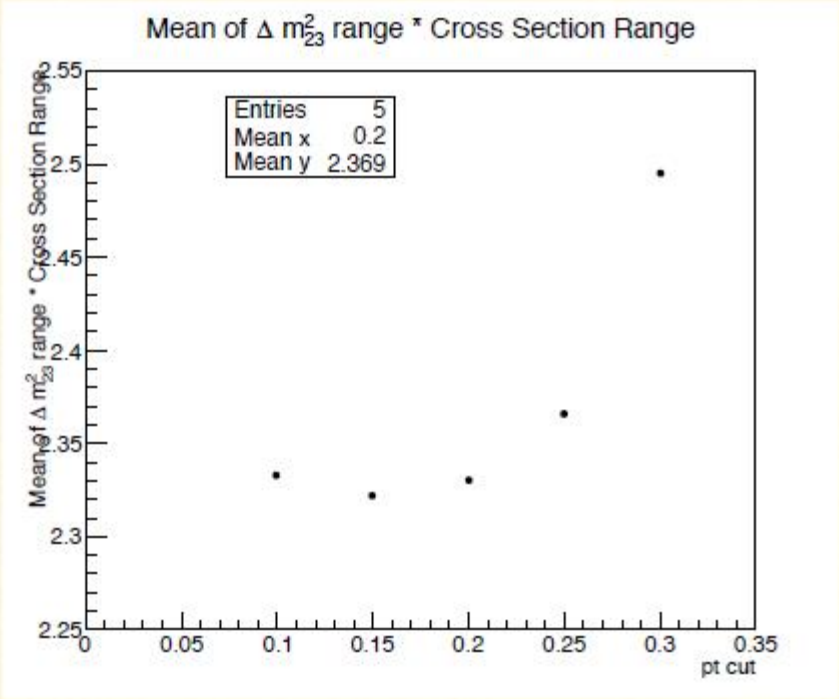
MARGINAL EVENTS

Giuliana @ PC 17 Feb

LAB	Event ID	Ev Class	Topology	zdec	DL	ptmiss	phi	P_t (GeV/c)	P_{dau} Total (GeV/c)	psum	kink	massa inv	m min inv	γ in decvtx	TFD
1st cand	9234119599	0μ	kink	435 ±35	1135 ±35	$0,52^{+0,32}_{-0,17}$	173±2	$0,47^{+0,24}_{-0,12}$	12^{+6}_{-3}	$24,3^{+3,9}_{-2,7}$	0,041±0,002	/	/	2	DONE
2nd cand	11113019758	0μ	trident	1446 ±10	1466 ±10	0,31±0,11	167,8±1,1	/	8,4±1,7	$12,7^{+1,7}_{-2,3}$	0,0874±0,0015	0,80± 0,12	0,96 ±0,13	0	DONE
3rd cand	12123032048	1μ	kink	151 ±10	376 ±10	/	/	0,69±0,05	2,8 [2,6; 3,0]	$6,8^{+0,9}_{-0,6}$	0,245±0,005	/	/	0	DONE
4th cand	12254000036	0μ	kink	406 ±30	1090 ±30	$0,55^{+0,3}_{-0,2}$	166^{+2}_{-31}	$0,82^{+0,3}_{-1,6}$	6,0 [4,8; 8,2]	$14,4^{+3,9}_{-2,7}$	0,137+0,004	/	/	0	DONE
5th cand	12227007334	0μ	kink	630 ±30	960 ±30	0,3±1	151±1	$1^{+1,1}_{-0,4}$	11^{+14}_{-4}	12^{+14}_{-4}	0,090±0,002	/	/	0	DONE
Bo-Pd	11143018505	0μ	kink	429,6	1160	0.876	151,8	0.24	2,7 [2,13; 3,70]	23.2	0.090	/	/	1	DONE
Bern	11172035775	0μ	kink	652	1100	0,90 [0,79;1,16]	140.4	0,68 [0,56; 0,90]	6,9 [5,7; 9,2]	32.2	0.098	/	/	0	NOT NEED
Nagoya	9190097972	0μ	kink	10	822	0,46	142,8	0,33	2,2 [1,6; 3,6]	9,6	0.146	/	/	0	NOT NEED
Bari	10123059807	0μ	trident	-648	140	0,6	82	/	>6,7	> 16,9	0.231	1,2	2	0	DONE
Nagoya	11213015702	0μ	trident	407	256	0,5	47,1	/	> 6,3	6.78	0.083	0.94	1.42	2	NOT NEED

Giuliana @ PC 13 Jan

BLIND ANALYSIS TO CHOOS p^{T}_{2ry} CUT FOR $\tau \rightarrow 1h$ DECAY CHANNEL



pt cut (GeV/c)	mean of Δm^2_{23} range (10^{-3} eV^2)	mean of $\sigma_{\nu\tau}$ range (10^{-38} cm^2 GeV^{-1})
0,1	2,149	1,098
0,15	2,152	1,093
0,2	2,134	1,102
0,25	2,156	1,108
0,3	2,211	1,139

More details about the procedure can be found in my presentation given @PC Meeting on 7/12/16: https://goo.gl/kBqII7

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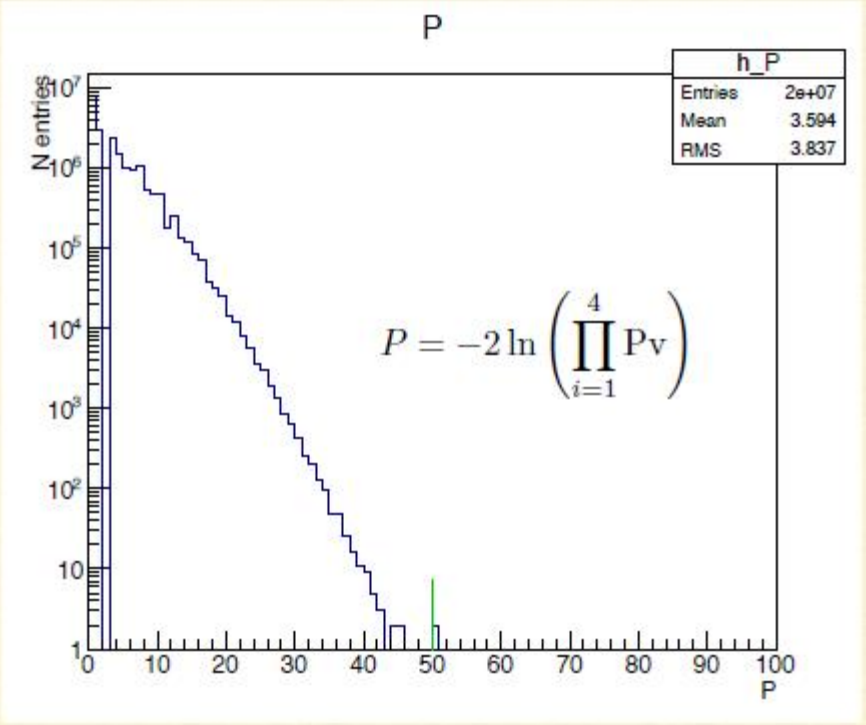
Minimum bias requirement optimization

