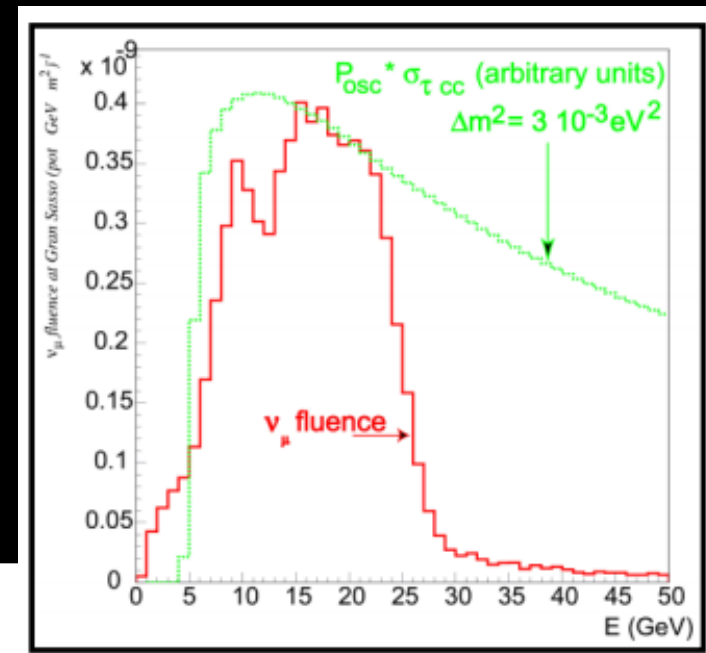
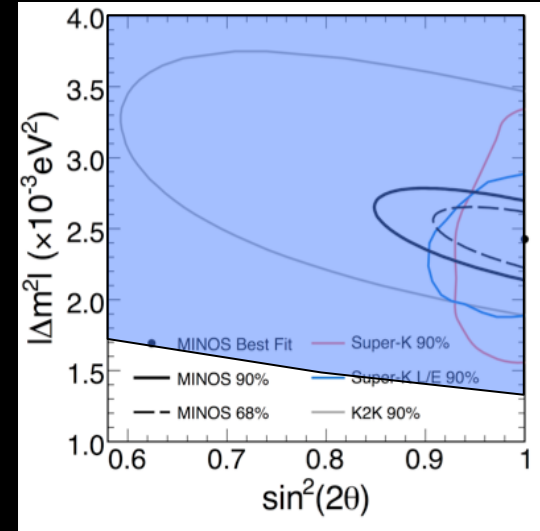
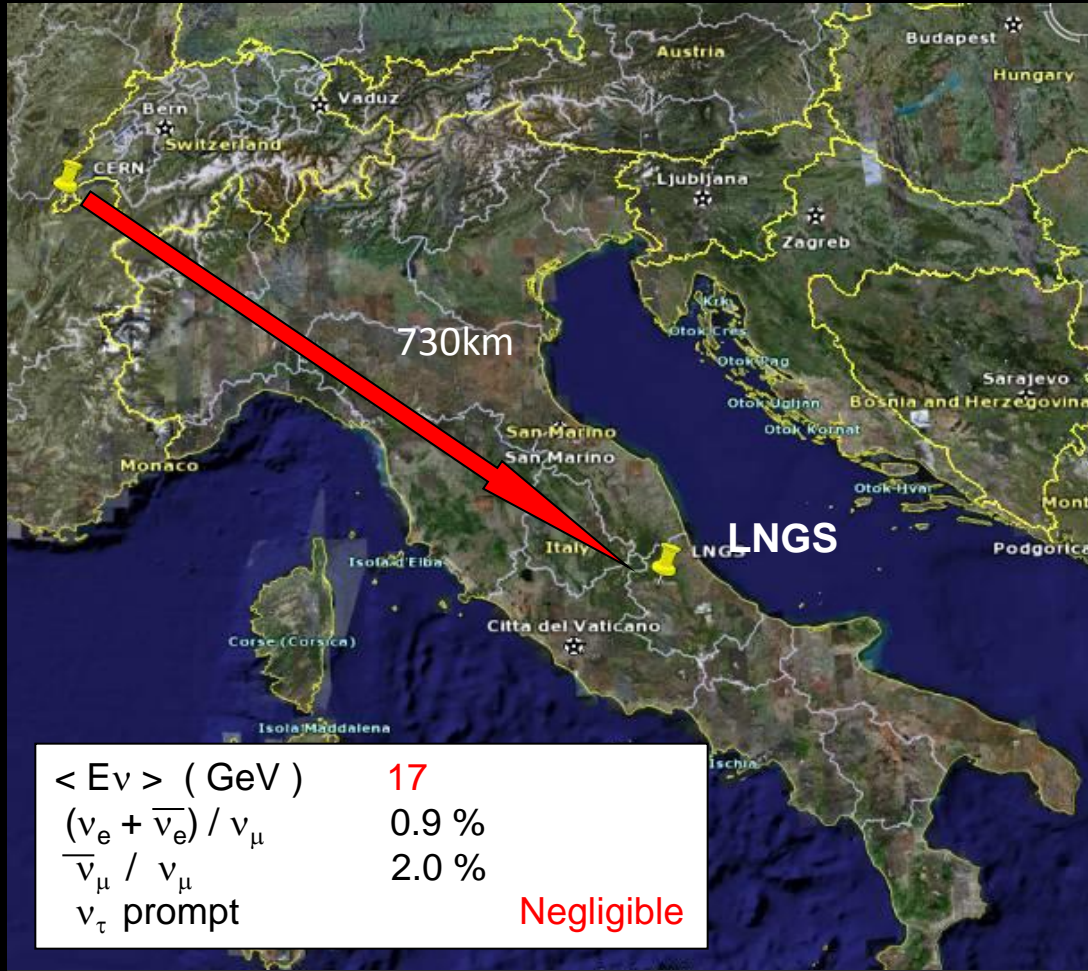


