Experimental Summary
-or rather personal chatting-

Xth Rencontres du Vietnam
Flavour Physics Conference

Quy Nhon, Vietnam, July 27 - August 2, 2014

Tatsuya Nakada
LPHE
EPFL
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LPHE

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

It was said in this conference

- CP violation was discovered 50 years ago! (Aushev, Ceccucci)

V.L.Fitch R.Turlay J.W.Cronin J.H.Christenson

Phys. Rev. Lett. 13 (1964) 138.

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Phys. Rev. Lett. 13 (1964) 138.

- But also

50 years ago quark was proposed by

Volume 8, number 3 PHYSICS LETTERS 1 February 1964

A SCHEMATIC MODEL OF BARYONS AND MESONS *

M. GELL-MANN
California Institute of Technology, Pasadena, California

Received 4 January 1964

A formal mathematical model based on field theory can be built up for the quarks exactly as for p, n, Λ in the old Sakata model, for example [3])

(instead of purely mathematical entities as they would be in the limit of infinite mass). Since charge and baryon number are exactly conserved, one of the quarks (presumably $u^{\frac{2}{3}}$ or $d^{-\frac{1}{3}}$) would be absolutely stable *, while the other member of the doublet would go into the first member very slowly by β-decay or K-capture. The isotopic singlet quark would presumably decay into the doublet by weak interactions, much as Λ goes into N. Ordinary

and

AN SU_3 MODEL FOR STRONG INTERACTION SYMMETRY AND ITS BREAKING

G. Zweig *)

CERN - Geneva

8182/TH.401
17 January 1964

ABSTRACT

Both mesons and baryons are constructed from a set of three fundamental particles called aces. The aces break up into an isospin doublet and singlet. Each ace carries baryon number $\frac{1}{3}$ and is consequently fractionally charged. SU_3 (but not the Eightfold Way) is adopted as

REFERENCES

4) Dr. Gell-Mann in a recent preprint, Physics Letters, to be published, has independently speculated about the possible existence of these particles. His primary motivation for introducing them differs from ours in many respects.

This provoked me a question

- Is flavour a quantum number related to internal symmetry?
- Are “charges” (electric, strong and weak) flavour?
- Are isospins flavour?
- etc. etc.

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- Is flavour a quantum number related to internal symmetry?
- Are "charges" (electric, strong and weak) flavour?
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- etc. etc.
- Let me define like this:
  "Flavour physics is measuring properties of the processes with changing flavours, literally or virtually, **with precision**." ("virtually", since I have EDM or $\mu(g-2)$ in my mind)

Exp. presented in this conference

Quarks	Charged leptons	Neutrinos	Others
BABAR	BABAR	T2K	SHIP
BELLE	BELLE	NOvA	
BES III	BES III	MicroBooNE	EDM
		SHINE	
ATLAS	?	(The MICE & nuSTORM R&D)	
CDF	?	Daya Bay	
CMS	?	Various very short baseline experiments	
D0	?		
LHCb	LHCb	ICECUBE	
NA62	MEG	GERDA	
KOTO	Mu2E		
KLOE	COMET		
(ORKA)			

completed, active, in preparation

being considered

and not all the experiments are covered

Quark sector

- It has been impressive (for me) to see that B physics at LHC, i.e. hadron machine (Rademacker, Schiller, Walder, Nguyen, MTresch, FTresch, FSimonetto, Egorychev, Canale, Shaheen), became truly complimentary and competitive to the $e^{+}e^{-}$ machines (Staric, Rotondo, Beleno, Neri, Cai)

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in the proceedings…

Table 2 summarises the performance of the LHC experiments for measuring CP violation parameters in one year of data taking.

Table 2: Performance of the LHC experiments in one year (10^7 s).