Giuliana @ PC 13 Jan

MINIMUM BIAS (8 CHANNELS): SIGNIFICANCE

	BKG	N OBS	P-VALUE
τ→1h	0,04	3	1,115e-05
τ→μ	0,0043	1	0,004279
τ→3h	0,18	1	0,164776
τ→e	0,03	0	1
τ→1h	1,32	3	0,147554
τ→μ	0,05	0	1
τ→3h	0,16	2	0,0115233
τ→e	0,01	0	1

PSEUDO EXPERIMENTS	2*10^7
P*	50,08
N PS EXP CON P>P*	2
COMBINED P-VALUE	1E-07
SIGMA	5,20



Preliminary results: more Pseudo-experiments needed + cross-check

Giuliana @ PC 17 Feb

CROSS CHECK BY SATO-SAN

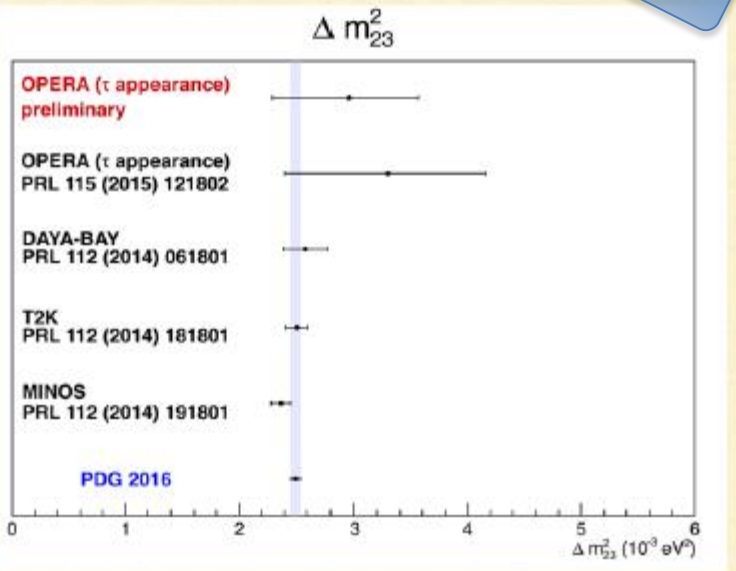
(using expected events as in my Presentation @PCMeeting 13Jan2017)

- A cross check for significance evaluation using 8 channel background expectation was done by p* method and also by Log likelihood ratio method together with 8channel signal expectation.
- 21 survived PE by L> L* in p* method out of 10^9 PE.
  P_value = $(2.10 \pm 0.46) \times 10^{-8}$
- 26 survived PE by LR>LR* in log likelihood ratio method in 10^9PE.
  P_value = $(2.60 \pm 0.51) \times 10^{-8}$
- It would better to increase PE statistics for error on P_value.
- Any way a factor 4 or 5 smaller P_value than 5th tau paper !
  5.42 - 5.53 σ

Giuliana @ PC 17 Feb

ΔM^2_{23} EVALUATION (C.L. evaluated with Feldman-Cousins method)

	# expected signal events	# expected bkg events	# Observed events	Δm^2_{23} (10^{-3} eV^2) (68% C.L)	Δm^2_{23} (10^{-3} eV^2) (90% C.L)
5 tau paper ($\Delta m^2_{23} = 2{,}44 \cdot 10^{-3}$)	2.64	0.25	5	3.3	[2.0; 5.0]
min bias ($\Delta m^2_{23} = 2{,}5 \cdot 10^{-3}$)	5.88	1.86	10	$2.95^{+0.62}_{-0.65}$	[1.98; 3.95]



Absolute ν_τ-nucleon cross section evaluation

Agreement with SM value within 1 σ

$\sigma^{const} = 0{,}67 \cdot 10^{-38}$ cm^2 GeV^{-1}

	Observed events	Cross section (cm^2 GeV^{-1}) *68% C.L*	Cross section (cm^2 GeV^{-1}) *90% C.L*
min bias (1h pt cut=0,15GeV) ($\Delta m^2_{23} = 2{,}5 \cdot 10^{-3}$)	10	$0.93^{+0.43}_{-0.37} \cdot 10^{-38}$	$[0.42; 1.67] \cdot 10^{-38}$