# OPERA $\nu_\tau$ Appearance detection

Covers the region indicated by Super-K, K2K & MINOS

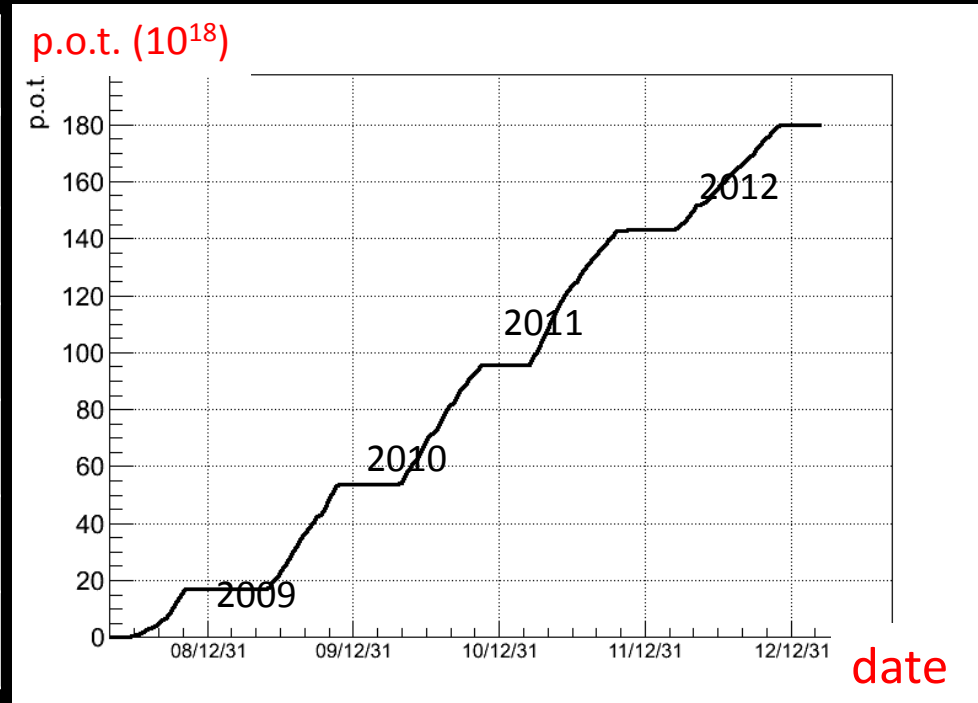


$$P(\nu_\mu \rightarrow \nu_\tau) \sim \sin^2(2\theta_{23}) \cdot \sin^2\left(1.27 \cdot \frac{\Delta m_{23}^2}{E} \cdot L\right) \sim 1.7\%$$

$$\sin^2 2\theta_{23} = 1.0, \quad \Delta m_{23}^2 = (2.43 \pm 0.13) \times 10^{-3} \text{eV}^2$$