	ATLAS	CMS	LHC-B
Luminosity [cm^{-2} s^{-1}]	10^{33}	10^{33}	1.5×10^{32}
sin 2α with $B_d \to \pi^+\pi^-$			
$\sigma(m_B)$ [MeV/c^2]	50	27	14
$\sigma(\sin 2\alpha)_{stat.}$	0.04	0.06	0.04
background/signal	~1	~1	can be made to ~0
sin 2β with $B_d \to J/\psi K_S$			
$\sigma(m_B)$ [MeV/c^2]	16	12	7
$\sigma(\sin 2\beta)_{stat.}$	0.02	0.04	0.02
γ with $B_d \to DK^*$ and $B_s \to D_s K$			
$\sigma(\gamma)_{stat.}$	-	-	6° to 12°
$\delta\gamma \equiv \gamma - \gamma'$ with $B_s \to J/\psi\phi$			
$\sigma(m_B)$ [MeV/c^2]	16	-	6
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LHCb by Schiller 1 fb^{-1}

$$\gamma = (115^{+28}_{-43})^\circ \text{ from } B^0_s \to D_s K$$

LHCb by Rademacker 3 fb^{-1}

$$\gamma = (67.2 \pm 12) \quad \text{from } B_u \to DK$$

in the proceedings…

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CMS by Simonetto 20 fb^{-1}

$$\varphi_s = -0.03 \pm 0.11\ (\text{stat.}) \pm 0.03\ (\text{syst.})\ \text{rad}$$

ATLAS by Walder 4.9 fb^{-1}

$$\phi_s = 0.12 \pm 0.25\ (\text{stat.}) \pm 0.05\ (\text{syst.})\ \text{rad}$$

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LHCb Phys. Rev. D 87, 112010 (2013) 1 fb^{-1}

$$\phi_s = 0.07 \pm 0.09 \pm 0.01 \ (J/\psi\phi)$$

LHCb by Schiller 3 fb^{-1}

$$\phi_s = 0.070 \pm 0.068 \pm 0.008 \ (J/\psi\pi\pi)$$

Quark sector

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- In 2nd Rencontres du Vietnam on 21st to 28th Oct 1995 in Ho Chi Minh City, I had a pleasure to
  – see a total eclipse
  – to present the LHC potential for B physics
- Experiments are doing well

Quark sector

- Both hadron machines and e^+e^- machines are now contribution to all B, D, K flavour physics in really competitive and complementary way:
  → Progress in the detector technology has been crucial to realise this progress for the hadron experiments to profit high production cross section and high beam flax.

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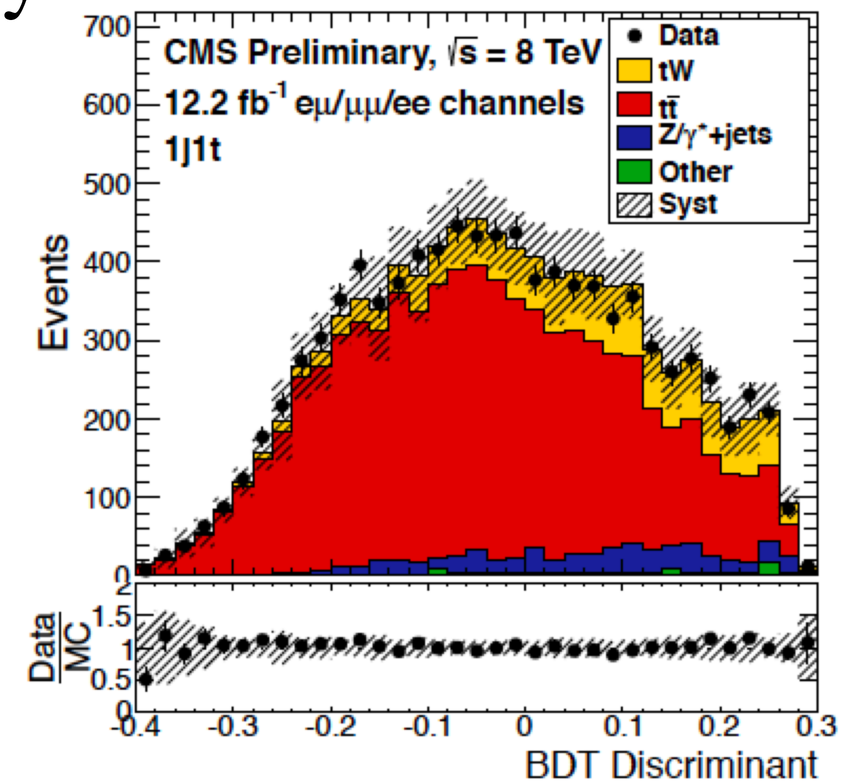
  → Progress in the detector technology has been crucial to realise this progress for the hadron experiments to profit high production cross section and high beam flax.
  → For charm, fixed target experiments were already competitive with Si micro-strip detector and basically triggerless data taking + simultaneous offline reconstruction, while B had to wait for colliders due to the cross section.