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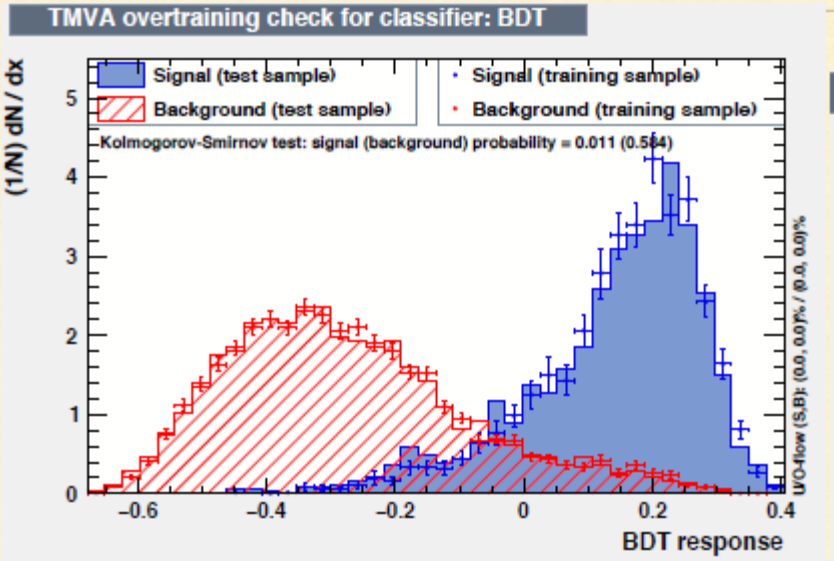
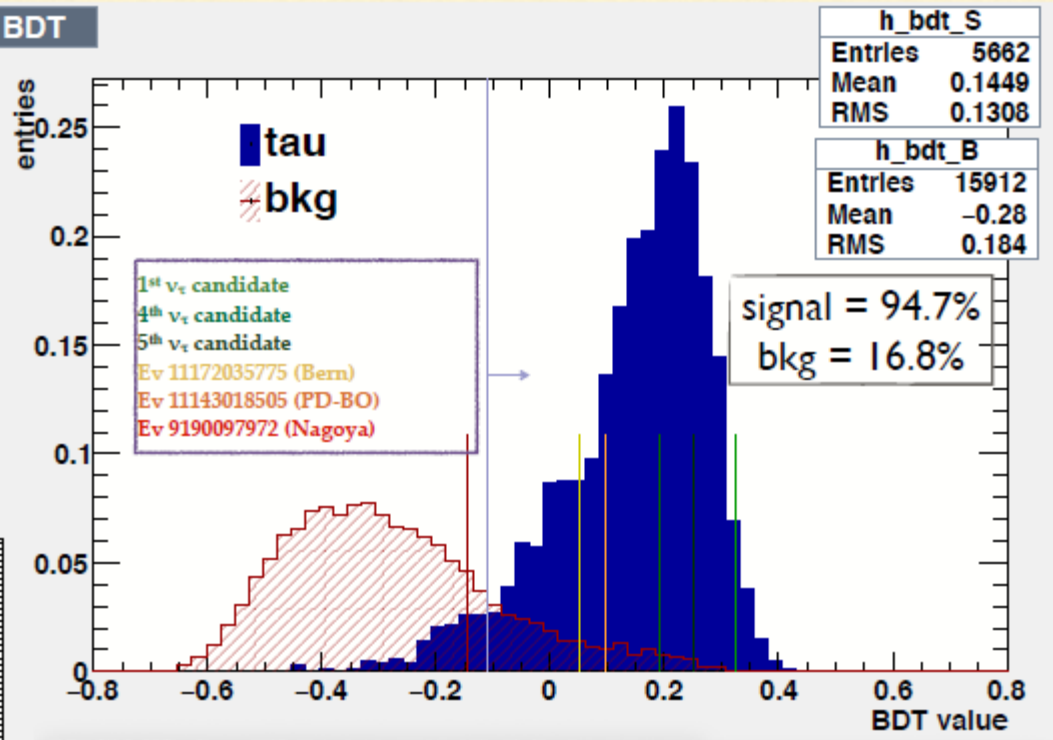
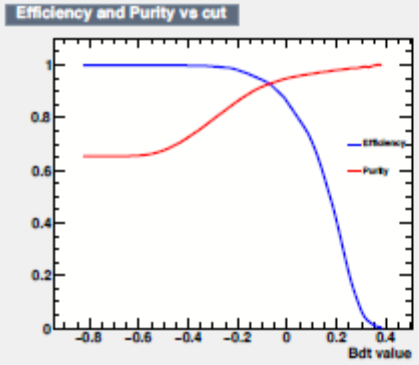
We are sensitive to a product of oscillation probability and cross-section

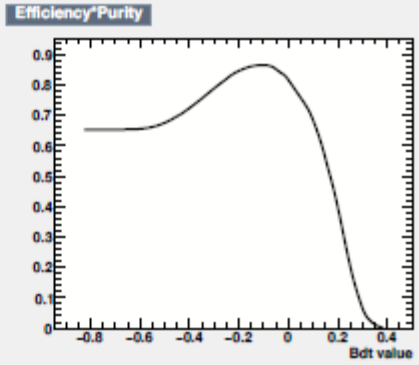
Giuliana @ PC 17 Feb

τ→1h: KINEMATICAL VARIABLES









- τ distribution weighted for oscillation Probability
- charm distribution weighted for charm production Probability
- had reint weight = 1