# Final performances of the CNGS beam after five years (2008 ÷ 2012) of data taking

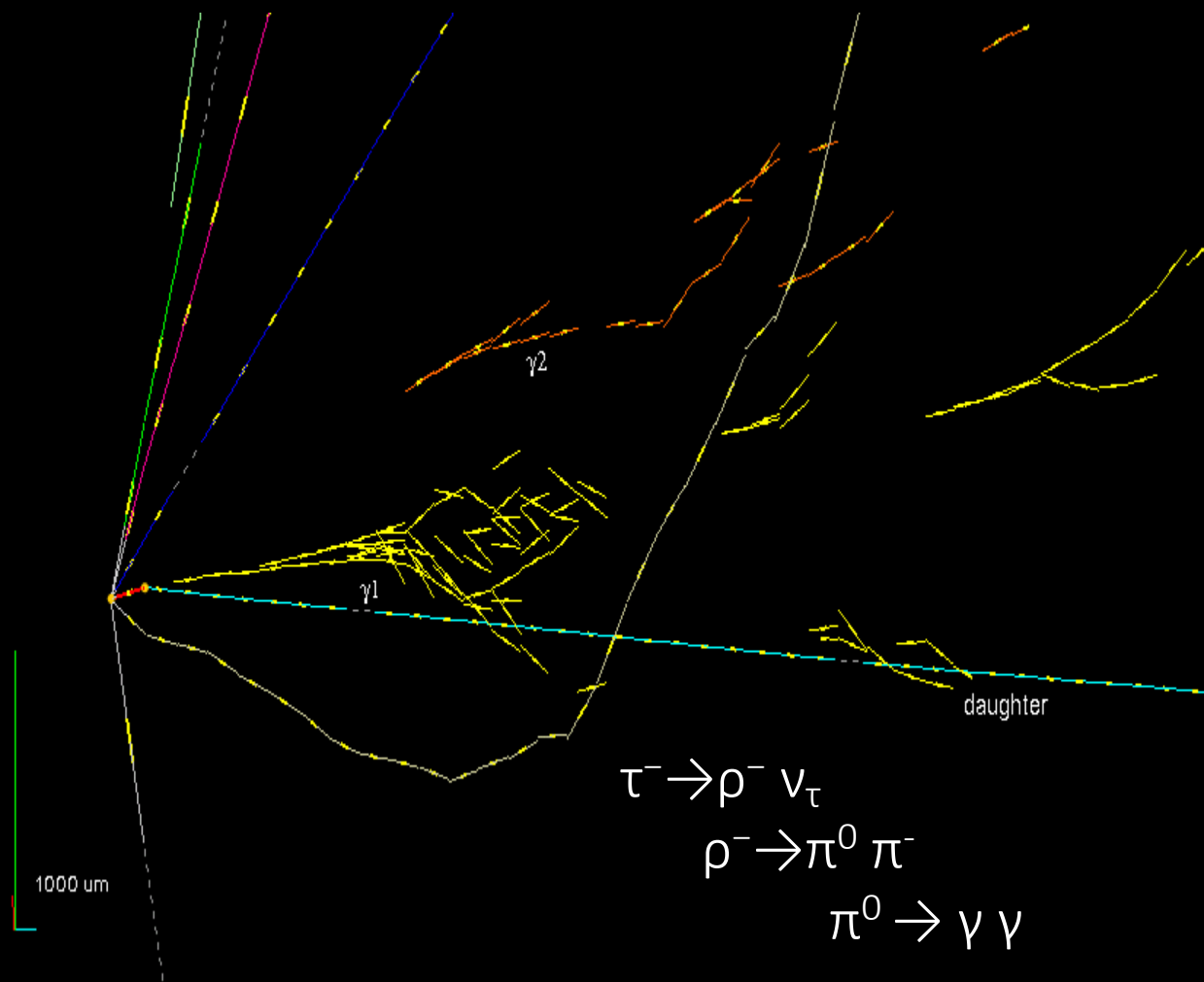
Year	Beam days	P.O.T. ( $10^{19}$ )
2008	123	1.74
2009	155	3.53
20010	187	4.09
2011	243	4.75
2012	257	3.86
<b>Total</b>	<b>965</b>	<b>17.97</b>



Overall 20% less than the proposal value (22.5)