Quark sector

- Both hadron machines and e^+e^- machines are now contribution to all B, D, K flavour physics in really competitive and complementary way:
- LHC (and Tevatron) high p_T experiments plays a unique role in top flavour physics
  - e.g. $|V_{td}||V_{tb}|$, $|V_{ts}||V_{tb}|$, $|V_{td}||V_{ts}|$: B and K loop and Δm's vs $|V_{tb}|$ from the tree level

Direct $|V_{tb}|$ measurement

- Basic assumption: single top production at Tevatron and LHC is proportional to $|V_{tb}|^2$
- Top reconstruction is usually done with lepton + jet + b-tagging + missing energy
  i.e. another $|V_{tb}|^2$ (Shaw)



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  i.e. another $|V_{tb}|^2$ Interesting prospect!

	ch.	< $\|V_{tb}\|$	$\|V_{tb}\|$ measured value
CDF (1.96 TeV)	s+t	0.84	
D0 (1.96 TeV)	s+t	0.92	1.12 +0.09 – 0.08
CMS (7+8 TeV)	t	0.92	0.998 ± 0.038 (exp.) ± 0.016 (th.)
ATLAS (7 (8) TeV)	t	0.88 (0.78)	1.02 ± 0.07 (0.97 +0.09 – 0.10)
CMS	Wt	0.78	1.03 ± 0.12 (exp.) ± 0.04 (th.)
ATLAS	Wt	0.72	1.10 ± 0.12 (exp.) ± 0.03 (th.)

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- Many progress in CP violation and rare decays in K (Goudzovski, Nanjo, Moskal, Wang), D (Staric, Rademacker) and B (Rademacker, MTresch, FTresch, MRotondo, FSimonetto) and in spectroscopy (Egorychev, Canale, Shaheen, Neri, Cai) and production. Sorry for not spending time for these!

Lepton Sector

- When I arrived at SIN (present PSI) in 1984, there was an experiment called SINDRUM, looking for $\mu \to 3e$ and obtained $< 1.0 \times 10^{-12}$, then later modified the detector to measure $\mu \to e$ conversion ($\mu \to e\gamma$ at Los Alamos). Neutrino oscillations boosted the interest on charged lepton flavour violation experiments and benefiting progress in technology.