Signal & Bkg normalized for the number of expected events

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Budimir

NUMU DISAPPEARANCE

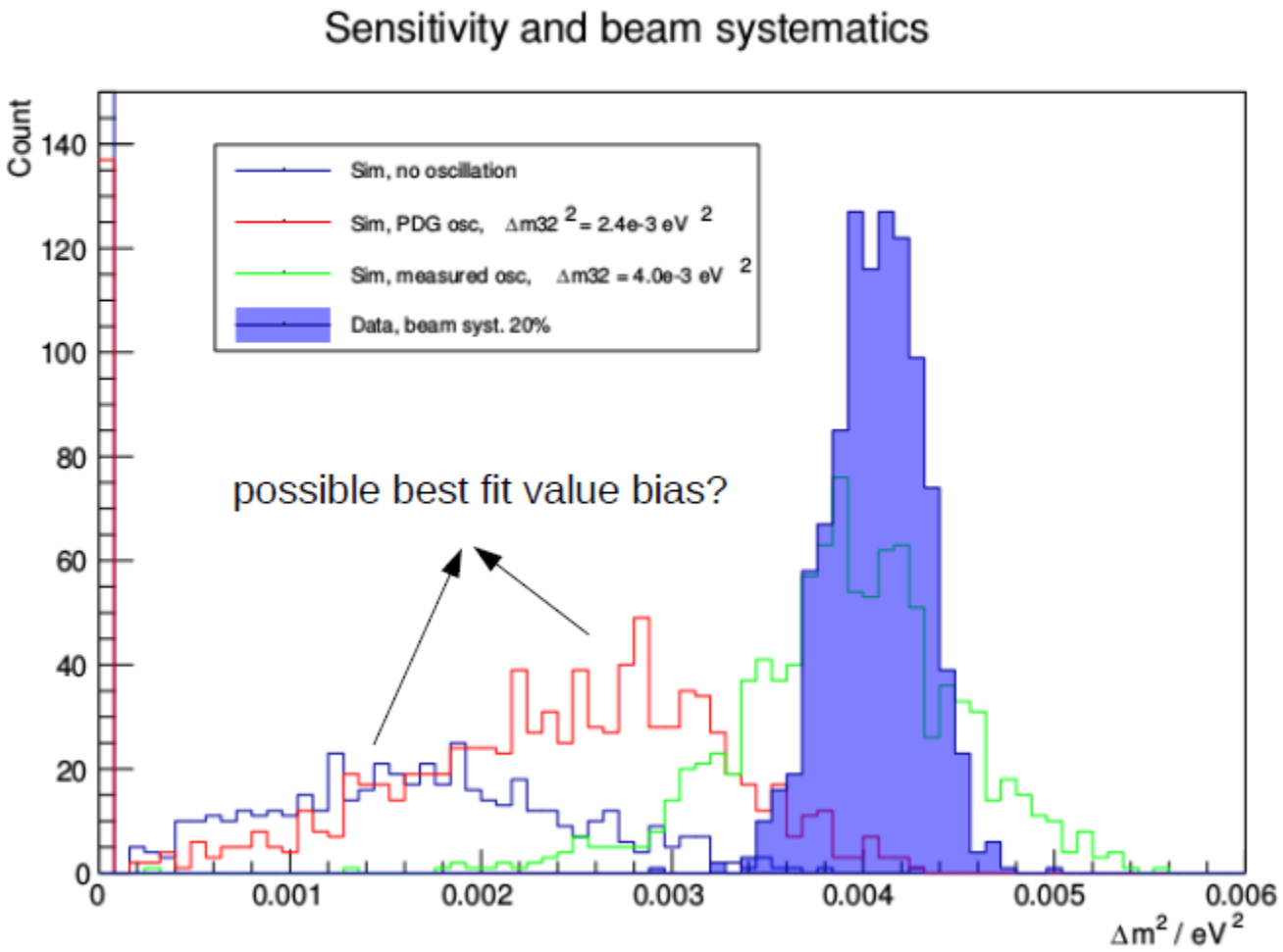
What's new since last meeting

Budimir @ PC 13 Jan

- Beam uncertainty systematics study
  - conclusion – systematic effects from beam uncertainty are much smaller that statistical uncertainty of the fit
- The main idea – use a single data set and preform multiple fits, each one with different smeared MC set

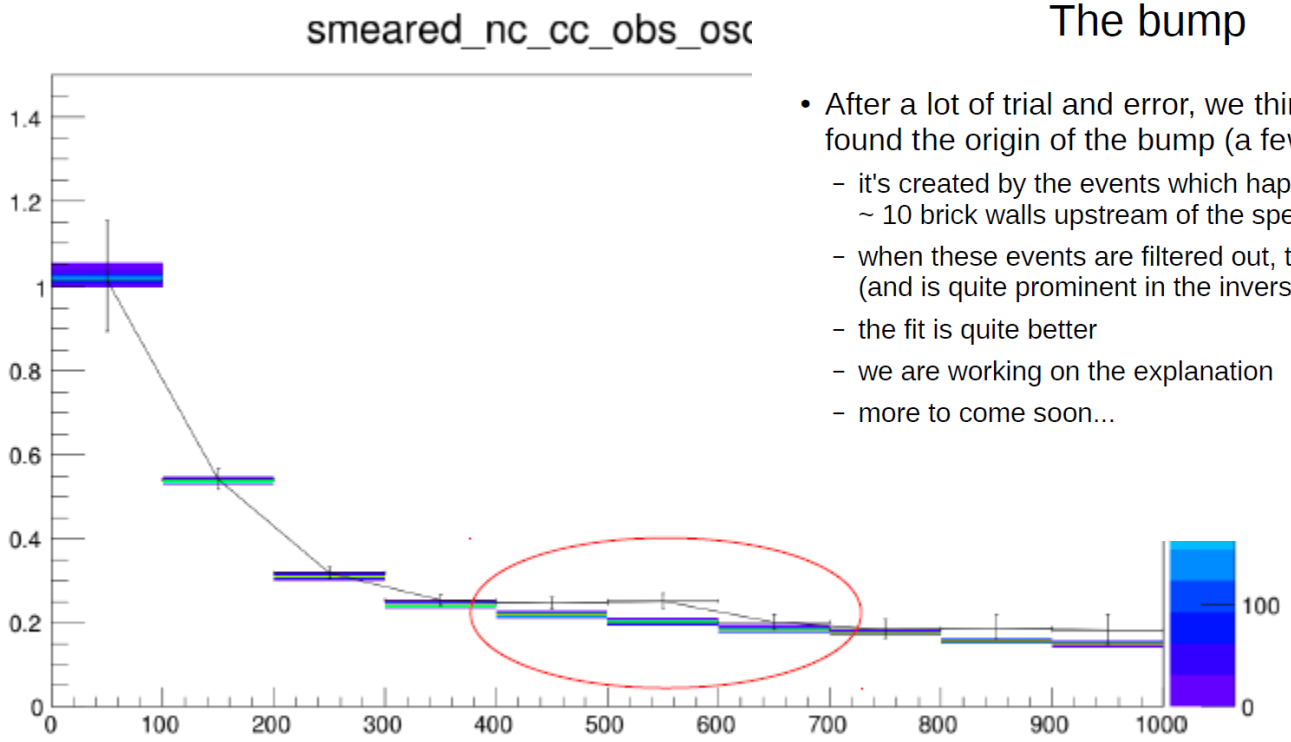
Budimir @ PC 15 Mar

Sensitivity plots - zoom



Which bins push the dm^2 value up (zoom)?

Budimir @ PC 15 Mar



The bump

- After a lot of trial and error, we think we have found the origin of the bump (a few days ago)
  - it's created by the events which happened in the first ~ 10 brick walls upstream of the spectrometer
  - when these events are filtered out, the bump is gone (and is quite prominent in the inverse filter)
  - the fit is quite better
  - we are working on the explanation
  - more to come soon...

