The landscape of Flavour Physics towards the high intensity era

KAON EXPERIMENTS

Augusto Ceccucci/CERN

Pisa, December 9, 2014

TATSUYA NAKADA'S DESPERATE FLAVOUR QUESTIONS

- My really desperate questions concerning the flavour are:
- **Why do we have "three" families?**
- **Why are the two mass matrices "as they are"?**

- I am not sure whether I will see the solution before I die (SUSY may answer many important questions, but not those).

Tatsuya Nakada, Experimental Summary, Rencontres du Vietnam,
Quy Nhon (Vietnam) , July 27 - August 2, 2014

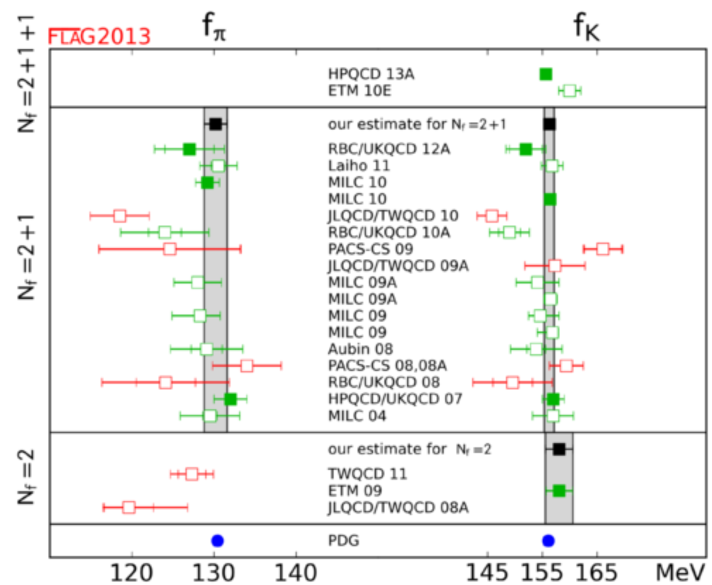
KAON LEPTONIC DECAYS

$$\Gamma(K \to \mu\bar{\nu}_\mu(\gamma)) \; = \frac{G_\mu^2 |V_{us}|^2}{8\pi} f_K^2 m_K m_\mu^2 \left(1 - \frac{m_\mu^2}{m_K^2}\right)^2 \left[1 + \frac{\alpha}{\pi} C_K\right]$$

$$\begin{aligned} G_\mu &= 1.16637(1) \times 10^{-5}\ \mathrm{GeV}^{-2} \\ m_\mu &= 105.658357\ \mathrm{MeV} \\ m_\pi &= 139.57018(35)\ \mathrm{MeV} \\ m_K &= 493.677(13)\ \mathrm{MeV} \end{aligned}$$

Short-distance EW correction

$$\frac{\Gamma(K \to \ell\bar{\nu}_\ell)}{\Gamma(\pi \to \ell\bar{\nu}_\ell)} = \left(\frac{|V_{us}|}{|V_{ud}|}\right)^2 \left(\frac{f_K}{f_\pi}\right)^2 \frac{m_K\left(1 - \frac{m_\ell^2}{m_K^2}\right)^2}{m_\pi\left(1 - \frac{m_\ell^2}{m_\pi^2}\right)^2} \left[1 + \frac{\alpha}{\pi}(C_K - C_\pi\right.$$



V_{us} from semileptonic decays

$$\Gamma(K_{\ell 3(\gamma)}) = \frac{C_K^2 G_F^2 m_K^5}{192\pi^3} S_{\rm EW} |V_{us}|^2 |f_+^{K^0\pi^-}(0)|^2 \times I_{K\ell}(\lambda_{K\ell}) \left(1 + 2\Delta_K^{SU(2)} + 2\Delta_{K\ell}^{\rm EM}\right)$$

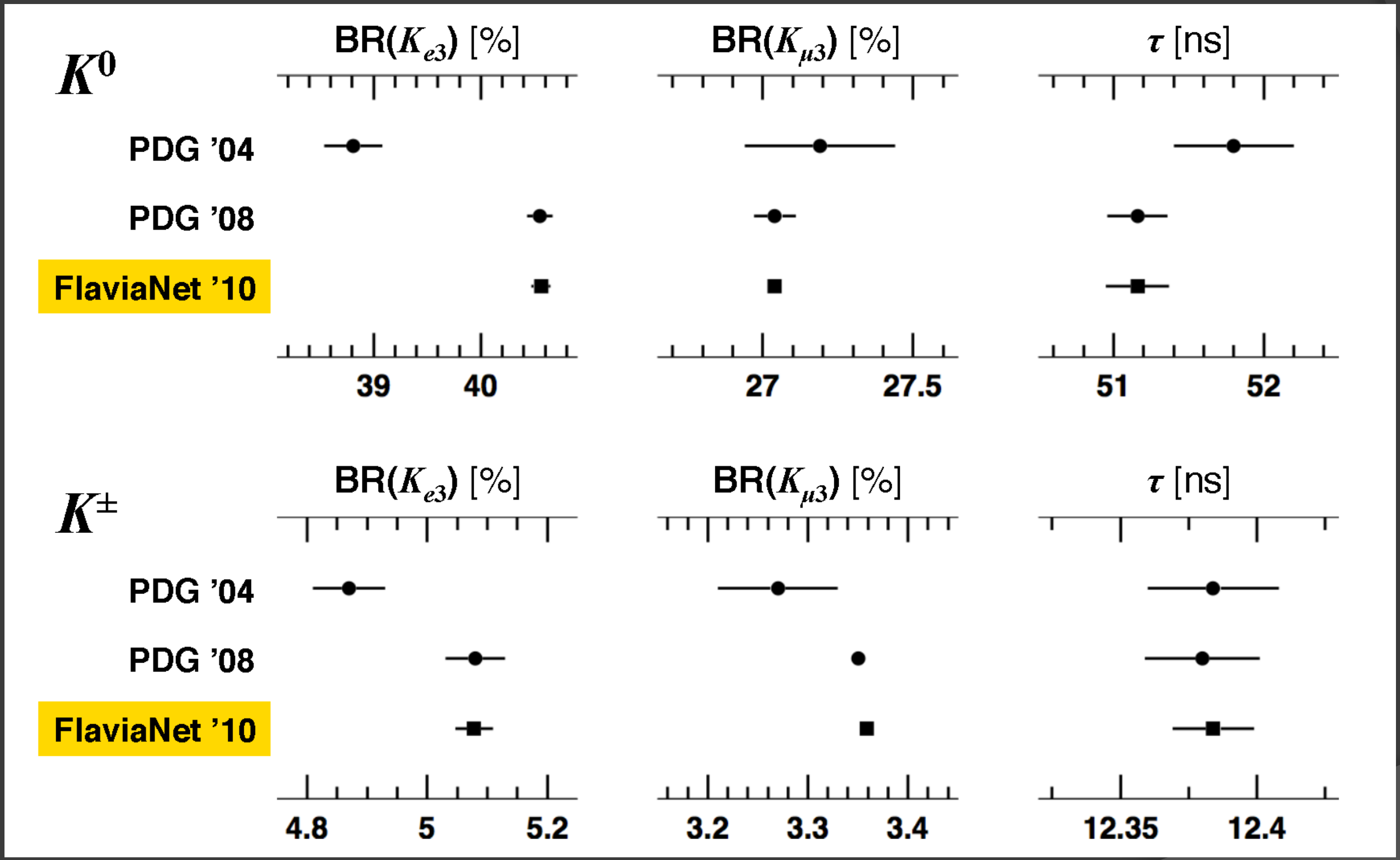
with $K \in \{K^+, K^0\}$; $\ell \in \{e, \mu\}$, and:

C_K^2 1/2 for K^+, 1 for K^0

$S_{\rm EW}$ Universal SD EW correction (1.0232)

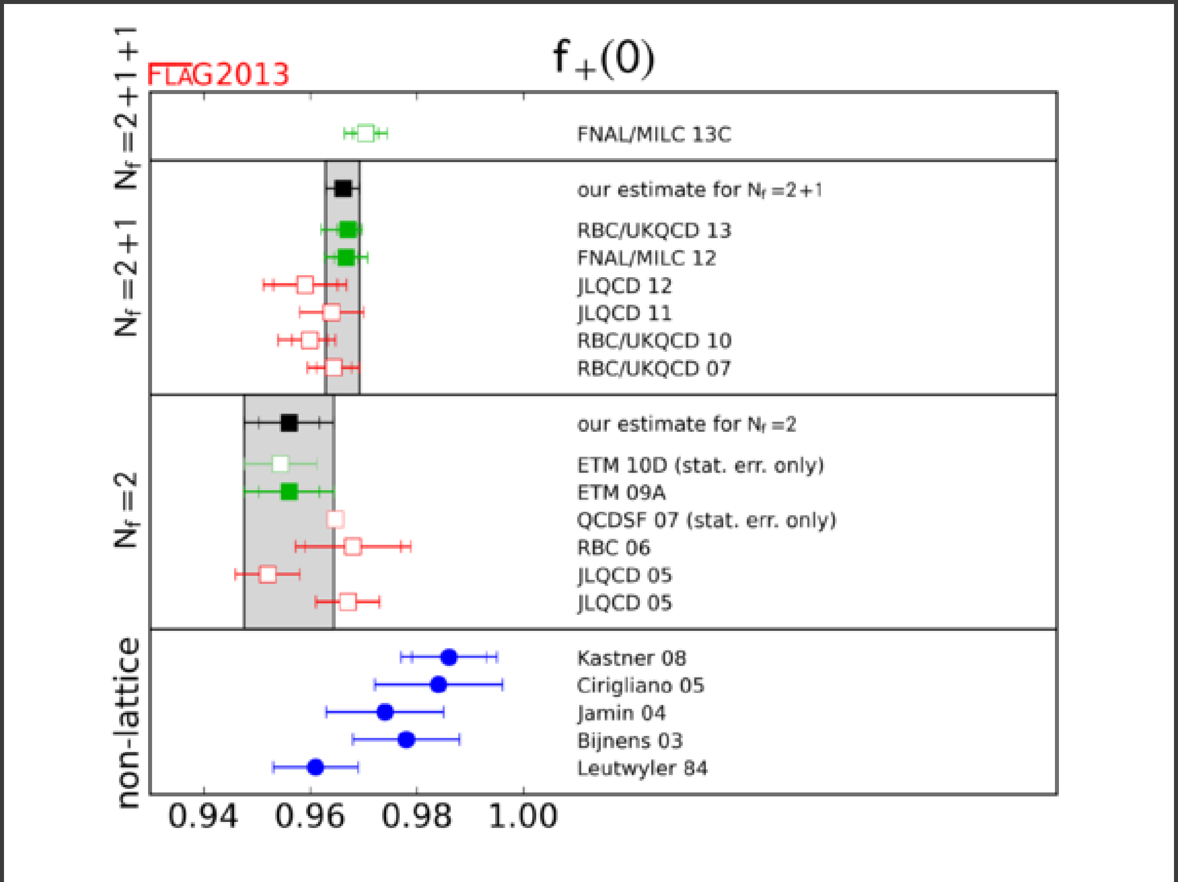
Input from Experiment		Input from Theory	
$\Gamma(K_{\ell 3(\gamma)})$	Rates with well determined radiative corrections	$f_+^{K0\pi-}(0)$	Hadroni matrix element (form factor) at zero momentum transfer (t =0)
	•Branching Ratios	$\Delta_K^{SU(2)}$	Form factor correction for SU(2) breaking
	•Lifetimes		
$I_{K\ell}(\{\lambda\}_{K\ell})$	Integral of form factor over phase space: parameterizes evolution in t	$\Delta_{K\ell}^{EM}$	Long distance EM effects
	•K_{e3}: Only λ_+ (or λ_+', λ_+'')		
	•$K_{\mu3}$: Need λ_+ and λ_0		

Evolution of Experimental Input…



"V_{us} Revolution" with experimental input changing ~ 5% in some cases…..
Input from many experiments: **BNL865, KTeV, ISTRA+, KLOE, NA48, NA48/2**

...and of the theoretical one: $f_+(0)$



The LQCD calculations are Improving, for instance they go beyond “quenched” approximations ($N_f = 2$)