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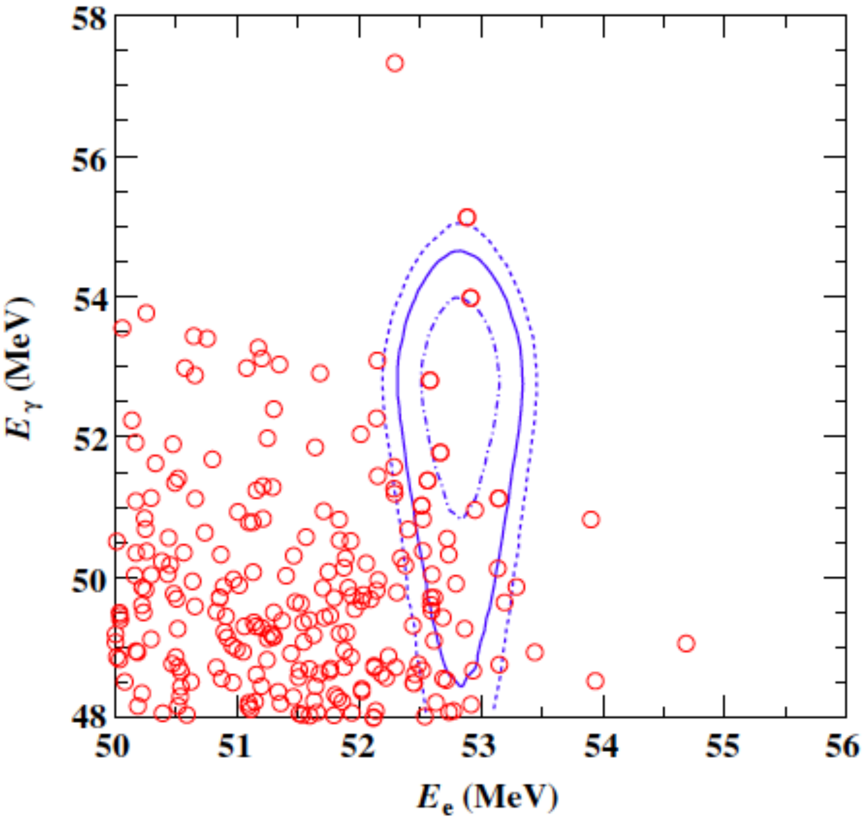
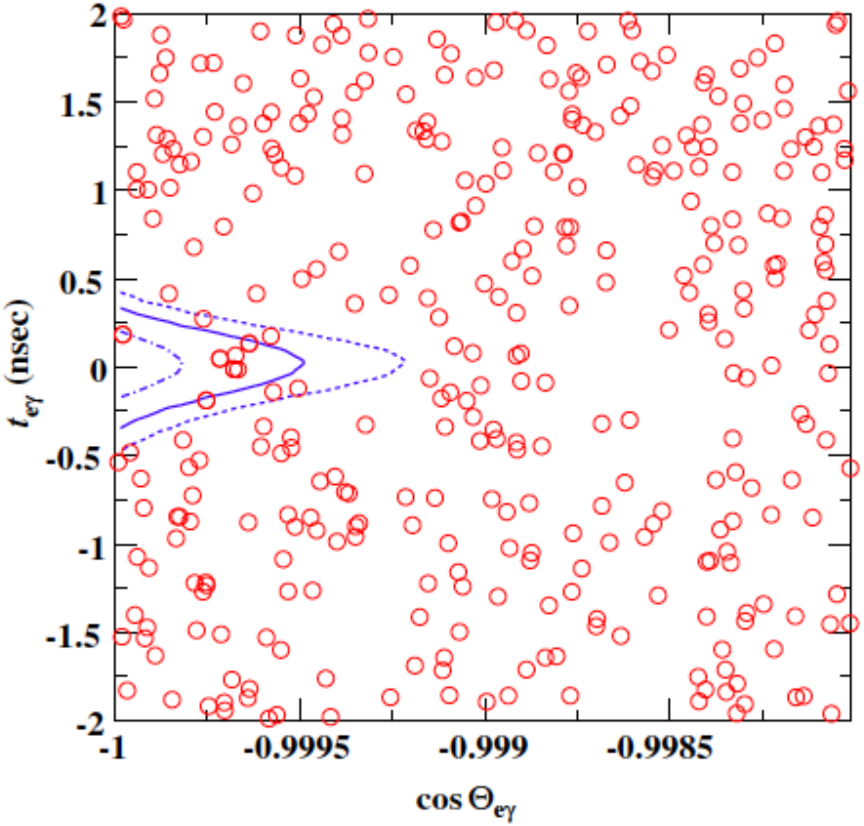
Phy. Rev. Lett. 110, 201801 (2013)





- $<5.7\times10^{-13}$ (90%CL)
- twice more data in hand but start to see background
  → upgrade: sensitivity goal 5×10^{-14}

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- Now MEG is taking data $\mu\rightarrow e\gamma$ (Grigoriev)
- And several are lining-up: $\mu\rightarrow e$ Mu2E and COMET (Tassielli, Nam), and some others, e.g. mu3e, and activities in τ decays

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- If we do not see anything, how far should we push down the sensitivity? What are the benchmark models?