Conclusions

Budimir @ PC 15 Mar

- I think we are finally at the final stage of this analysis
  - systematics seem to be under control – both beam and the detector
- next steps
  - recheck everything
  - make more rigorous statistical analysis
  - finish

Updates on annual modulation : Nicoletta, Andrea, Alessandro

Multiplicity Distributions in CC Interactions : Cagin

Open data event sample : Cagin, Sergey

Test of Lorentz violation : offline

OTHER ACTIVITIES

Nicoletta @ PC 13 Jan

Update on the annual modulation of atmospheric muons

N. Mauri, A. Longhin, A. Paoloni

OPERA PC Meeting, 13 Jan 2017

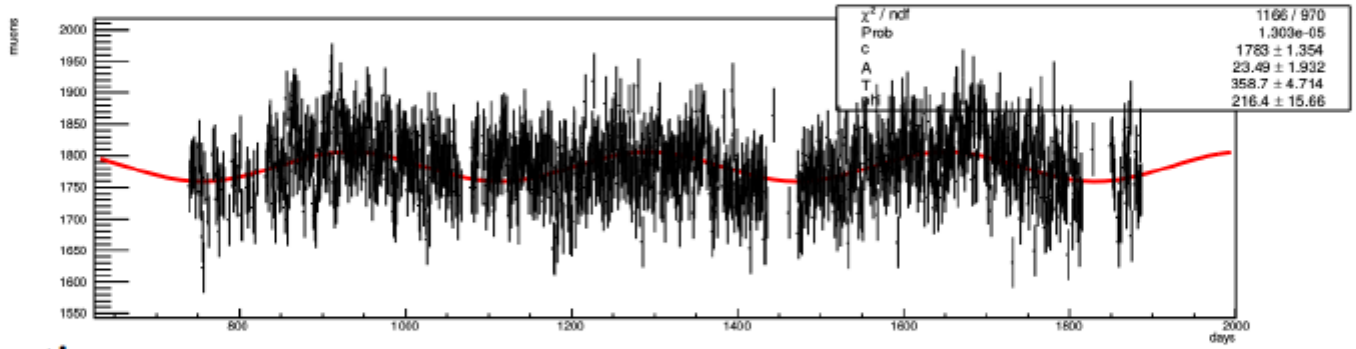
Nicoletta @ PC 13 Jan

Data Set selection

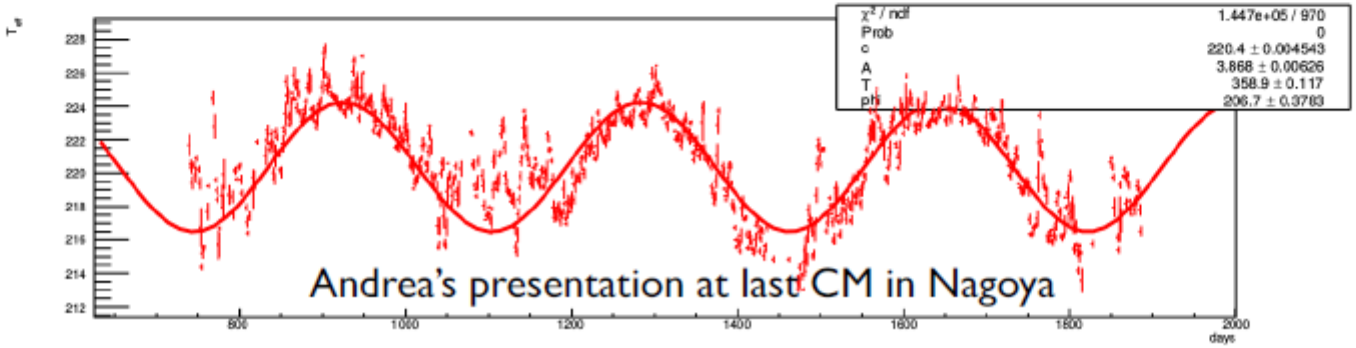
- Issue on the daily rate expected in OPERA

  → investigate in order to use also 2008 and 2009 data sets

- Rate of atmospheric muons in files stored at ccage seems to be different from what expected: some modifications in the OpRec package WITHOUT DOCUMENTATION



TT Selection



Andrea's presentation at last CM in Nagoya

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Nicoletta @ PC 13 Jan

Processing of the complete data set (2008→ 2012)

- Several difficulties arisen in processing data with different OpRelease versions (a lot of time spent in several productions with the same bug, NOT DOCUMENTED)
  - Extrema ratio: reinstallation at CNAF of the "old" software used for the Charge Ratio, still productions with some crashes
- In this talk: two different productions patched together
  - production done for the muon charge ratio during periods with the CNGS beam on, i.e. with the complete detector on (TT + RPC)
  - production with the "official" OpRec that DO NOT reconstruct events contained in the spectrometer during periods with the RPC switched off
- Different daily rate:

  TT+RPC: average rate (single muons) R_μ ~ 3400 events/day

  TT: : average rate (single muons) R_μ ~ 1950 events/day,

  nearly stable over the 5 years 2008→2012

  → Normalized one to the other

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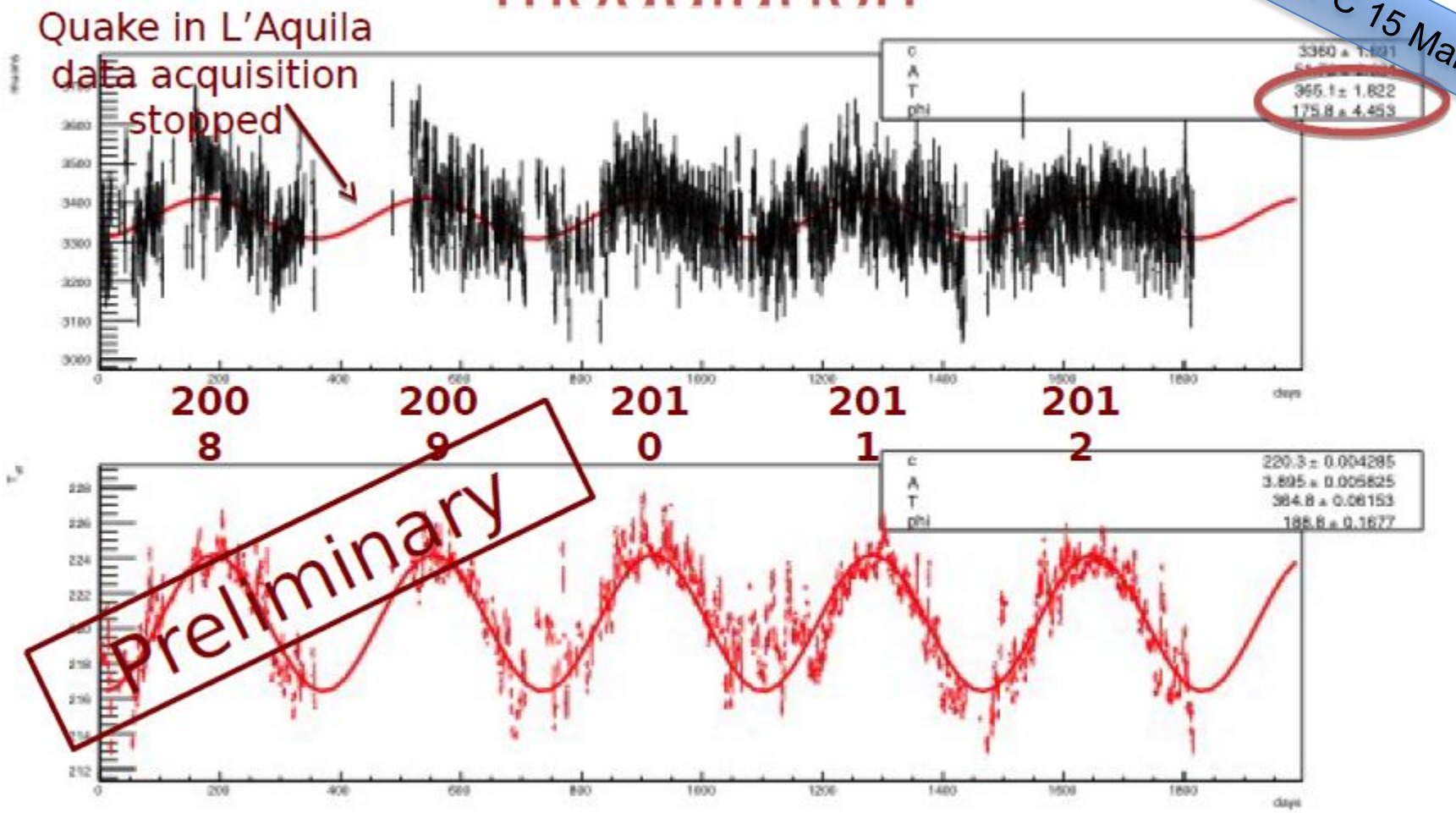
Preliminary results: rate modulation

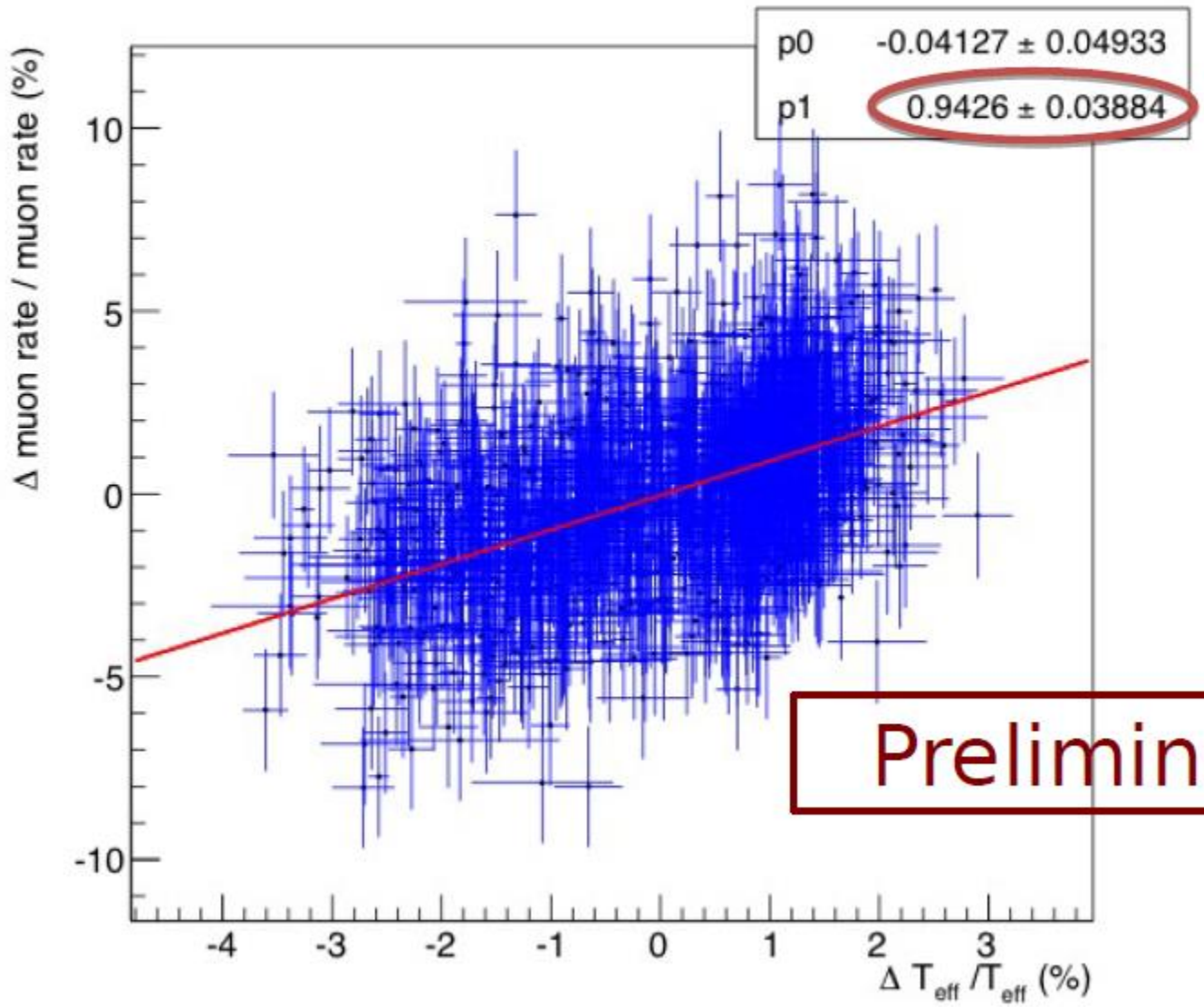
Nicoletta @ PC 15 Mar



- Only single muons (reconstructed multiplicity in 3D == 1)
- Beam angle window cut in order to eliminate beam contamination