# 1<sup>st</sup> $\nu\tau$ event

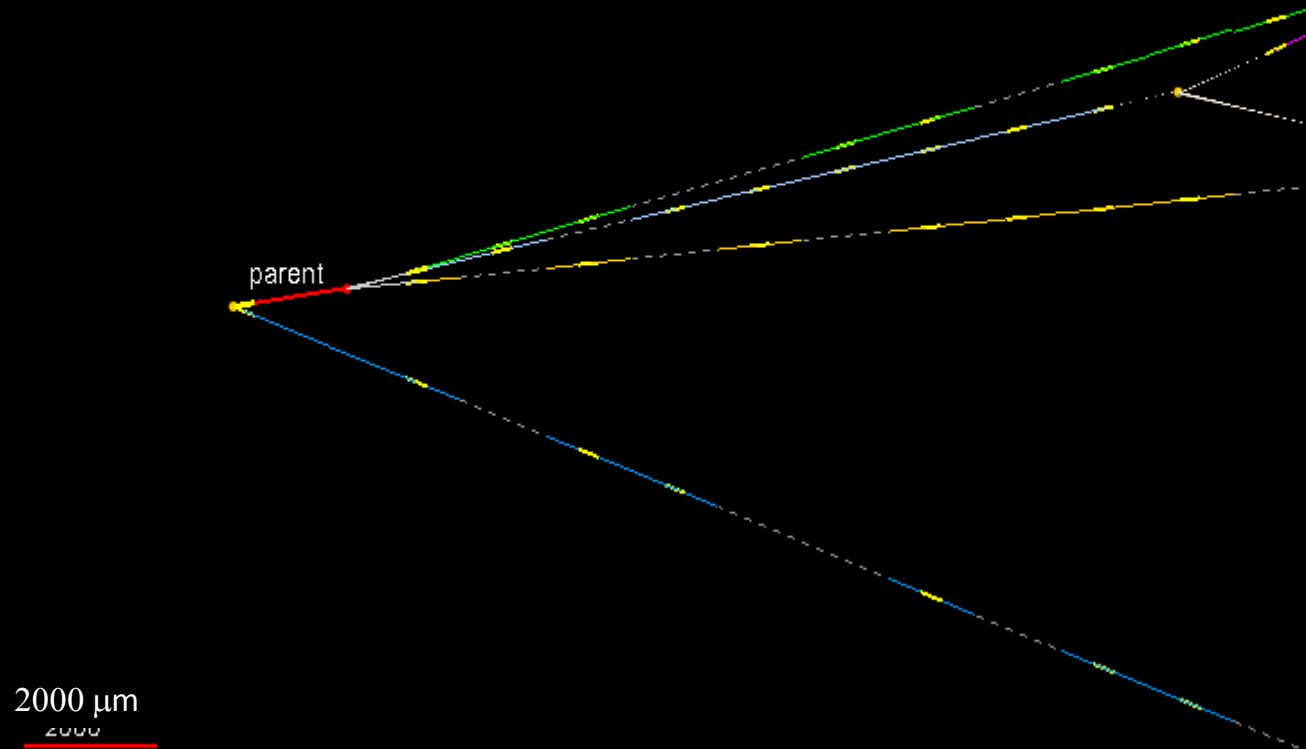
2010



# 2<sup>nd</sup> $\nu\tau$ event

2012

$\tau \rightarrow 3h$



3<sup>rd</sup>  $\nu\tau$  event

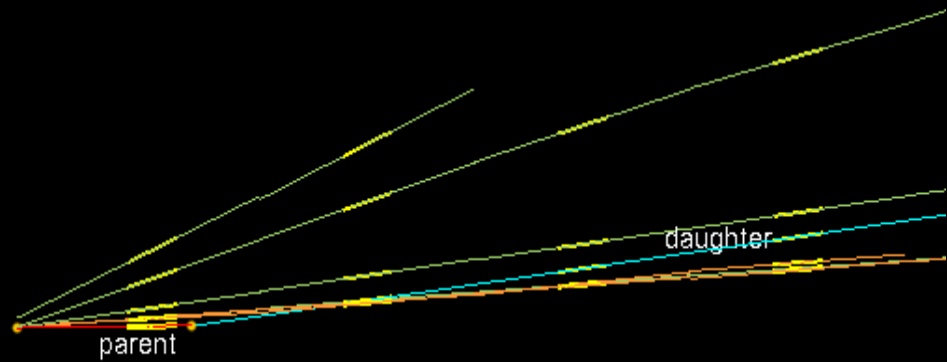
2013

$$\tau^- \rightarrow \mu^-$$

# 4<sup>th</sup> $\nu\tau$ event

2014

$\tau \rightarrow \pi\nu$



1000

$\nu\mu\rightarrow\nu\tau$  Observation paper has been published in PTEP.  
Please cite this paper when you will refer OPERA.