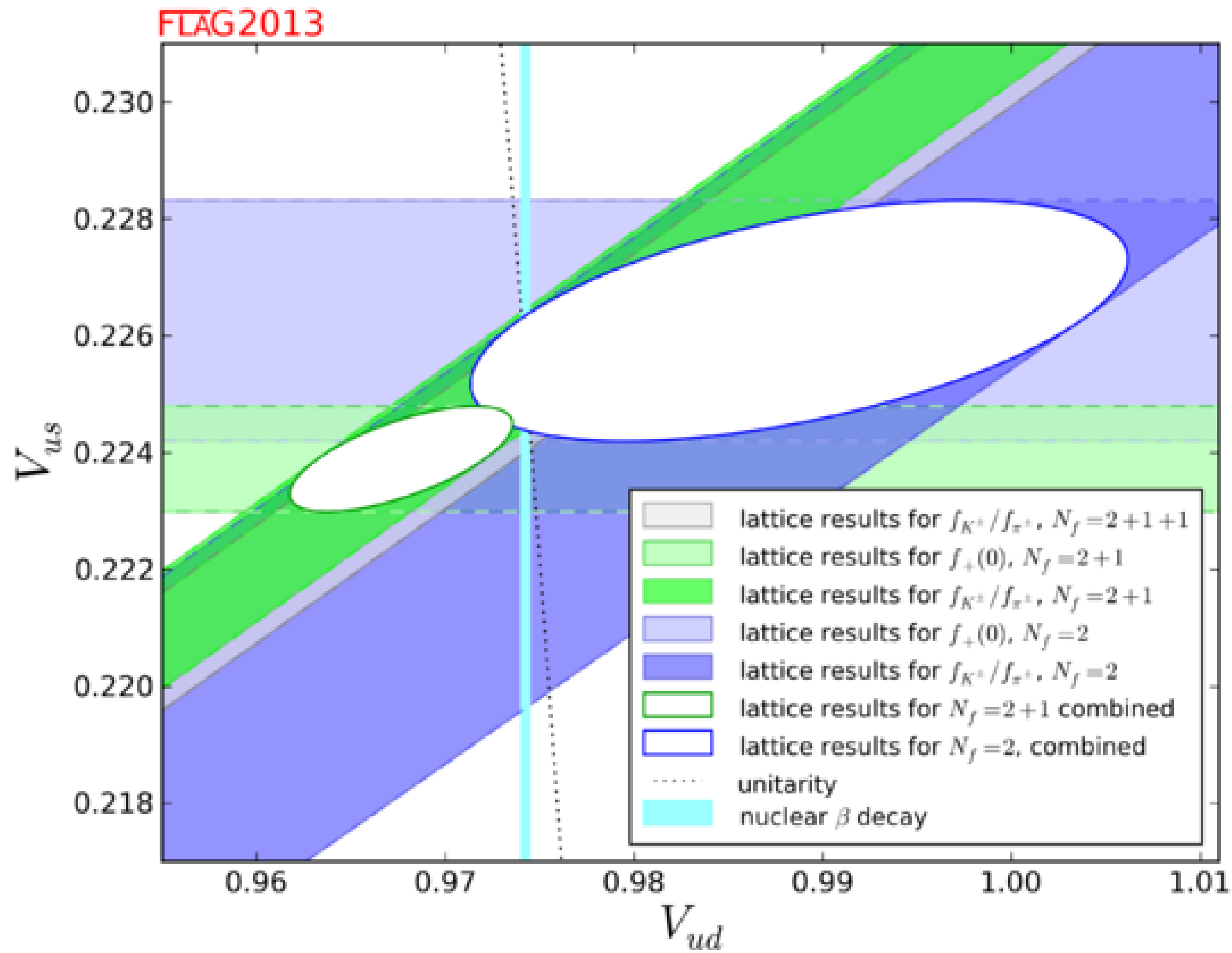
The **Cabibbo** angle can be precisely determined **(~0.4%)!**

Unitarity test of CKM the first row (PDG 2014):

$|V_{ud}|^2|+|V_{us}|^2+|V_{ub}|^2=0.9999 \pm 0.0006$

$|V_{us}| = 0.2253 \pm 0.0008$

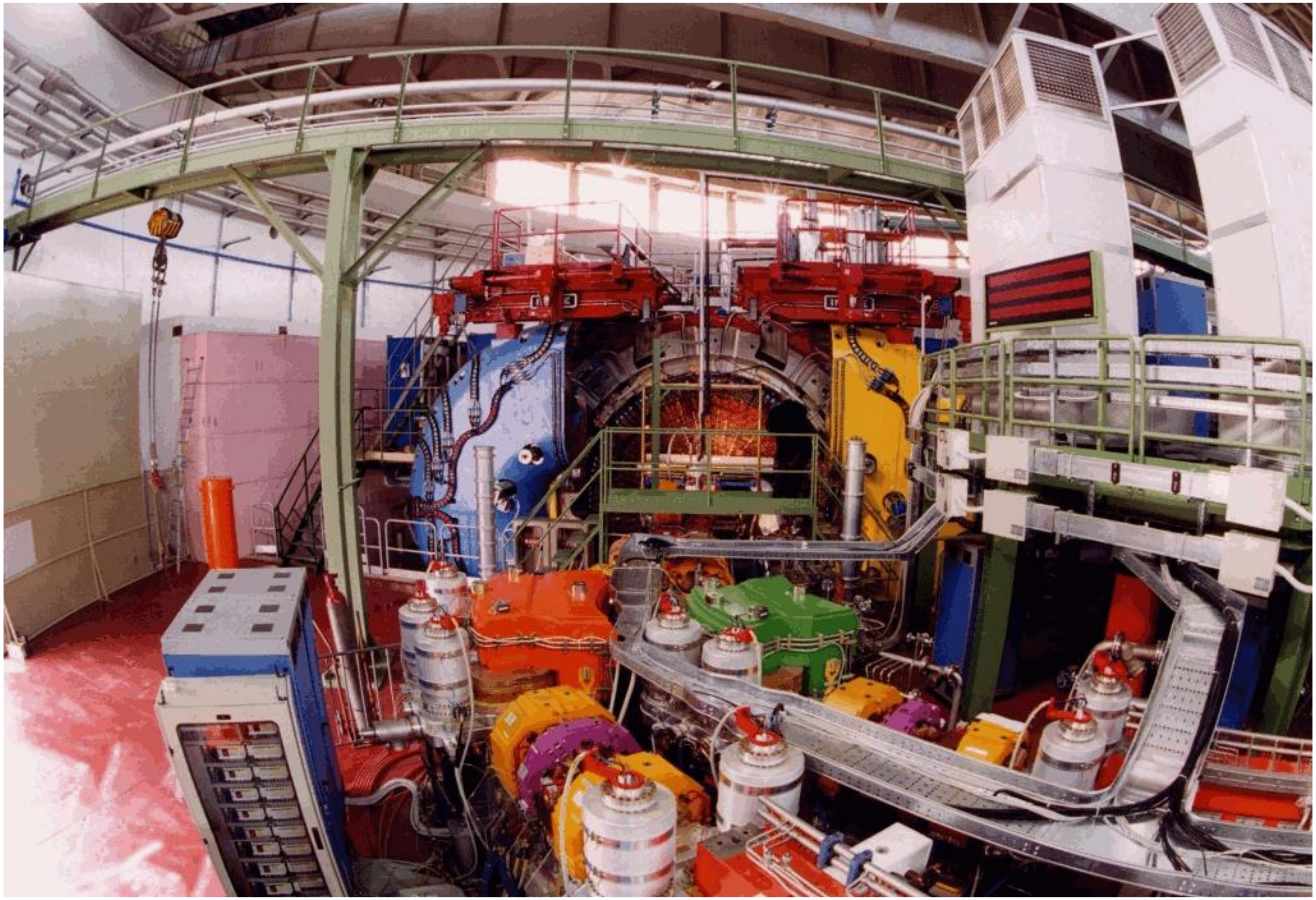
V_US AND THE LATTICE



Experiment (nuclear and particle physics) and lattice QCD

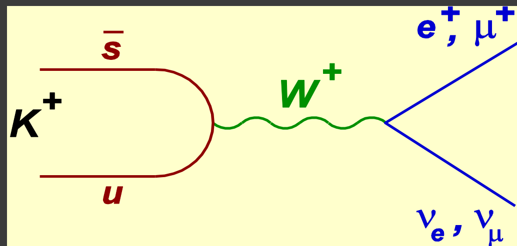
KLOE-2 - LNF

Expect significant progress on leptonic and semileptonic decays



Lepton Universality in K
$R_K = K_{e2}/K_{\mu 2}$

SM

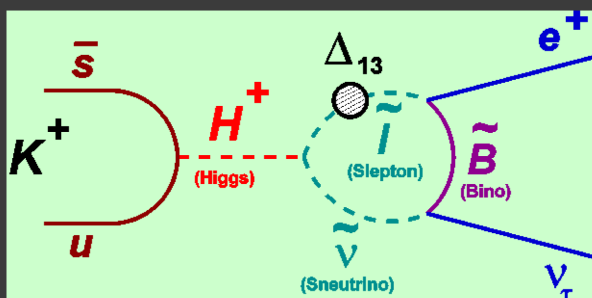


$$R_K = \frac{\Gamma(K^\pm \to e^\pm \nu)}{\Gamma(K^\pm \to \mu^\pm \nu)} = \frac{m_e^2}{m_\mu^2} \cdot \left(\frac{m_K^2 - m_e^2}{m_K^2 - m_\mu^2}\right)^2 \cdot (1 + \delta R_K^{\mathrm{rad.corr.}})$$

$R_K^{SM} = (2.477 \pm 0.001) \times 10^{-5}$

Cirigliano & Rosell PRL 99 (2007) 231801

BSM, LFV



e.g. Masiero, Paradisi Petronzio
PRD 74 (2006) 011701,
JHEP 0811 (2008) 042

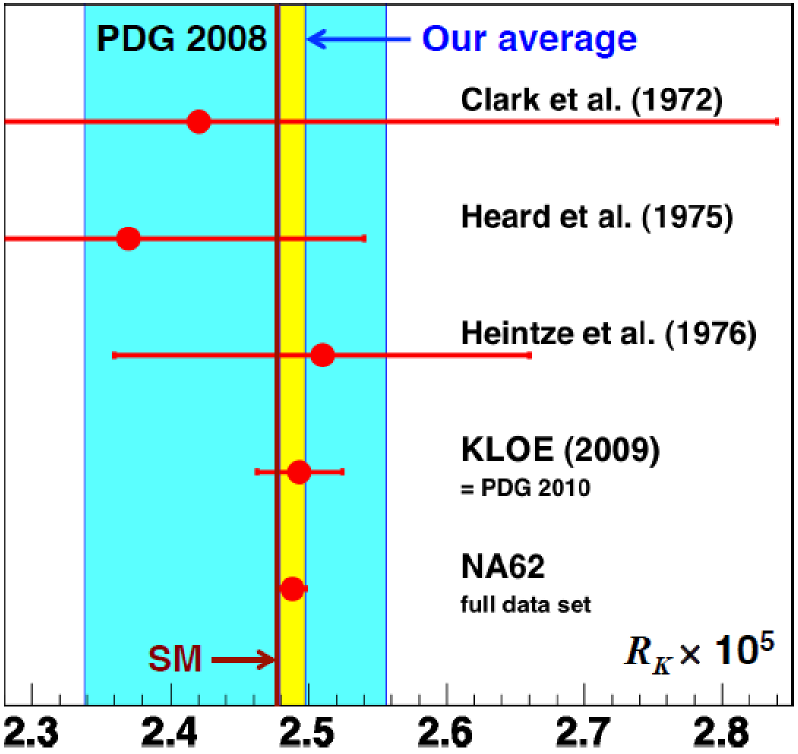
$$R_K^{LFV} \approx R_K^{SM} \left[1 + \left(\frac{m_K^4}{M_{H^\pm}^4} \right) \left(\frac{m_\tau^2}{M_e^2} \right) |\Delta_{13}|^2 \tan^6 \beta \right]$$