Preliminary results: α1

Nicoletta @ PC 15 Mar



Conclusions

Nicoletta @ PC 15 Mar

• Preliminary results on the annual modulation of atmospheric muons with the complete OPERA data set 2008-2012

- period T = (365 ± 2) days and phase = (176 ± 4) days from the sinusoidal fit over the 5 years
- $\alpha_T = 0.94 \pm 0.04$

both compatible with other LNGS experiments

Cagin @ PC 7 Dec

Study of Charged Particle Multiplicity Distributions in High Energy Neutrino-Lead Interactions in the OPERA Detector

Çağın KAMISCIOGLU

METU-OPERA

OPERA PC meeting
7/12/2016

Cagin @ PC 7 Dec

Study of Charged Particle Multiplicity Distributions in High Energy Neutrino-Lead Interactions in the OPERA Detector

Çağın Kamışcıoğlu *[1] and Ali Murat Güler[2]

[1]Ankara University
[2]METU

Abstract

In this note, we report a study of charged particle multiplicities initiated in high energy charged current neutrino interactions in the OPERA detector. We present charged particle average multiplicities, the dispersion and investigate the KNO scaling in different kinematical regions based on event-by-event analysis. The results are presented in a form suitable for use in the validation of Monte Carlo generators of neutrino-lead interactions.

1 Introduction

The mean multiplicity of charged hadrons is an important characteristics of the final hadron states in hard scattering processes. It reflects the dynamics of the interaction process. Therefore, mean multiplicity of charged hadrons has been studied extensively in cosmic rays, fixed target and collider experiments (give ref). These data are useful to improve models of particle productions which are available as Monte Carlo event generators.

In this paper, we report the results on charged-hadron production initiated in high energy charged-current neutrino interactions:

$$\nu_\mu + n \rightarrow \mu^- + X^+, X^+ \rightarrow hadrons$$

$$\nu_\mu + p \rightarrow \mu^- + X^{++}, X^{++} \rightarrow hadrons$$

The basic unit of the OPERA target is ECC bricks, which are stacks of interleaved emulsion films and lead plates. Emulsion films act as high precision trackers while lead plates provide a massive target for neutrino interactions. The excellent spatial resolution of nuclear emulsion allows the identification of event topology and measurement of trajectory of charged particles. Therefore, it is well suited for the investigation of the multiplicity moments of charged particles. However, only few studies of charged-particle multiplicity in neutrino-nucleon interactions were made with nuclear emulsion technology.

In the following, a short description of the OPERA experimental setup and of the procedure used to locate neutrino interactions in the OPERA target is given, the data sample and analysis are described. Then, multiplicity moments and investigation of KNO scaling in different kinematical regions based on event-by-event measurement will be presented in a form suitable for use in the validation of Monte Carlo generators of neutrino–lead interactions.