<http://arxiv.org/abs/1407.3513>

**PTEP**

Prog. Theor. Exp. Phys. 2014, 101C01 (10 pages)  
DOI: 10.1093/ptep/ptu132

Letter

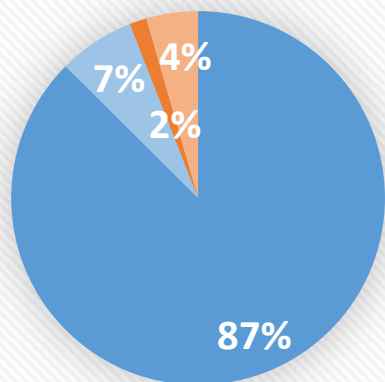
## Observation of tau neutrino appearance in the CNGS beam with the OPERA experiment

### OPERA Collaboration

N. Agafonova<sup>1</sup>, A. Aleksandrov<sup>2</sup>, A. Anokhina<sup>3</sup>, S. Aoki<sup>4</sup>, A. Ariga<sup>5</sup>, T. Ariga<sup>5,\*</sup>, T. Asada<sup>6</sup>, D. Bender<sup>7</sup>, A. Bertolin<sup>8</sup>, C. Bozza<sup>9</sup>, R. Brugnera<sup>8,10</sup>, A. Buonauro<sup>2,11</sup>, S. Buontempo<sup>2</sup>, B. Büttner<sup>12</sup>, M. Chernyavsky<sup>13</sup>, A. Chukanov<sup>14</sup>, L. Consiglio<sup>2</sup>, N. D'Ambrosio<sup>15</sup>, G. De Lellis<sup>2,11</sup>, M. De Serio<sup>16,17</sup>, P. Del Amo Sanchez<sup>18</sup>, A. Di Crescenzo<sup>2,11</sup>, D. Di Ferdinando<sup>19</sup>, N. Di Marco<sup>15</sup>, S. Dmitrievski<sup>14</sup>, M. Dracos<sup>20</sup>, D. Duchesneau<sup>18</sup>, S. Dusini<sup>8</sup>, T. Dzhatdoev<sup>3</sup>, J. Ebert<sup>12</sup>, A. Ereditato<sup>5</sup>, R. A. Fini<sup>16</sup>, T. Fukuda<sup>21</sup>, G. Galati<sup>16,17</sup>, A. Garfagnini<sup>8,10</sup>, G. Giacomelli<sup>19,22,†</sup>, C. Goellnitz<sup>12</sup>, J. Goldberg<sup>23</sup>, Y. Gornushkin<sup>14</sup>, G. Grella<sup>9</sup>, M. Guler<sup>7</sup>, C. Gustavino<sup>24</sup>, C. Hagner<sup>12</sup>, T. Hara<sup>4</sup>, T. Hayakawa<sup>6</sup>, A. Hollnagel<sup>12</sup>, B. Hosseini<sup>2,11</sup>, H. Ishida<sup>21</sup>, K. Ishiguro<sup>6</sup>, K. Jakovcic<sup>25</sup>, C. Jollet<sup>20</sup>, C. Kamiscioglu<sup>7,26</sup>, M. Kamiscioglu<sup>7</sup>, T. Katsuragawa<sup>6</sup>, J. Kawada<sup>5</sup>, H. Kawahara<sup>6</sup>, J. H. Kim<sup>27</sup>, S. H. Kim<sup>28</sup>, N. Kitagawa<sup>6</sup>, B. Klicek<sup>25</sup>, K. Kodama<sup>29</sup>, M. Komatsu<sup>6</sup>, U. Kose<sup>8</sup>, I. Kreslo<sup>5</sup>, A. Lauria<sup>2,11</sup>, J. Lenkeit<sup>12</sup>, A. Ljubcic<sup>25</sup>, A. Longhin<sup>30</sup>, P. Loverre<sup>24,31</sup>, M. Malenica<sup>25</sup>, A. Malgin<sup>1</sup>, G. Mandrioli<sup>19</sup>, T. Matsuo<sup>21</sup>, V. Matveev<sup>1</sup>, N. Mauri<sup>19,22</sup>, E. Medinaceli<sup>8,10</sup>, A. Mereaglia<sup>20</sup>, M. Meyer<sup>12</sup>, S. Mikado<sup>32</sup>, M. Miyanishi<sup>6</sup>, P. Monacelli<sup>24</sup>,

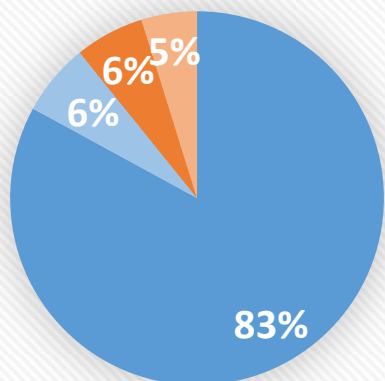
# Status of the Analysis

## Vertex Location



■ 1st ■ 2nd ■ 1st\_tobe ■ 2nd\_tobe

## Decay Search



■ 1st ■ 2nd ■ 1st\_tobe ■ 2nd\_tobe

brick	Location	DS	Expected Final sample	Location complete	DS complete
1st	5878	5575	~6000	0.98	0.93
2nd	443	420	~700	0.63	0.6
all	6321	5995	~6700	0.94	0.89