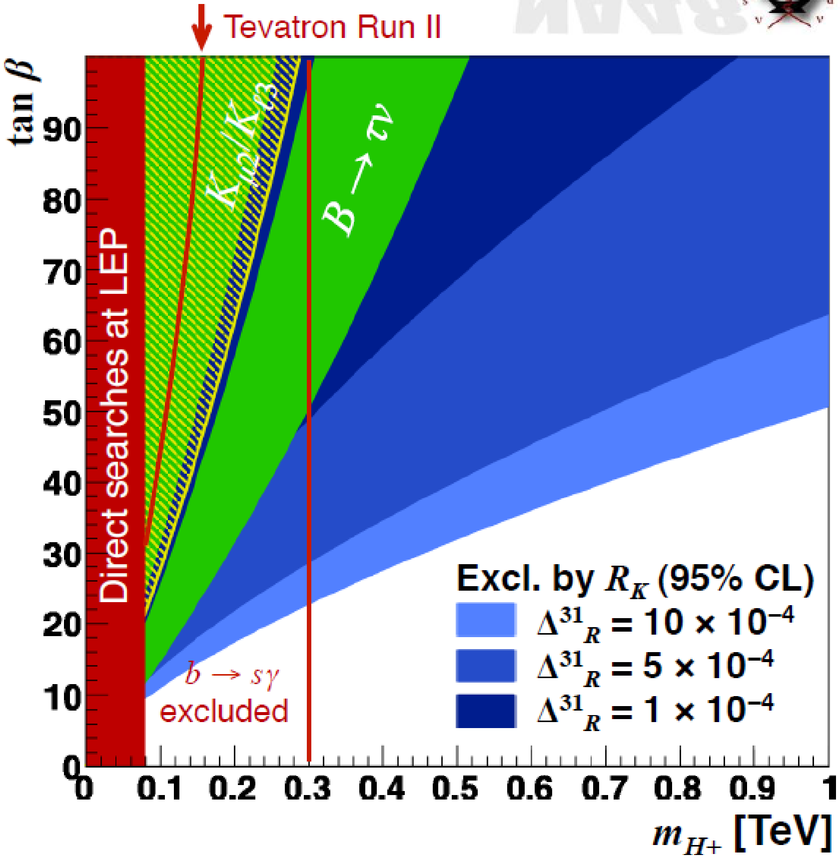
Example:

($\Delta_{13} = 5 \times 10^{-4}$, $\tan\beta = 40$, $M_H = 500$ GeV/c^2)

$R_K^{MSSM} = R_K^{SM}(1+0.013)$.

R_K: world average





Average	$R_K \times 10^5$	$\delta R_K/R_K$
PDG 2008	2.447±0.109	4.5%
Current	**2.488±0.009**	**0.4%**

MSSM with R parity

$$R_K^{LFV} \approx R_K^{SM} \left[1 + \frac{m_K^4}{m_H^4} \frac{m_\tau^2}{m_e^2} |\Delta_R^{31}|^2 \tan^6 \beta \right]$$

A Standard Model view of CP-Violation in Kaons

- Neutral Kaon Mixing (ππ, semi-leptonic)

$$|\varepsilon| = \frac{G_F^2 f_K^2 m_K m_W^2}{12\sqrt{2}\pi^2 \Delta m_K} \hat{B}_K \{\eta_1 S(x_c)\,\mathrm{Im}\left(V_{cs}V_{cd}^*\right)^2 + \eta_2 S(x_t)\,\mathrm{Im}\left(V_{ts}V_{td}^*\right)^2$$
$$+ 2\eta_3 S(x_c, x_t)\,\mathrm{Im}\left(V_{cs}V_{cd}^* V_{ts}V_{td}^*\right)\}$$

$$|\varepsilon| = (2.228 \pm 0.011)\times 10^{-3}$$

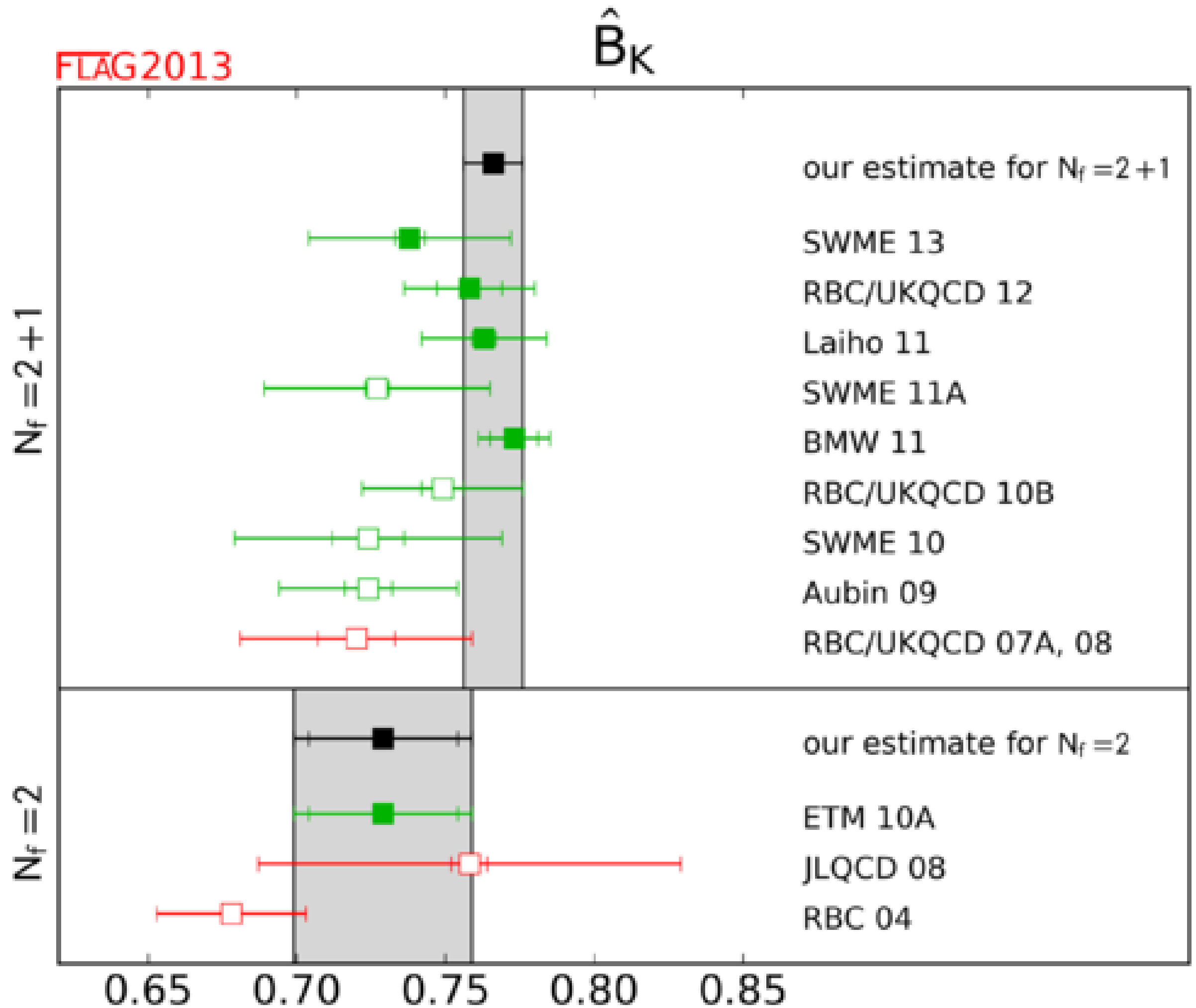
- Neutral Kaon Decays into ππ

$$\mathrm{Re}\frac{\varepsilon'}{\varepsilon} \propto \mathrm{Im}(V_{td}V_{ts}^*)\left[P^{1/2} - P^{3/2}\right]e^{i(\phi_{\varepsilon'} - \varphi_{\varepsilon})}$$

PDG Average

$$\mathrm{Re}\frac{\varepsilon'}{\varepsilon} = (1.68 \pm 0.14)\times 10^{-3}$$

LATTICE QCD: BAG PARAMETER



Precision is becoming remarkable and requires to take into account corrections to ε_K

CORRECTIONS TO EPSILON_K

- In usual applications ξ=Im A_0 / Re A_0 was taken to be equal to zero
- Given the Lattice QCD precision this in no longer acceptable as pointed out by Buras and Guadagnoli (2008)
- The correction can be estimated using epsilon'/epsilon (!)
- Together with other factors it amounts to a ~-8% correction
- Overall the SM prediction for ε_K is about 20% lower than the measured value...

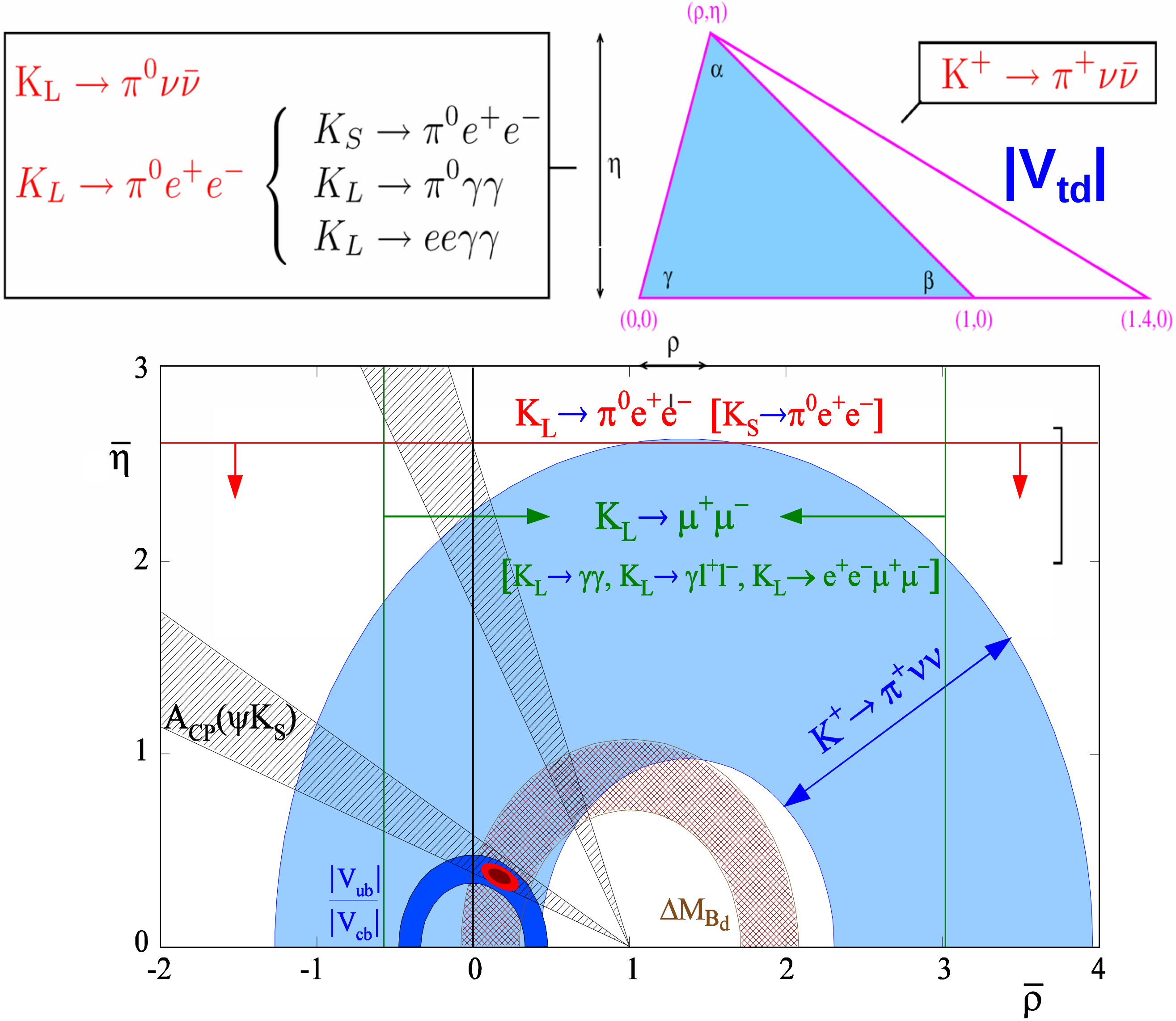
LATTICE QCD AND EPSILON'/EPSILON

- The computation of non-leptonic matrix elements is very complex
- Important progress on the $K \to \pi\pi$ (I=2) amplitudes (arXiv:1206.5142, T.Blum, P. Boyle, N. Christ et al.) which translates into an electroweak penguin contribution:

$$\mathrm{Re}\frac{\varepsilon'}{\varepsilon}|_{EWP} = -(6.25 \pm 0.44(stat) \pm 1.19(syst)) \times 10^{-4}$$