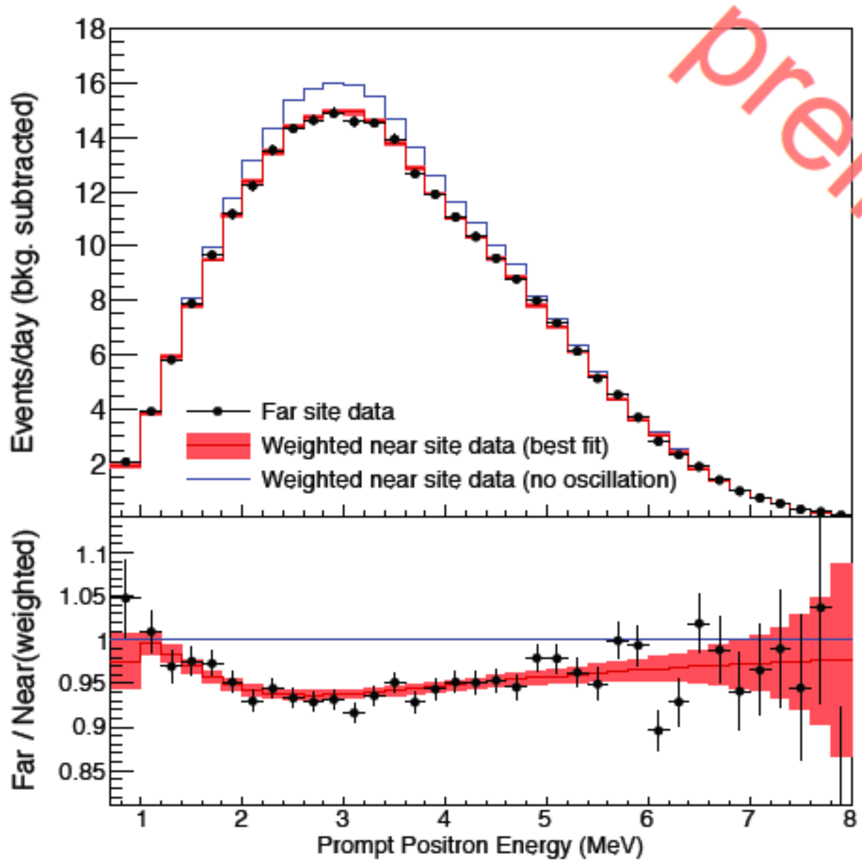
Lepton Sector

- If we do not see anything, how far should we push down the sensitivity? What are the benchmark models?
- If we see something, a signal of $\mu \rightarrow e\gamma$ for example, what kind of measurements are then needed?
  - How to probe the Lorentz structure of new physics current?
  - What would be the impact for quark and neutrino sectors?

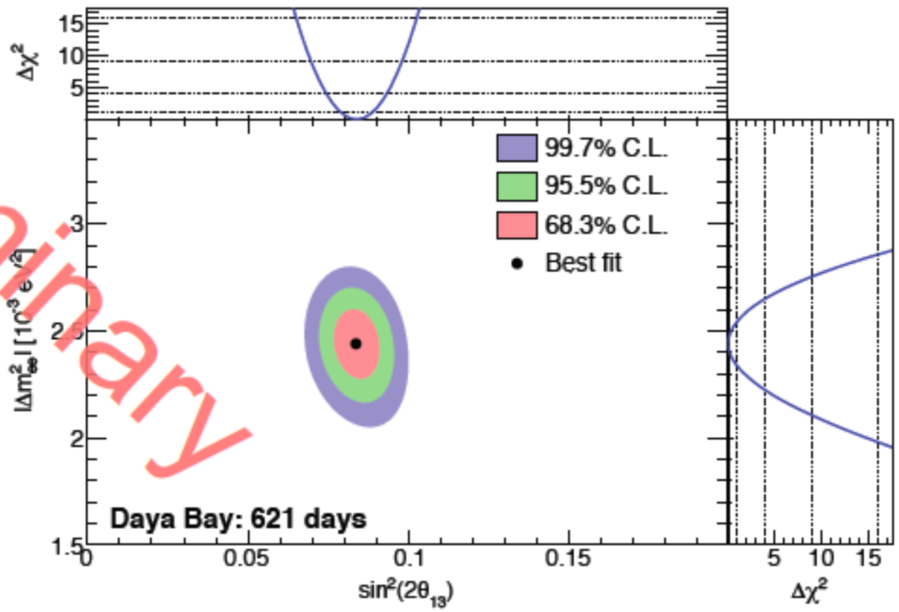
Neutrinos

- Impressive to see how quickly Daya Bay experiment (Wang) can collect data: powerful nuclear reactors! (also RENO in this context). With more data, analysis is getting more and more detailed.