Expected form Reference data of 2008-2009 Run. ( Non selection sample)

- 1 ) Decay search Finished Rate  $\sim 89\%$   
( conventional analysis sample )  
**+ 700 events within 2015.**
- 2 ) Improvement on Scanning Speed & Quality  
HTS                      BDT  
**+ 800 events? until mid of 2016.**
- 3 ) Improve  $\Delta m^2$  .  
by Including border decay candidates  
(Present value  $1.8 \sim 5.0 \times 10^{-3} \text{ eV}^2$ )<sub>8</sub>





並列画像処理PC群

超広視野レンズ

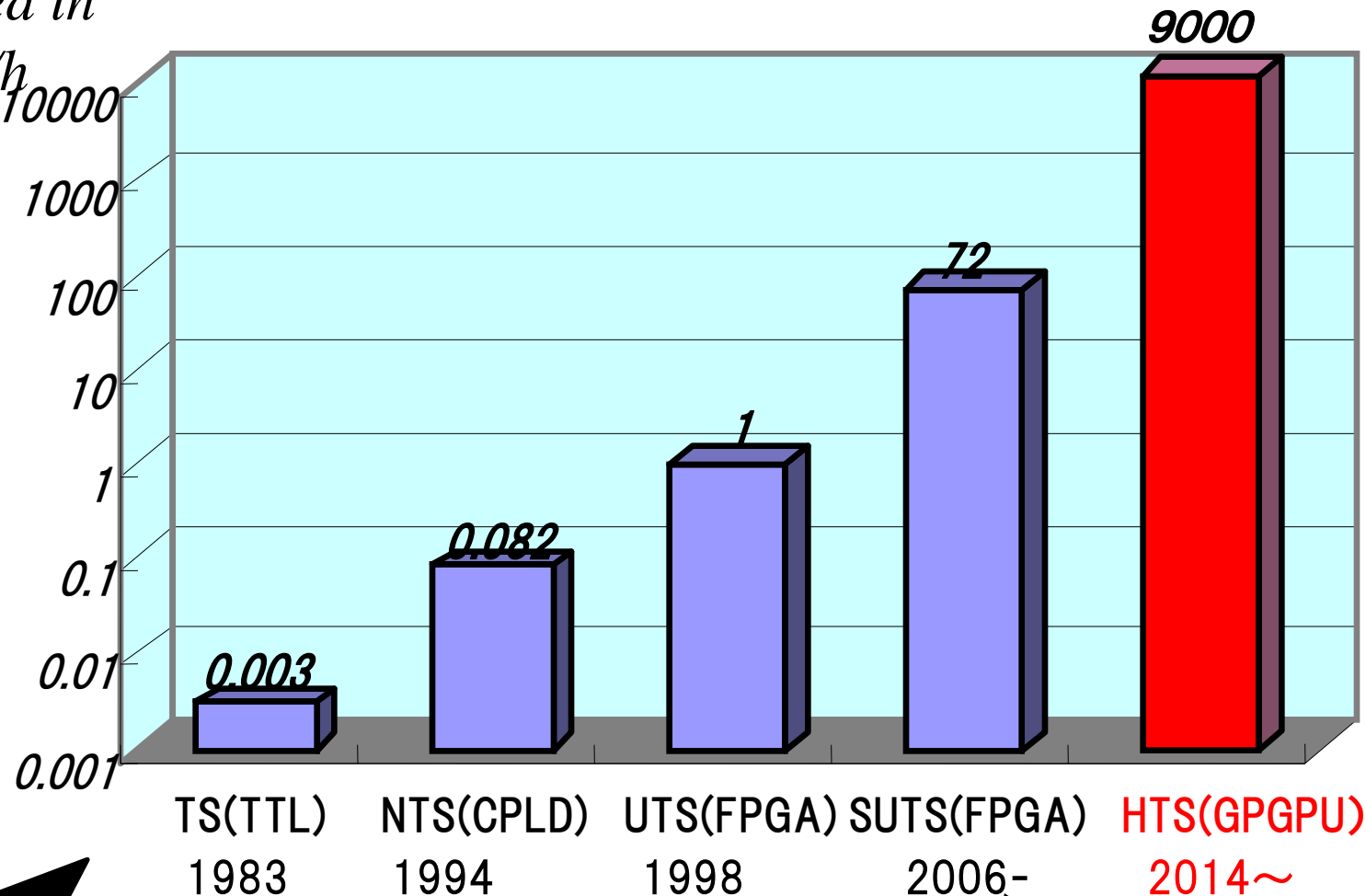
72chカメラヘッド

高制震ステージ

超高速原子核乾板読み出し装置  
HTS ( Hyper Track Selector )