- There is hope for a *ab initio* calculation of the QCD penguin which is even more difficult
- Epsilon'/Epsilon is very sensitive to new physics, a reliable determination of the SM contribution is very important

Kaon Rare Decays (Overview)



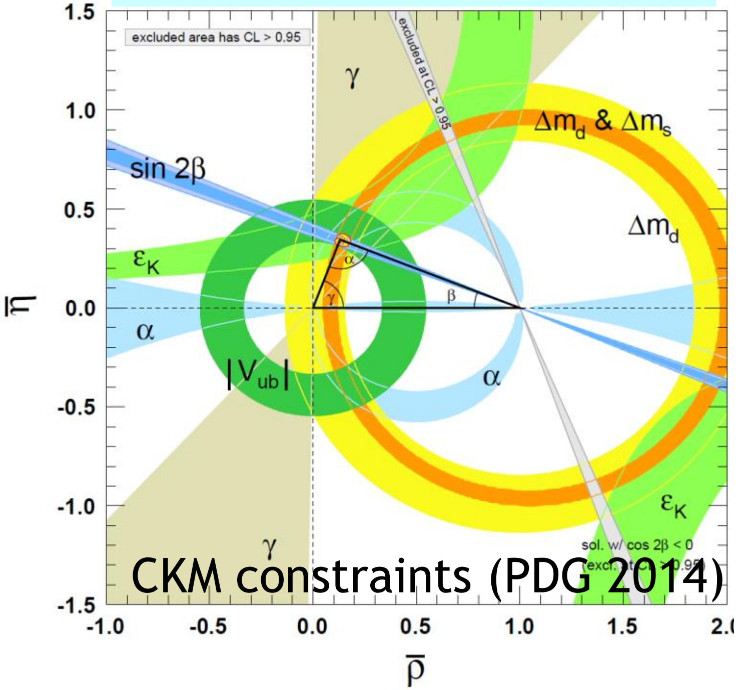
G. Isidori

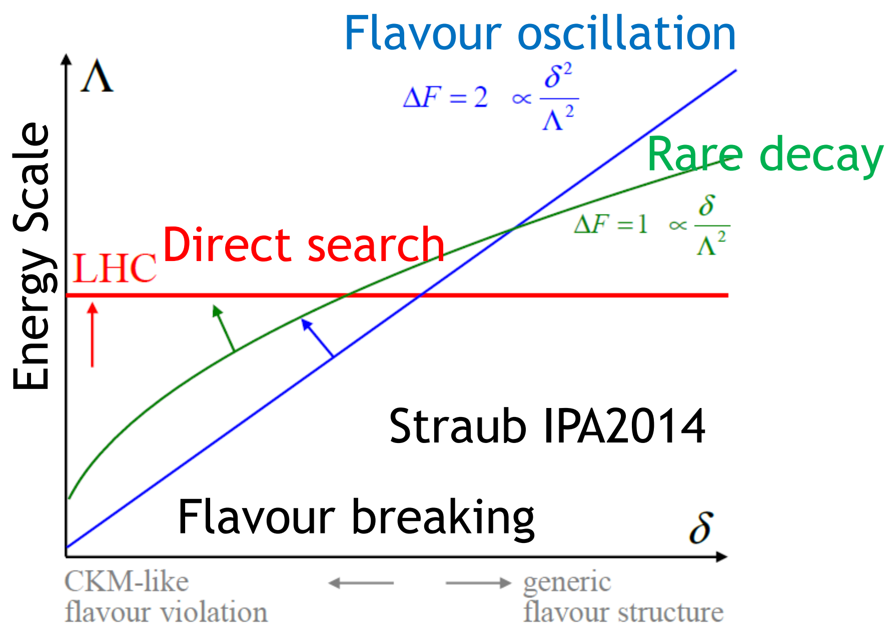
“NO-LOSE” THEOREM

Measure precisely SM parameters <u>or</u> explore structure of New Physics

$$Br(K^+ \to \pi^+ \nu\bar{\nu}) \to |V_{td}V_{ts}^*|^2$$

$$Br(K_L^0 \to \pi^0 \nu\bar{\nu}) \to (\mathrm{Im}V_{td}V_{ts}^*)^2$$

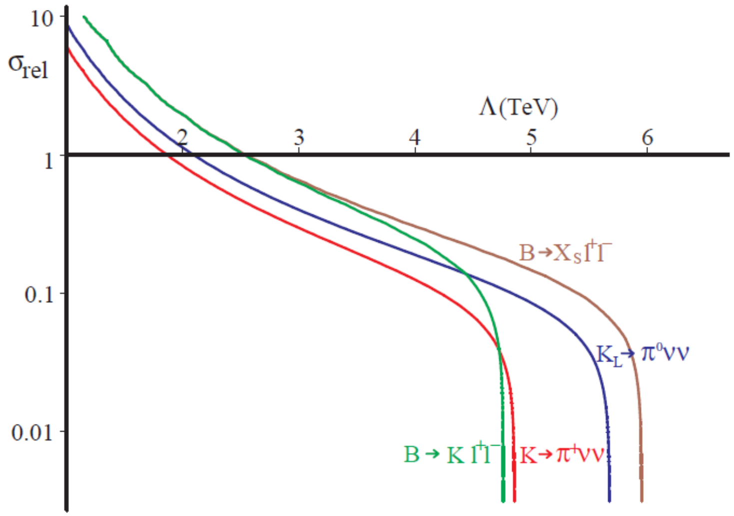


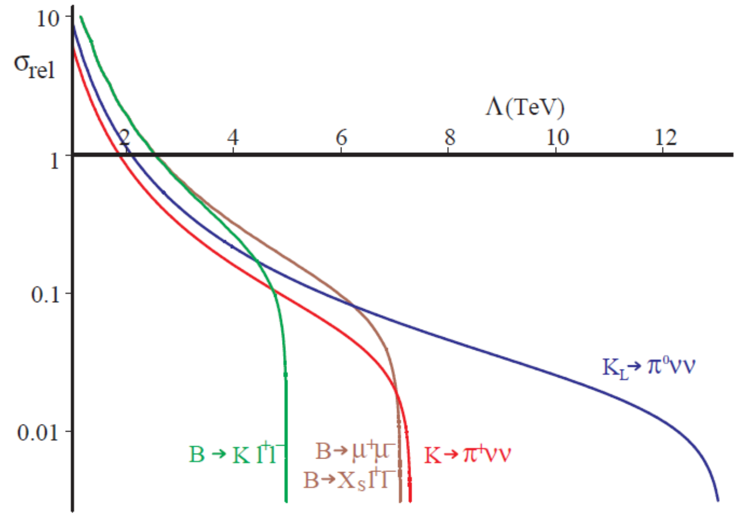


Standard Model

Sensitivity to New Physics

SENSITIVITY TO NEW PHYSICS SCALE FOR "MINIMAL FLAVOUR VIOLATION"





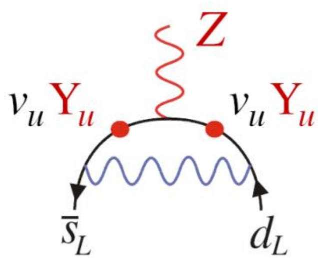
10% Overall CKM error

1% Overall CKM error

D'Ambrosio, Giudice, Isidori, Strumia (2002)

Kaon Rare Decays and NP: EXAMPLE 1

C. The Z penguin (and its associated W box)

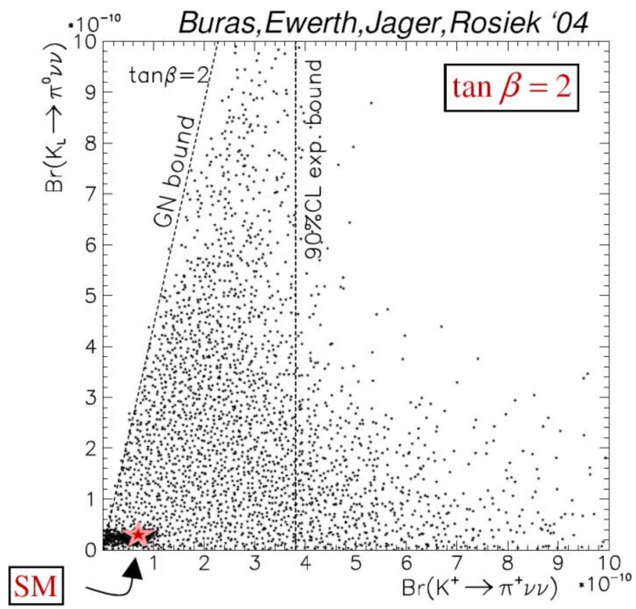


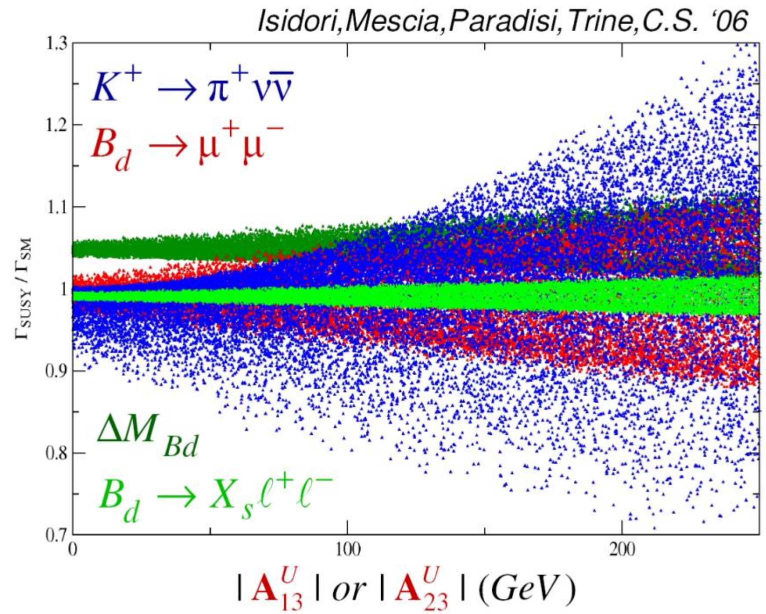
- $SU(2)_L$ breaking: $SM : v_u^2 Y_u^{*32} Y_u^{31} \sim m_t^2 V_{ts}^* V_{td}$

$$MSSM : v_u^2 A_{\tilde{u}}^{*32} A_{\tilde{u}}^{31} \sim m_t^2 \times O(1)\,?$$

$$MFV : v_u^2 A_{\tilde{u}}^{*32} A_{\tilde{u}}^{31} \sim m_t^2 V_{ts}^* V_{td} \left|A_0 a_2^* - \cot\beta\mu\right|^2 .$$

- Relatively slow decoupling (w.r.t. boxes or tree).