Beautiful result from Daya Bay



- The far-site expected spectra are predicted



$$\sin^2 2\theta_{13} = 0.084^{+0.005}_{-0.005}$$

$$|\Delta m^2_{ee}| = 2.44^{+0.10}_{-0.11} \times 10^{-3}\mathrm{eV}^2$$

$$\chi^2/NDF = 134.7/146$$

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- T2K came back after the earthquacke. Hopefully, they will have long stable running to see the progress in δ-θ_{13} plot. (Paolone)

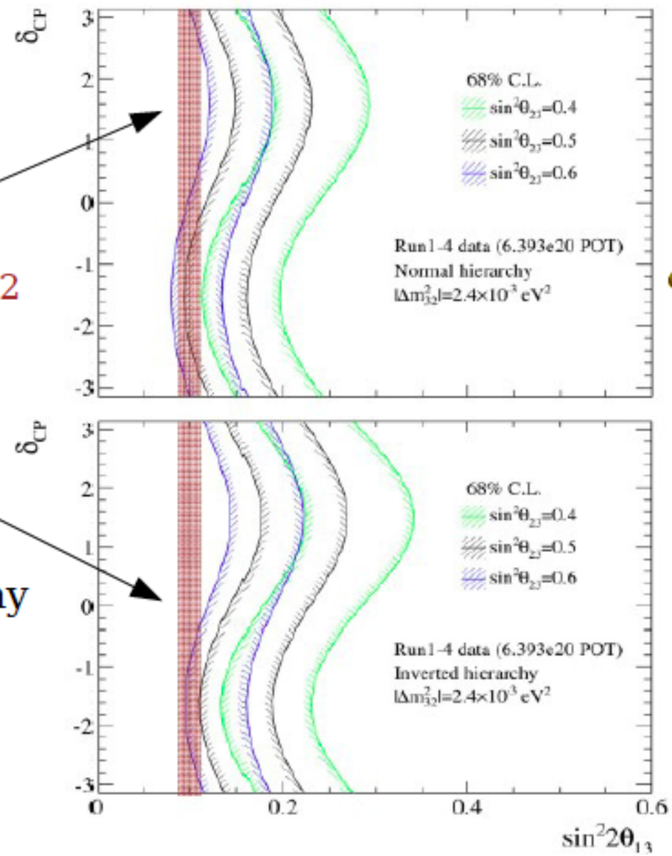
Intriguing T2K result

- Significant dependence on value of θ_{23}
- Need to increase the value of θ_{23} to account for T2K's observed number of events

(NOTE: These are 1D contours for values of δ_{CP}, not 2D contours in δ_{CP}- θ_{13} space)

Pink band represents PDG2012 reactor average value of $\sin^2 2\Theta_{13}=(0.098\pm0.013)$

Best overlap with reactor results is normal hierarchy And $\delta_{CP} = -\pi/2$



- Improved measurements of θ_{23} are important!

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- Double Chooz and NOνA (Paley) are now coming up. Some effort will be needed to catch up.
- Neutrino anomalies must be sorted out (Soderberg, Vacheret): LNSD/MiniBooNE, Ga source, Reactor (Daya Bay, D-Cooz, RENO): sterile neutrino or not?