# Development of the read-out speed of the Automated Nuclear Emulsion Read-out system

Speed in  $cm^2/h$

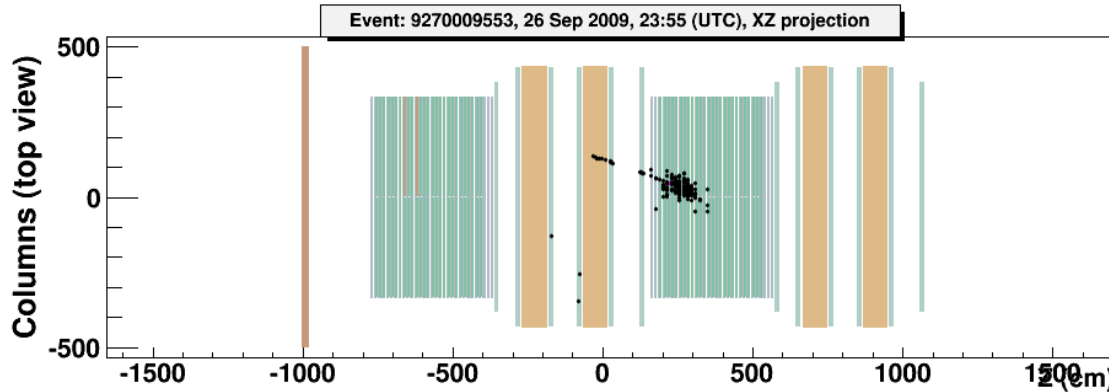


Mid. 1970  
Principle  
Proposed by Niwa K.

$\nu$   $\tau$  Observation  
DONUT

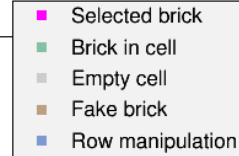
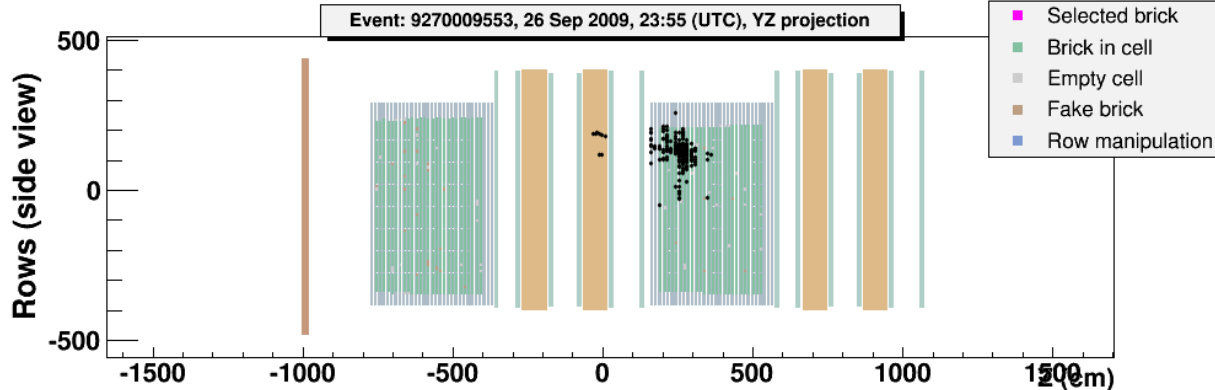
1<sup>st</sup>  $\nu\mu \rightarrow \nu\tau$  Event  
OPERA 2010

# Atmospheric Neutrino Events in OPERA



Estimation:

	Atm $\nu$	$\nu\tau$
Recorded	940	6.4
After Evis Cut	220	5.3
Selected	: ~150	1~2



Brick finding information: Super module 2

	BrickId	Wall	Side	Column	Row	Prob	CS x	CS y
brick 1:	1147970	6	1	23	49	0.38	-1.0	-1.0
brick 2:	1147940	6	1	23	50	0.18	-1.0	-1.0
brick 3:	1147832	5	1	22	50	0.15	-1.0	-1.0
brick 4:	1147827	5	1	23	50	0.11	-1.0	-1.0

Hadrons energy: 41.58 GeV

Muon track parameters:

Momentum: N/A

Tangent angle XZ: N/A

Tangent angle YZ: N/A

# Nuclear Emulsion

- Long history in Neutrino Research -

- 1978-1983 Fermilab E531  $\sim 100\text{kg}$   
charm  $\nu_{\mu} \rightarrow \nu_{\tau}$
- 1990-2000 CERN WA95 CHORUS  $\sim 1\text{ ton}$   
 $\nu_{\mu} \rightarrow \nu_{\tau}$  charm
- 1994-2001 Fermilab E872 DONUT  $\sim 1\text{ ton}$   
 $\nu_{\tau}$
- 2000- CERN CNGS01 OPERA 1250 ton  
 $\nu_{\mu} \rightarrow \nu_{\tau}$

R &D of Advanced high  
resolution Nuclear Emulsion  
Neutrino detector  
(計画研究 B01)

Aichi Univ. of Edu., Kobe, Nagoya , Nihon , Toho



# Nuclear Emulsion Gel Production Machine



Installed in Nagoya Univ.

R&D Machine

~1kg/lot

From 2010

Composed by a Maker  
Related to Fujifilm

# Emulsion Gel R&D

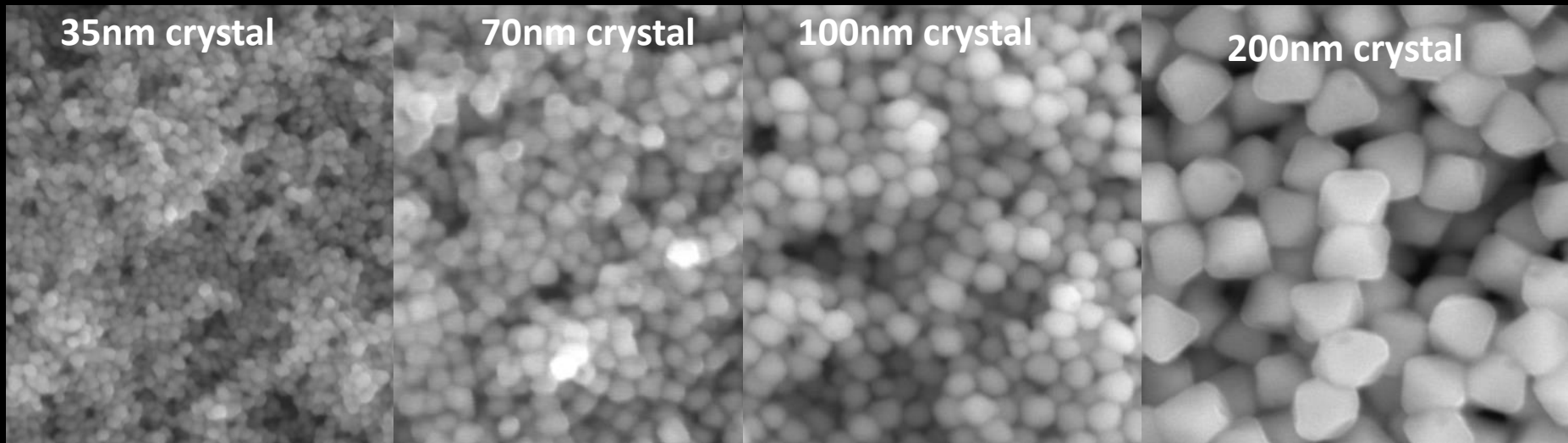
- R&D of recipes of Emulsion Gel matched to the physics aim.
  - With the help of OB engineers of FUJI film.
  - By Modern Emulsion Gel production machine installed in Nagoya.

## Nano Imaging Tracker (NIT) Type

Directional Dark Matter detection  
Neutrino Coherent Scattering

## OPERA Type

Neutrino exp, Radiography  
 $\gamma$  Telescope (GRAINE)



- Grain size 20nm ~ 400nm
- Sensitivity control by impurity doping & chemical treatment

# Production

- Re-realize Gel Mass production --- by ourselves

## 1) New Machine Installation (2014)

→ **Scale up** 3.5 kg/lot

→ 1<sup>st</sup> User: GRAINE

2) Contract to rent machine time from a company for the production of the Gel using our recipe & under our control. No quality assurance by the maker. We will do.

→ 20kg/lot Mass Production





Mass Pro  
Machine

~3.5kg/lot

From 2014

Installed in Nagoya Univ.

Composed by Nagoya  
Univ. Machine shop.

# Production

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→ 20kg/lot Mass Production

# Talks relating to Emulsion exp. in this Meeting

## Running project

Aoki S. (Kobe): GRAINE project: First massive production and use of "High sensitive emulsion gel film"

Fukuda T.(Toho): Neutrino experiments with nuclear emulsion at J-PARC

## Proposal prep.

Komatsu M.(Nagoya): Tau Neutrino physics in SHiP at CERN

## Idea

Sato O.(Nagoya): An Experiment to observe neutrino nucleus coherent scattering