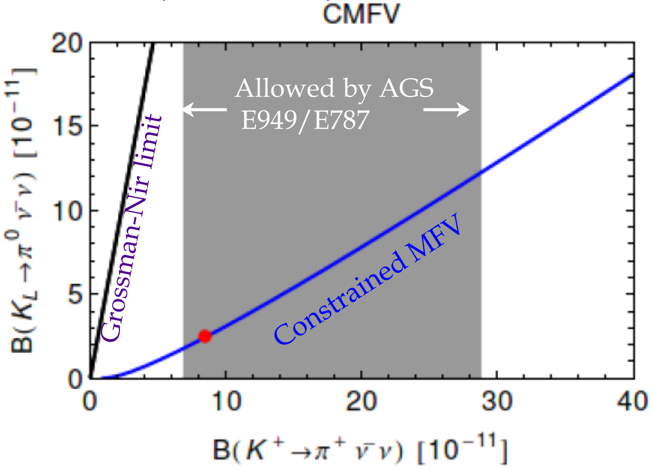


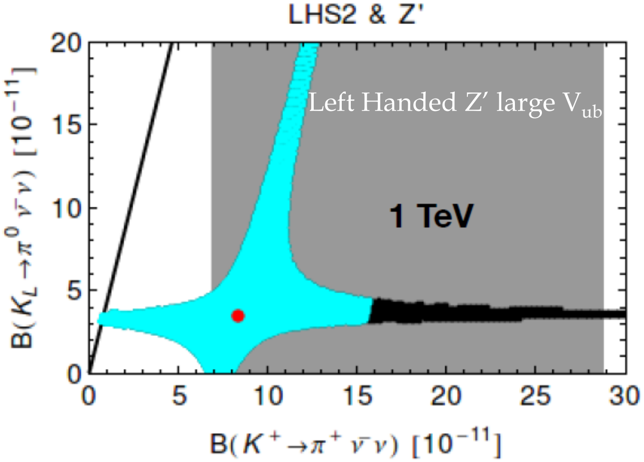


(courtesy by Christopher Smith)

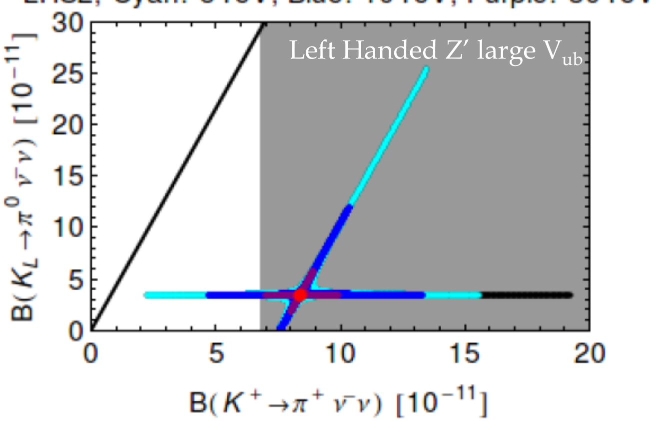
EXAMPLE 2: RARE *K* DECAY SENSITIVITY TO FLAVOR VIOLATING Z'

Buras, De Fazio, Girrbach arXiv: 1211.1896



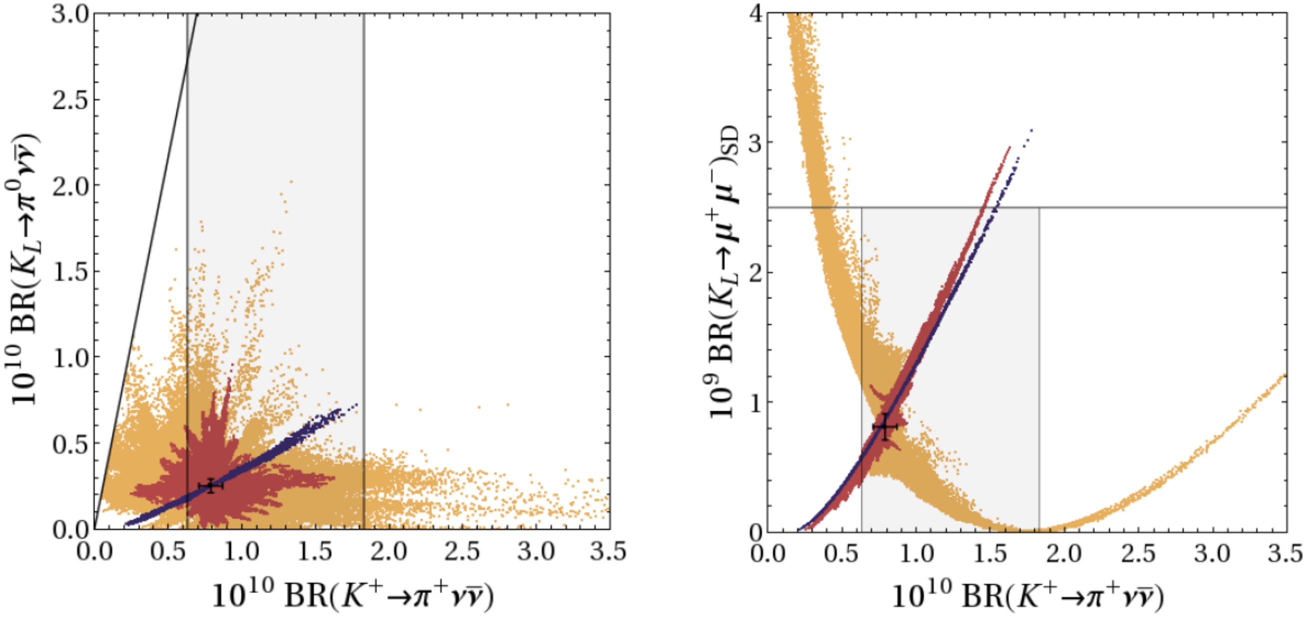


Complementary sensitivity to direct searches of new gauge bosons



EXAMPLE 3: FCNC Z COUPLINGS AND PARTIAL COMPOSITENESS

D.M. Straub arXiv:1302.4651



STILL ROOM FOR VISIBLE NEW PHYSICS EFFECTS IN FCNC KAON PHYSICS IN SPITE OF ALL THE STRINGENT HIGH-ENERGY AND HIGH-INTENSITY CONSTRAINTS

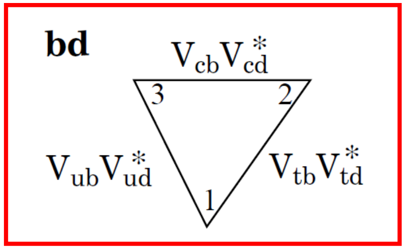
STATE OF THE ART

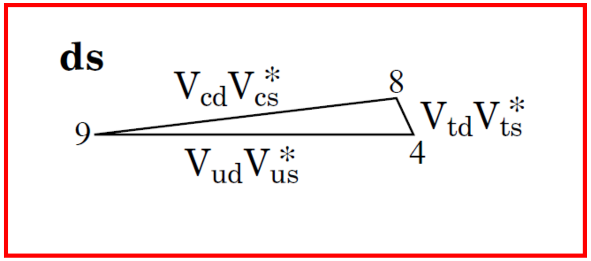
Decay	Branching Ratio ($\times 10^{10}$) Theory (SM)	Experiment
$K^+ \to \pi^+ \nu\bar{\nu}(\gamma)$	0.85 ± 0.07 [1]	$1.73^{+1.15}_{-1.05}$ [2]
$K_L^0 \to \pi^0 \nu\bar{\nu}$	0.27 ± 0.04 [3]	< 260 (90% CL) [4]
$B_s^0 \to \mu^+\mu^-$	32.3 ± 2.7 [5]	28^{+7}_{-6} [6]

[1] J. Brod, M. Gorbahn, PRD78, arXiv:0805.4119
[2] AGS-E787/E949 PRL101 (2008) 191802, arXiv:0808.2459
[3] M. Gorbahn arXiv:0909.2221
[4] KEK-E391a, arXiv:0911.4789v1
[5] A.J. Buras et al., EPJ C72, arXiv:1208.0934
[6]CMS-LHCb, CKM2014

UNITARITY TRIANGLE FOR KAONS

- When the bd UT is used, the variables extracted from kaons are affected by an apparent parametric uncertainty due to V_{cb}





- The six UTs are all born equal (in the SM they have the same measure of CP-violation, the Jarlskog invariant J_{CP})

- A remarkable feature is that in the *ds* UT

$$J_{CP} = 5.6 * sqrt(BR(K_L \to \pi^0 \nu \nu))$$

This is a determination which is basically free from theoretical error (down to 1-2%)

- It is to be compared with the current J_{CP} determination from the bd UT fit where the error ranges from 3% to 7% depending on the treatment of the errors

$$Br(K_L^0 \to \pi^0 \nu\bar{\nu})$$

HOLY GRAIL OF FLAVOUR PHYSICS?

- Why it is so special:

1. Apart from a small admixture (ε_K~2.228 10^{-3}), K^0_L is a CP eigenstate. Neglecting the CP-even state we can write:

$$<\pi^0\nu\bar{\nu}|A|K^0> \sim V_{td}V_{ts}^* X(x_t) + P_c(X) V_{cd} V_{cs}^*$$
$$<\pi^0\nu\bar{\nu}|A|\bar{K}^0> \sim V_{td}^*V_{ts} X(x_t) + P_c(X) V_{cd}^* V_{cs}$$

$$|K_L^0> \sim \frac{K^0 - \bar{K}^0}{\sqrt{2}}$$

2. In taking the difference, the charm part (which is almost real) drops off and only the imaginary part of the top contribution remains!

$$<\pi^0\nu\bar{\nu}|A|K_L^0> \sim \mathrm{Im} V_{td}V_{ts}^* X(x_t)$$

3. The main experimental background ($K^0_L \to \pi^0\pi^0$) is suppressed by CP conservation !
4. The very long life time of the K^0_L makes the interesting partial width "measurable" (Br~O(10^{-11}))

$Br(K_L^0 \to \pi^0 \nu\bar{\nu})$

Formulas from A.J. Buras et al. RMP 80, 2008

$$Br(K_L^0 \to \pi^0 \nu\bar{\nu}) = \kappa_L \times \left(\frac{\mathrm{Im}\,\lambda_t}{\lambda^5} X(x_t) \right)^2$$

$$\kappa_L = (2.231 \pm 0.013) \times 10^{-10} \left[\frac{\lambda}{0.225} \right]^8$$

Numerical example:

$$\lambda_i = V_{id} V_{is}^*$$

$$\mathrm{Im}\,V_{td}V_{ts}^* = \sin\beta_K \, |V_{td}V_{ts}^*| \sim 1.29 \times 10^{-4}$$

$$X(x_t) \sim 1.44$$

$$\lambda = \frac{|V_{us}|}{\sqrt{|V_{ud}|^2 + |V_{us}|^2}}$$

$$Br(K_L^0 \to \pi^0 \nu\bar{\nu}) \sim 2.3 \times 10^{-11}$$

EXPERIMENT: BR<2.6 10^{-8} 90%CL (E391a - KEK)
NEXT EXPERIMENT: KOTO (E14, J-PARC)

KOTO experiment

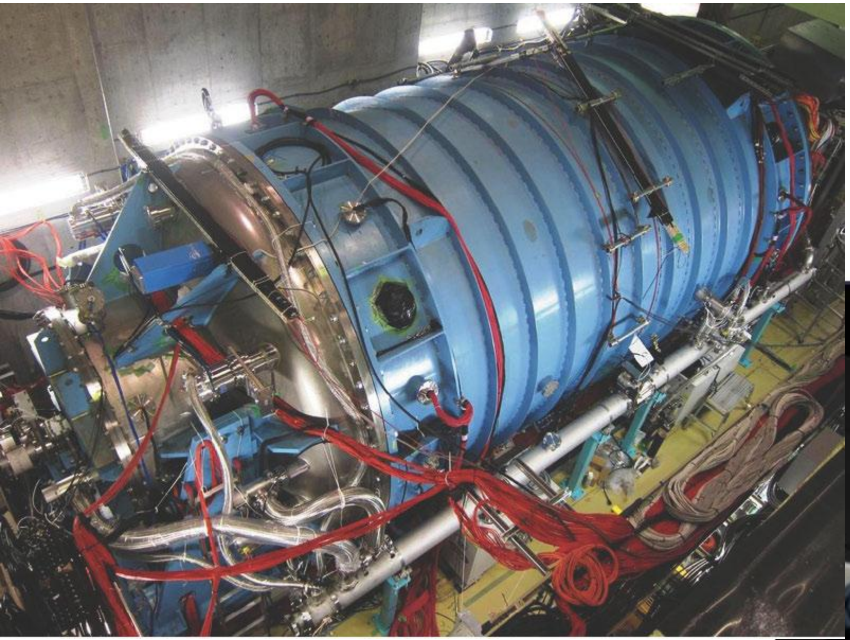
- Study of $K_L \to \pi^0 \nu \bar{\nu}$ @J-PARC 30GeV Main Ring.
  - Successor to the E391a experiment
  - Goal is to observe few SM events.