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2

Cagin @ PC 13 Jan

OPEN ACCESS DATA

Çağın Kamışçıoğlu

PC Meeting
13/01/17

1

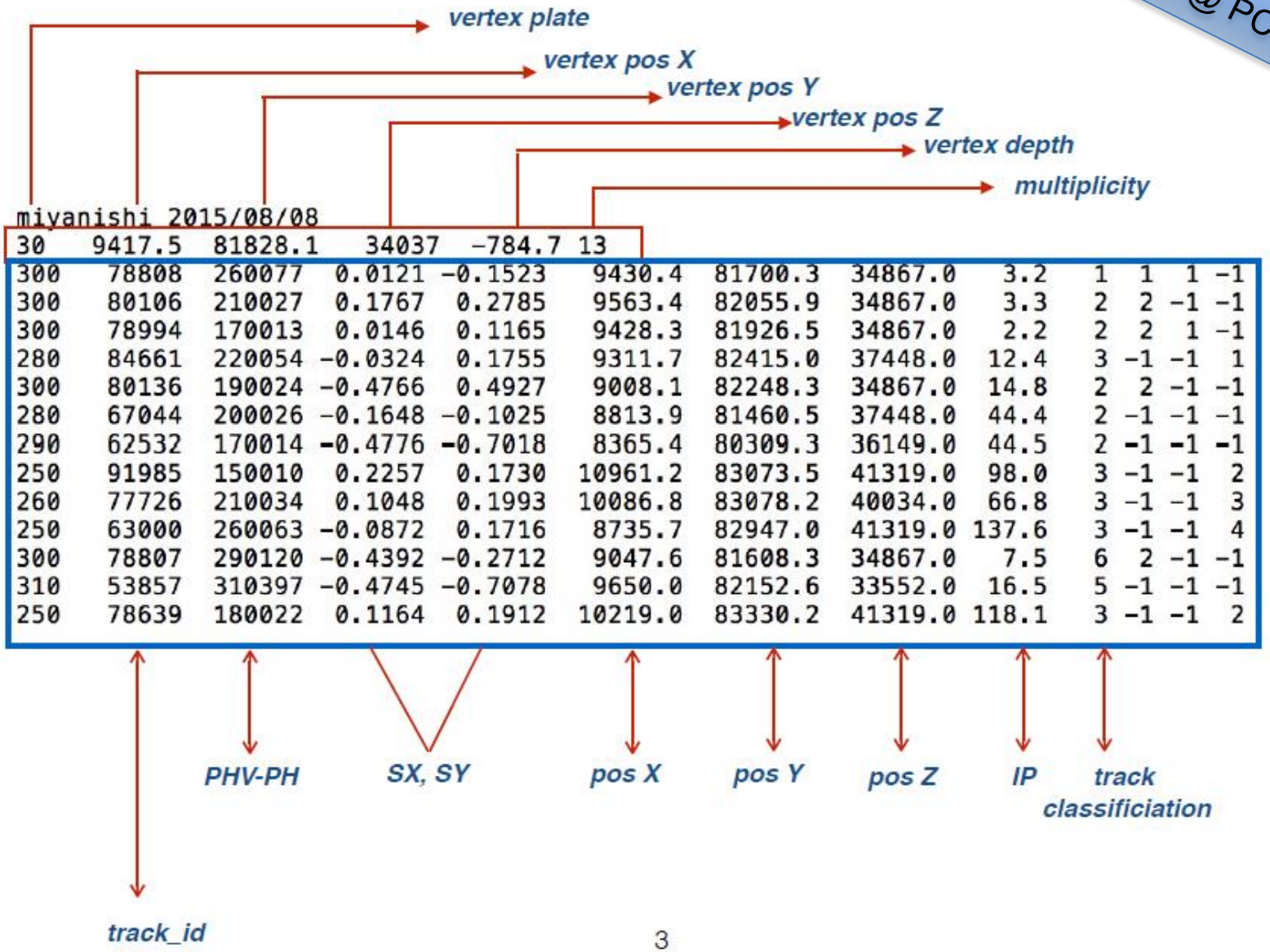
Data Sample

Cagin @ PC 13 Jan

Data set	*Japan DB*
Run	2010-2012
Data	Particle ID(shower/grey/black/ep) flag included (CC)
Event Status	DECAYSEARCHED
Event selection	Muon-ID=1 or Tracklength>19
Muon P	<=15 GeV/c^2
Total	892

Data Sample

Cagin @ PC 13 Jan



Sergey @ PC 15 Mar

Status of Event Display for Open Data Access

S.Dmitrievsky, JINR

OPERA PC Meeting, 2017/03/15

Task: To implement OPERA event display (two 2D-views of an event in ED + one simplified 3D-view of microtracks near the vertex in ECC) as a GUI web-application.

Sergey @ PC 15 Mar

The proposal of **Andrey Ustyuzhanin (AU)** from **Yandex team** was to write the new event display from scratch in Python language using the Matplotlib plotting library. (In this case no existing **C++** code from the **OpRelease** could be used directly.)

As the first step AU provided me with his examples of drawing of an ECC brick info implemented as **Jupyter notebooks** (interactive web-pages with input commands and the results of their executions displayed in the same window of a browser). Then he suggested to use a set of extensions (*dashboards layout*, *dashboards bundlers*, and *dashboards server*) for a notebook in order to convert it into a standalone web-application.

Workflow of development of a web-application from a Jupyter notebook

2

Test of Lorentz violation

- Giovanni is contacted to improve analysis by T. Katori.
  - http://arxiv.org/abs/1112.6395
  - direction dependent neutrino TOF

Neutrinos with Lorentz-violating operators of arbitrary dimension

V. Alan Kostelecký[1] and Matthew Mewes[2]
[1] *Physics Department, Indiana University, Bloomington, Indiana 47405, USA*
[2] *Physics Department, Swarthmore College, Swarthmore, Pennsylvania 19081, USA*
(Dated: IUHET 567, December 2011; published in Phys. Rev. D **85**, 096005 (2012))

The behavior of fermions in the presence of Lorentz and CPT violation is studied. Allowing for operators of any mass dimension, we classify all Lorentz-violating terms in the quadratic Lagrange density for free fermions. The result is adapted to obtain the effective hamiltonian describing the propagation and mixing of three flavors of left-handed neutrinos in the presence of Lorentz violation involving operators of arbitrary mass dimension. A characterization of the neutrino coefficients for Lorentz violation is provided via a decomposition using spin-weighted spherical harmonics. The restriction of the general theory to various special cases is discussed, including among others the renormalizable limit, the massless scenario, flavor-blind and oscillation-free models, the diagonalizable case, and several isotropic limits. The formalism is combined with existing data on neutrino oscillations and kinematics to extract a variety of measures of coefficients for Lorentz and CPT violation. For oscillations, we use results from the short-baseline experiments LSND and MiniBooNE to obtain explicit sensitivities to effects from flavor-mixing Lorentz-violating operators up to mass dimension 10, and we present methods to analyze data from long-baseline experiments. For propagation, we use time-of-flight measurements from the supernova SN1987A and from a variety of experiments including MINOS and OPERA to constrain oscillation-free Lorentz-violating operators up to mass dimension 10, and we discuss constraints from threshold effects in meson decays and Čerenkov emission.

Test of Lorentz violation

- I made contact to peoples who has worked for neutirno TOF in past.
  - Namely Stefano, Alessandro B., Alessandro P., Gabriele and Sergey.
- Only partial or faulty data available
  - Gabriele has old faulty (A1 and CTRI) data. Not the final one.
  - Alessandro Bertlin told that seems it is not possible to recover old data.
  - Alessandro P. and Sergay only has arrival time information for bunched beam run in 2012
- In conclusion
  - It seems difficult to perform another analysis for neutrino TOF without main contributor on this subject.

Outlook

- Papers in line
  - Double vertex event and multiplicity paper will be distributed very soon.
- Papers to be sent to internal referee
  - Nue and marginal event soon April to June
- Should be finalized and added
  - Numu disappearance
  - Combined analysis for all flavors
    - nutau, nue appearance and numu disappearance
    - Update of exotic oscillation in tau appearance
  - AoB

Agenda

- nue oscillation analysis : Matteo
- nue analysis statistics and paper status : Svetlana
- marginal event analysis : Giuliana
- numu disappearance analysis : Budimir
- cosmic ray annual modulation : Nicoletta

- Report from PTB

- Paper status report for double vertex event : Chiara
- Paper status report for multiplicity : Cagin
- Hadron BG study : Mizusawa
- Short decay search : Mustafa
- Open data event display