Neutrinos

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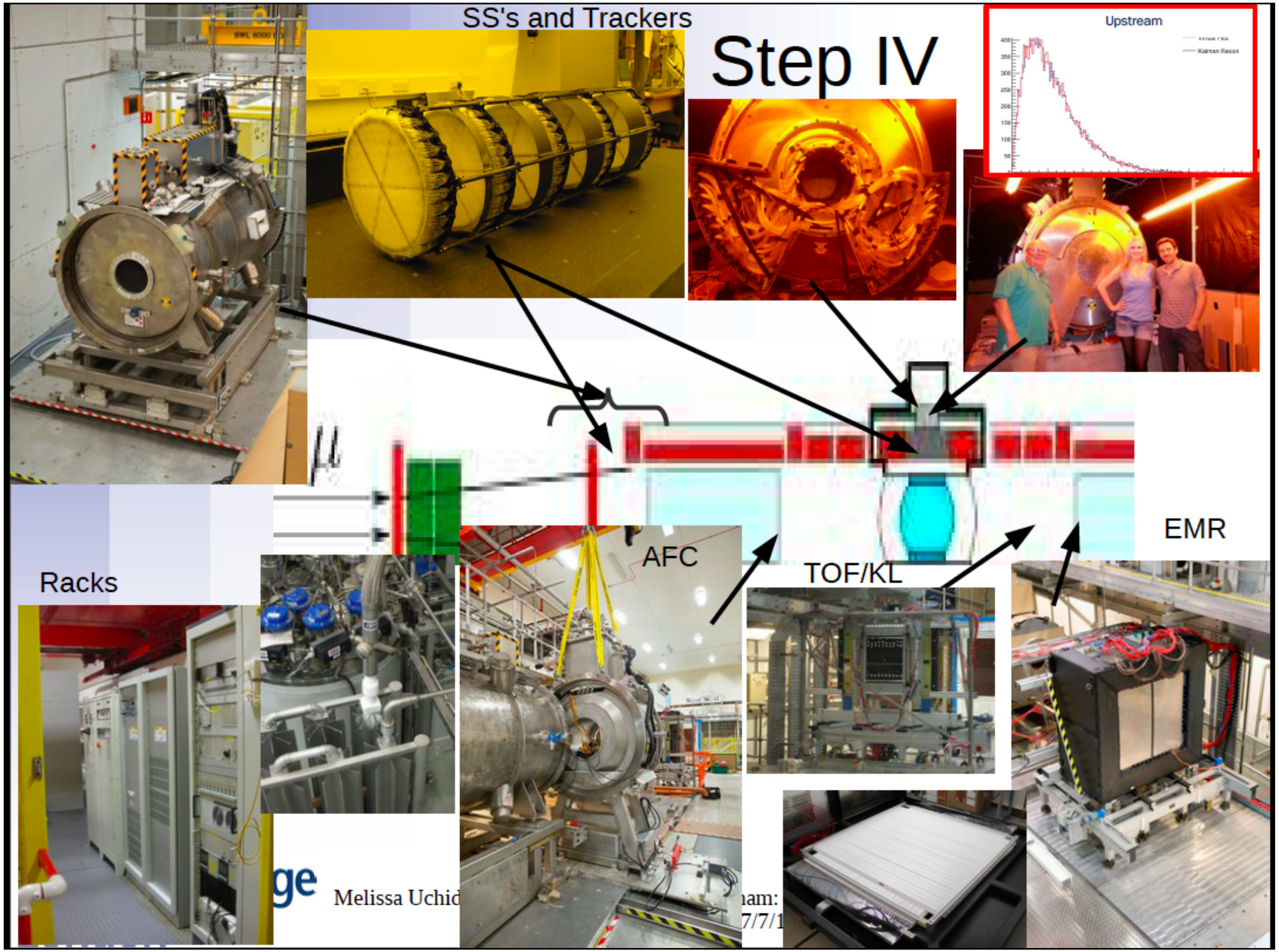
Neutrinos

- Glad to see that GERDA achieved a similar sensitivity to that of the previous experiment which claimed discovery. Looking forward to see the future progress.
- Since the value of θ_{13} became known, plan for the long baseline experiments is evolving, and timescale for MICE (Uchida) may need some rethinking. The idea of nuSTORM is intriguing, although not really needed for solving the sterile neutrino problem, I think. It should not become a "perpetual" R&D.

This is what you missed



Neutrinos

- Neutrino physics can establish a rather robust research plan rather independent of what happens elsewhere.
  At the same time, it seems (to me) that not much thoughts were made on how a great discovery in neutrino physics (Majorana neutrino, non 0 value of δ, …) would change the facility plan of the other sectors of particle physics, or this may be just my prejudice?

Others

- Since the energy scale for new physics is becoming less certain, we should keep eye on other possibilities:
  - Production of weakly interacting and long living particles with beam dump experiments (Serra), e.g. νMSM
  - Neutron (Ban), atomic, … dipole moment (T violation)
  - μ(g−2)
  - Axion
  - …

Final personal thoughts

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- However, flavour physics is no doubt a powerful tool to look for the next step beyond the Standard Model, whatever it turns out to be.
- We may not like the answer, but it will be still exiting.

To conclude

- I am very sorry to bother you to make a conclusion of conclusion (discussion session of the two vision talks) of conclusion (two vision talks, Bonivento, Titov) of conclusion (discussion session of each session) of conclusion (introduction talks of each sessions, Aushev, Patel, Cerri, Uwer, Ceccucci, Kuno, Kayser,),

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- and if I forgot names and experiments which should have mentioned, upgrade for example (Baldini, Bomben, Simonetto, Kim).

Please accept my sincere apology

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and to all the participants