J-PARC

3

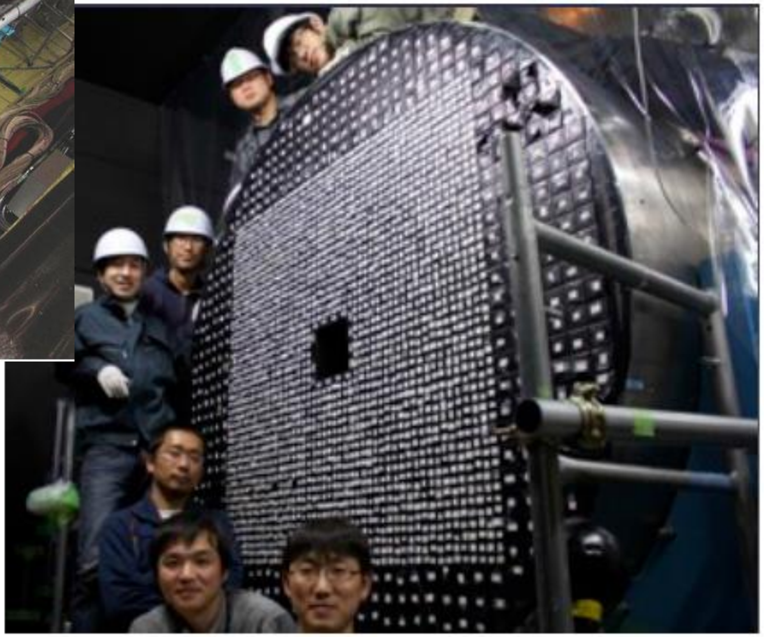
As presented by Koji Shiomi at CKM 2014 (Vienna)

KOTO - JPARC



Vacuum tank from E391a

Pure CsI recovered from FNAL KTeV Experiment



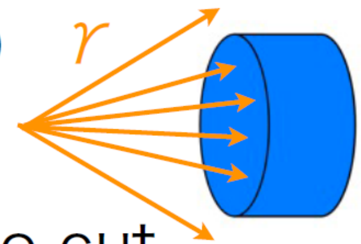
Current SES based on 100 h run in 2013 (Preliminary): 1.29×10^{-8}

Expect “nominal” beam intensity in 2017

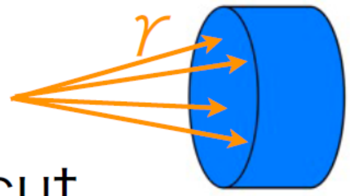
Veto detector performance

- 4 cluster samples

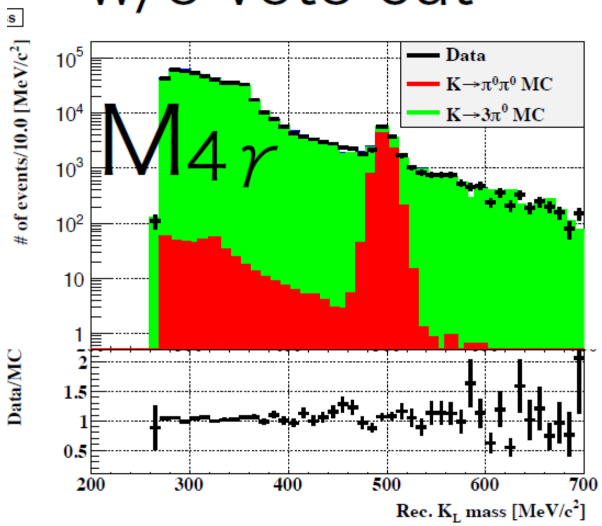
BR($K_L \to 3\pi^0$)
=20%



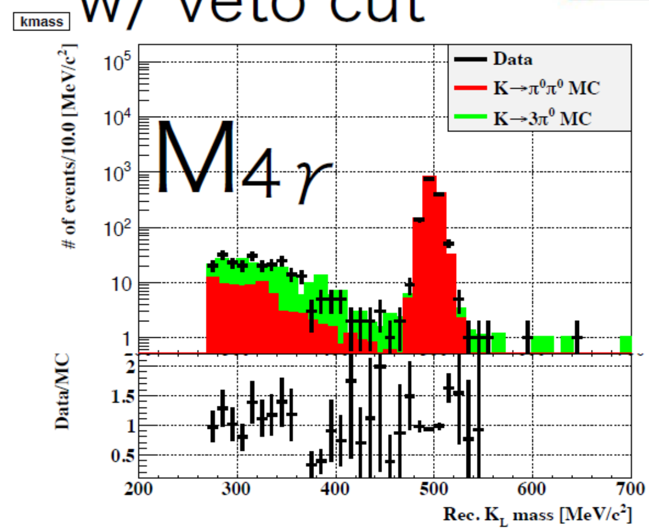
BR($K_L \to 2\pi^0$)
=8.6×10^{-4}



w/o veto cut



w/ veto cut



$Br(K^+ \to \pi^+ \nu\bar{\nu})$

$$Br(K^+ \to \pi^+ \nu\bar{\nu}) = \kappa_+ \left(1 + \Delta_{EM}\right) \times$$

$$\left[\left(\frac{\mathrm{Im}\,\lambda_t}{\lambda^5} X(x_t) \right)^2 + \left(\frac{\mathrm{Re}\,\lambda_c}{\lambda} P_c(X) + \frac{\mathrm{Re}\,\lambda_t}{\lambda^5} \right)^2 \right]$$

$$\kappa_+ = (5.173 \pm 0.025) \times 10^{-11} \left[\frac{\lambda}{0.225} \right]^8$$

$$\lambda = \frac{|V_{us}|}{\sqrt{|V_{ud}|^2 + |V_{us}|^2}}$$

$$\kappa_+ = r_{K^+} \cdot \frac{3\alpha^2 Br(K^+ \to \pi^0 e^+ \nu)}{2\pi^2 \sin^4 \theta_W} \cdot \lambda^8$$

$$\lambda_i = V_{id} V_{is}^*$$

Formulas from A.J. Buras et al. RMP 80, 2008

$Br(K^+ \to \pi^+ \nu\bar{\nu})$ (MY NUMEROLOGY)

$$Br(K^+ \to \pi^+ \nu\bar{\nu}) \propto 1.56\times10^{-4} \times$$

$$\left[|V_{td}V_{ts}^*|^2 \; X(x_t)^2 + 2\lambda^5 P_c(X)\,|V_{td}V_{ts}^*|\,X(x_t)\cos\beta_K + \lambda^{10} P_c(X)^2 \right] \approx$$

$$[\quad 4.40 \quad + \quad 3.68 \quad + \quad 0.87 \quad] \times 10^{-11} =$$

$$8.95\times10^{-11}$$

The charm- top-quark interference term is comparatively large

$$\cos\beta_K = \cos\beta - \beta_s \approx 0.94$$

For this set of values the m_c the parametric uncertainty is:
$\delta Br/Br \sim 0.68\ \delta P_c/P_c$

$$|V_{td}V_{ts}^*| \sim 3.69\times10^{-4} \quad \text{(PDG 2014)}$$

$$X(x_t) \sim 1.44 \quad \text{(Buras et al.)}$$

$$P_c(X) = 0.41 \pm 0.05 \quad \text{(Buras et al.)}$$

CHARGED K BEAMS

"Stopped"

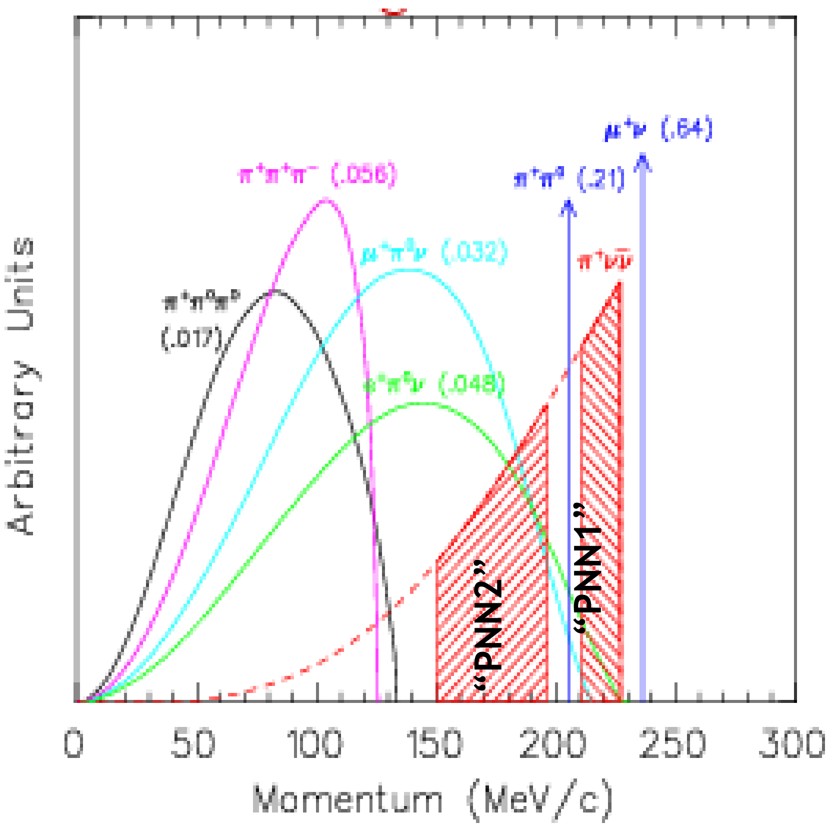
- Work in Kaon frame
- High Kaon purity (Electro-Magneto-static Separators)
- Compact Detectors

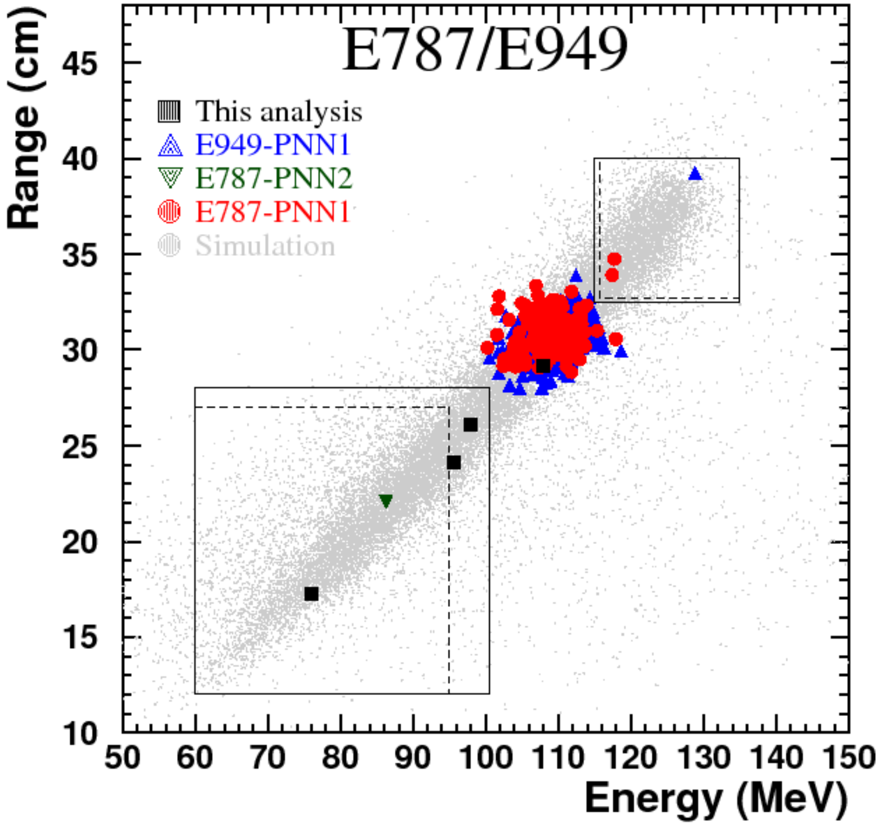
"In-Flight"

- Decays in vacuum (no scattering, no interactions)
- RF separated or Unseparated beams
- Extended decay regions

Exp	Machine	Meas. or UL 90% CL	Notes
	Argonne	$< 5.7 \times 10^{-5}$	Stopped; HL Bubble Chamber
	Bevatron	$< 5.6 \times 10^{-7}$	Stopped; Spark Chambers
	KEK	$<1.4 \times 10^{-7}$	Stopped; $\pi^+ \rightarrow \mu^+ \rightarrow e^+$
E787	AGS	$(1.57^{+1.75}_{-0.82}) \times 10^{-10}$	Stopped
E949	AGS	$(1.73^{+1.15}_{-1.05}) \times 10^{-10}$	Stopped; PPN1+PPN2
NA62	SPS		In-Flight; Unseparated

STATE OF THE ART: E787/E949 DECAYS AT REST

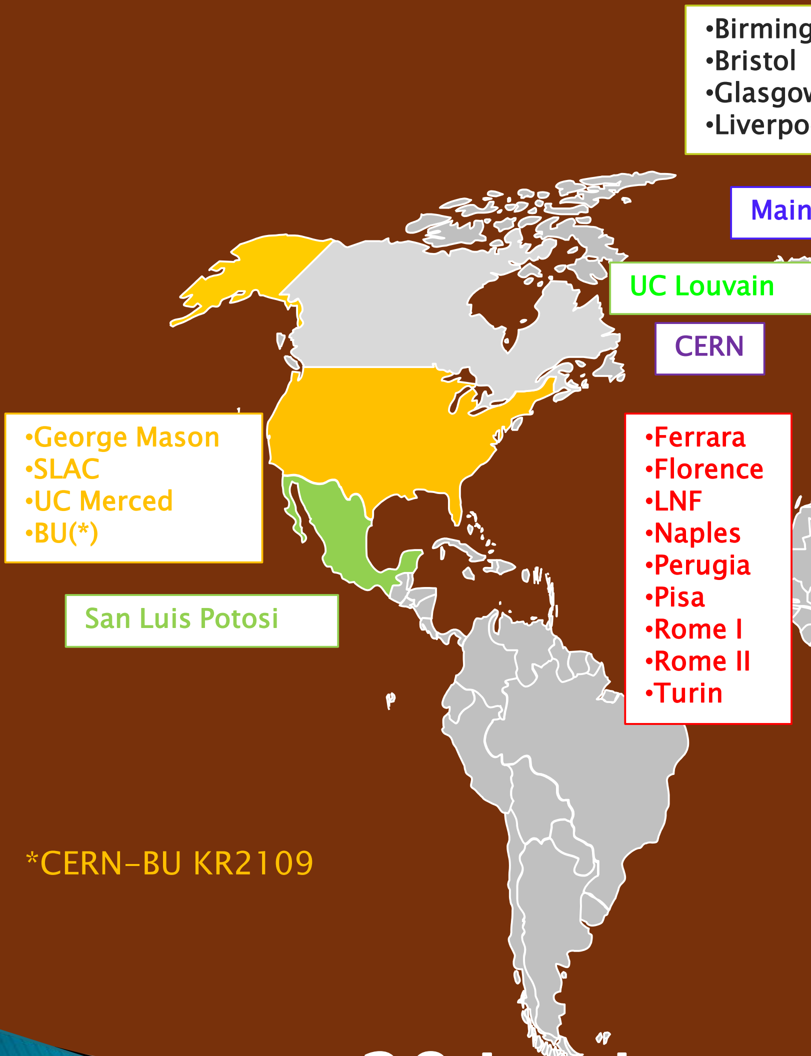




$$B(K^+ \rightarrow \pi^+ \nu\bar{\nu}) = (1.73^{+1.15}_{-1.05}) \times 10^{-10}$$

PRL101, arXiv:0808.2459, AGS-E787/E949

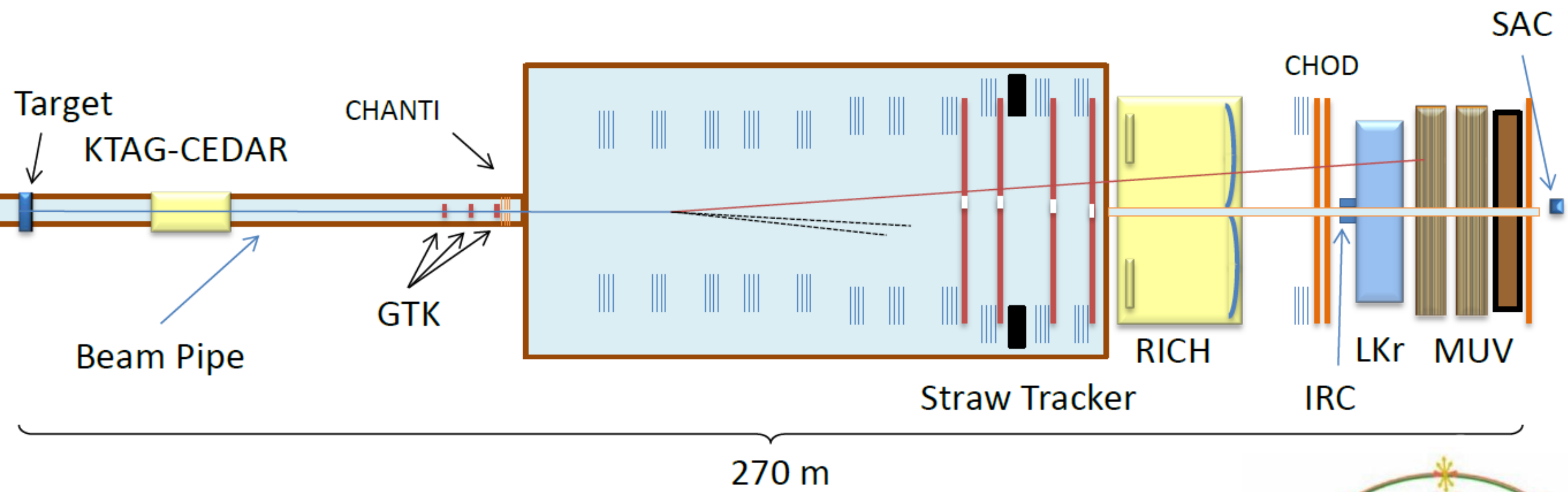
NA62 Collaboration



*CERN-BU KR2109

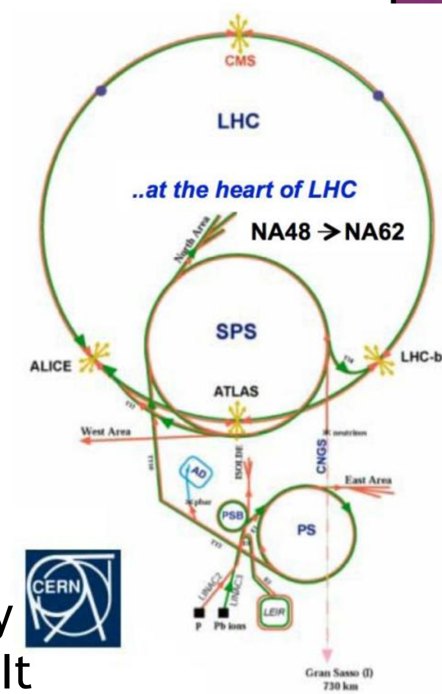
28 Institutes, 213 Collaborators

NA62 SCHEMATIC LAYOUT



10^{12} / s protons from SPS (400 GeV/c) on Be target (~1 λ)

750 MHz secondary beam: 75 GeV/c
•Positive polarity
•Kaon fraction ~6%
•Δ p/p ~ 1%
•Useful kaon decays ~10% (5 MHz)

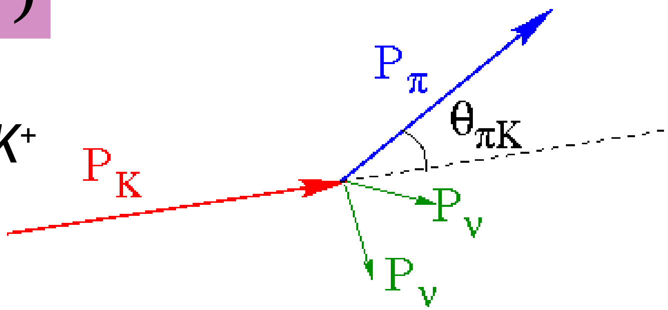


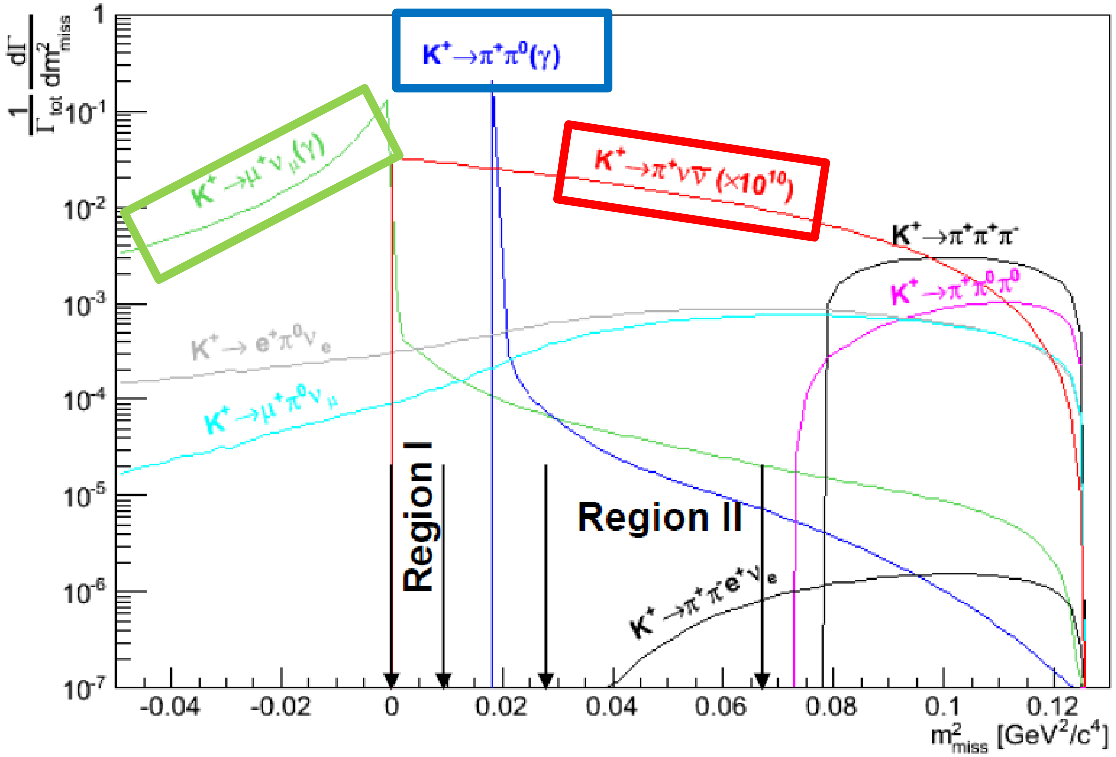
NA62 is designed for a specific "silver bullet" measurement. This requires high beam rate, full PID, hermetic coverage, very light, high-rate tracking and state-of-the-art trigger and DAQ. It paves the way to a broad physics program

NA62 IN-FLIGHT TECHNIQUE

$$Br(K^+ \to \pi^+ \nu \bar{\nu})$$

- Calorimetry to veto extra particles
- Very light trackers to reconstruct the K^+ and the π^+ momenta
- Full particle identification





$$m^2_{miss} = (P_K - P_{\pi^+})^2$$

NA62 SENSITIVITY

Decay	evt/year*
$K^+ \to \pi^+ \nu\nu$ [SM] (flux 4.5×10^{12})	45
$K^+ \to \pi^+ \pi^0$	5
$K^+ \to \mu^+ \nu$	1
$K^+ \to \pi^+ \pi^+ \pi^-$	< 1
$K^+ \to \pi^+ \pi^- e^+ \nu$ + other 3 tracks decays	< 1
$K^+ \to \pi^+ \pi^0 \gamma$(IB)	1.5
$K^+ \to \mu^+ \nu \gamma$(IB)	0.5
$K^+ \to \pi^0 e^+ (\mu^+) \nu$, others	negligible
Total background	< 10

One year = 100 days, 50% Efficiency
With new CERN-LHC running cycle we expect more days / year

INSTALLATION AND START UP

- The picture shows the last large element being installed (STRAW4)
- Beam time 2014: October 6 – December 15
- Currently writing ~9 TB of data / day

NA62 DETECTOR STATUS

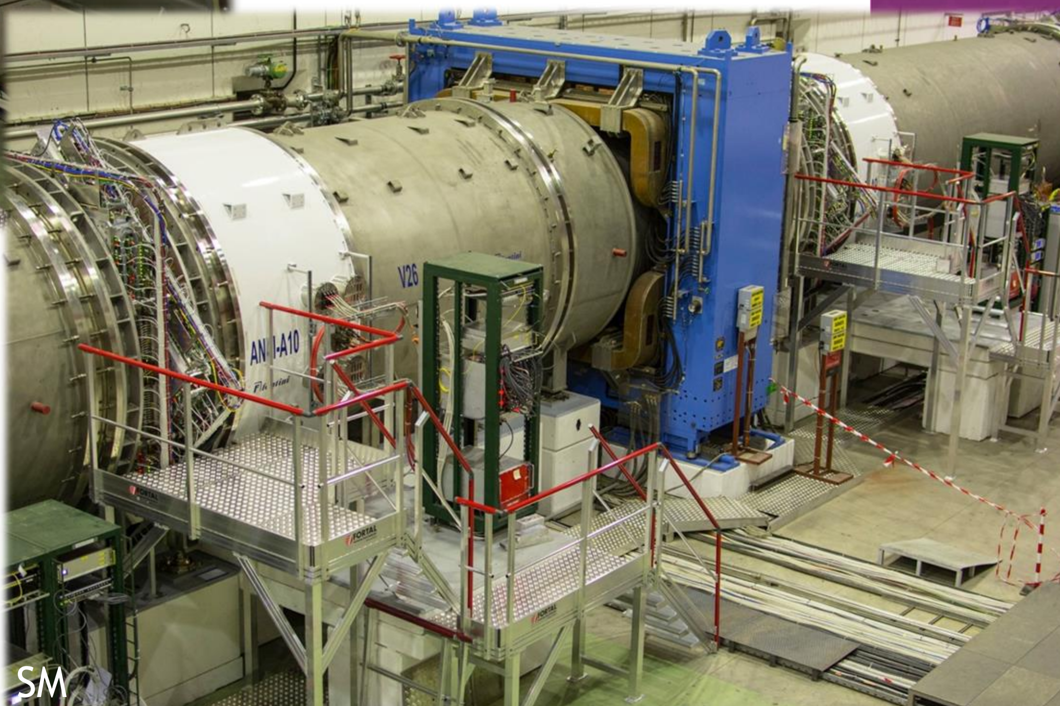
View of ECN3

LAV 1-5 in TTC8

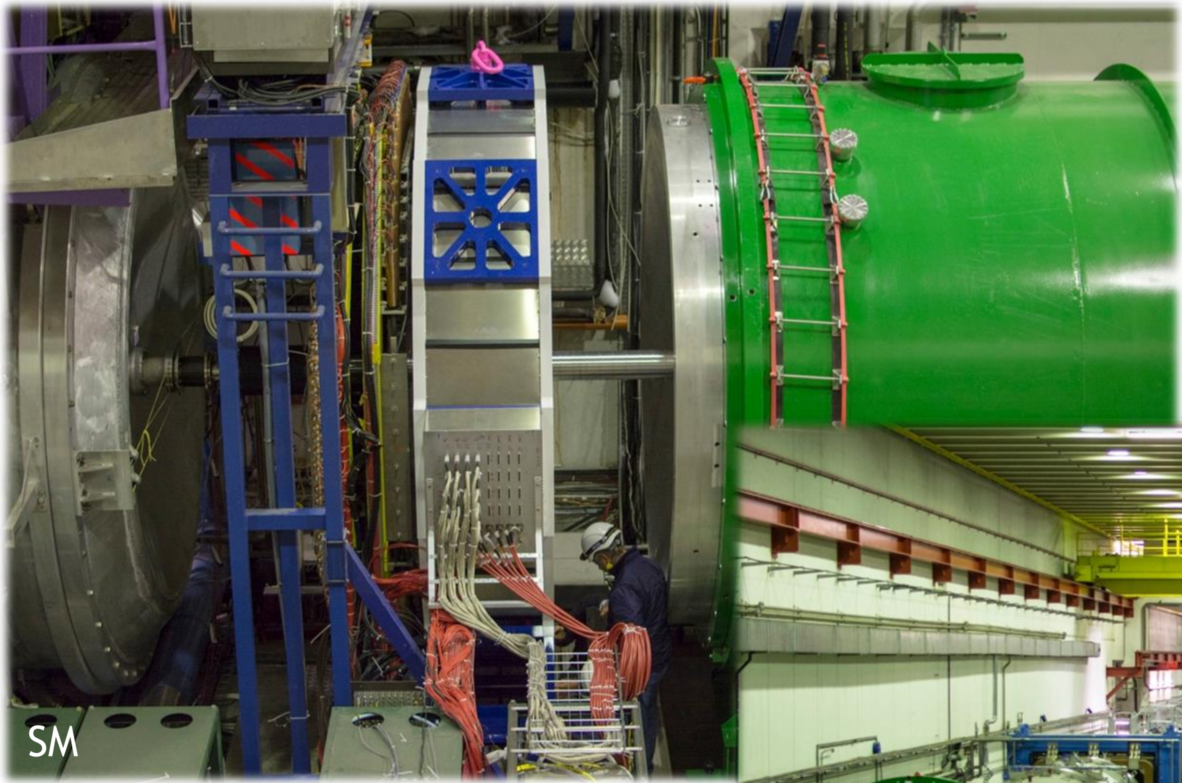
NA62 DETECTOR STATUS

RICH Straw 4 and LAV11

Straw3 - LAV10 - MNP33 - Straw2 - LAV9



NA62 DETECTOR STATUS

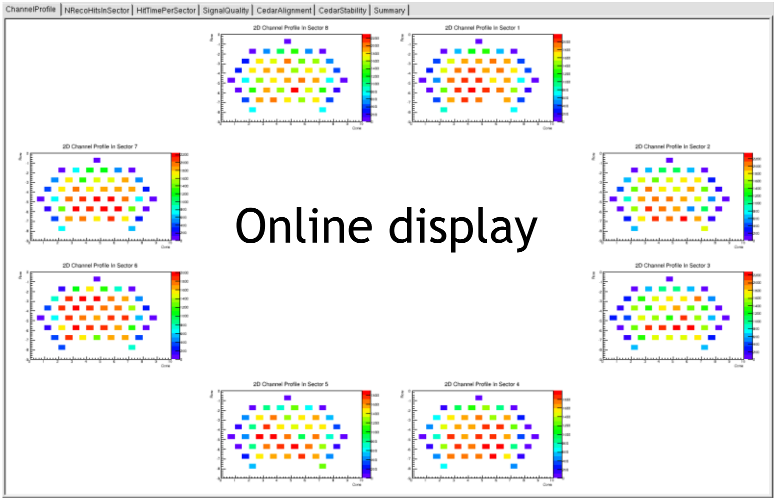


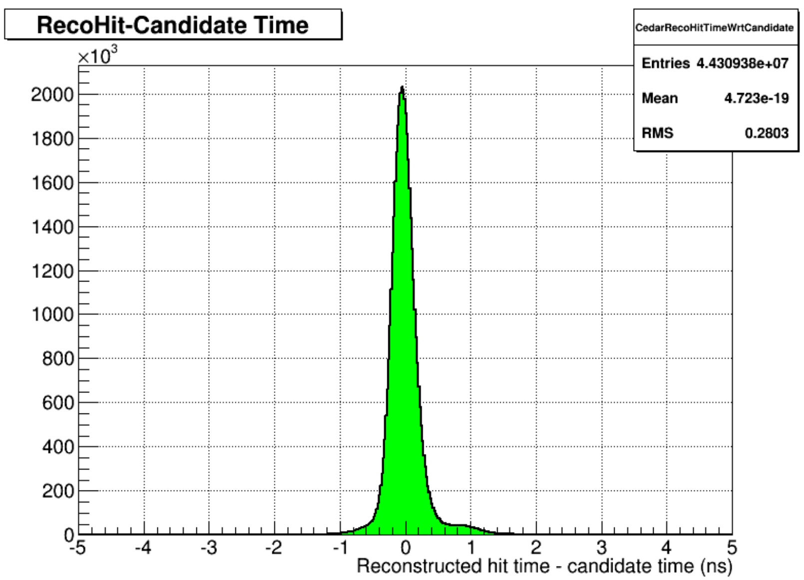
LKr - CHOD LAV12 and RICH

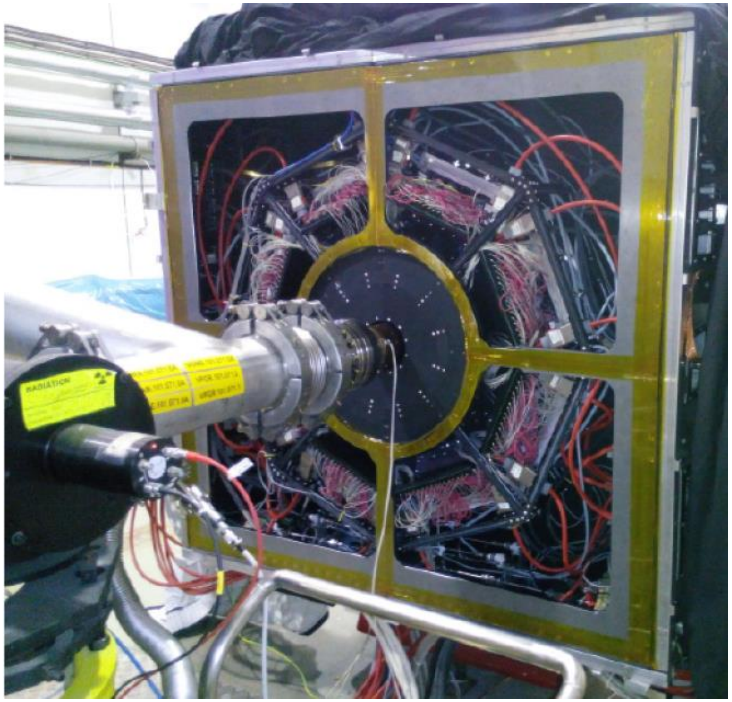
NA62 view from LKr

KTAG

Birmingham, Bristol, Liverpool



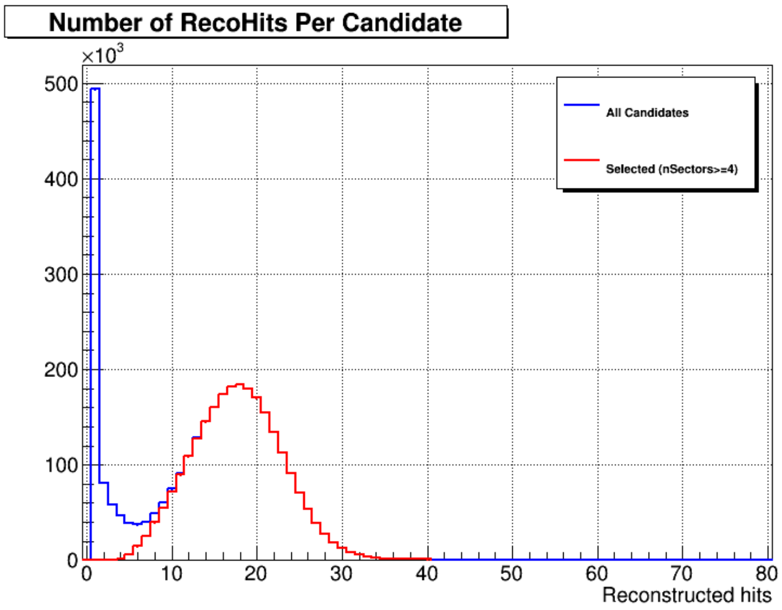


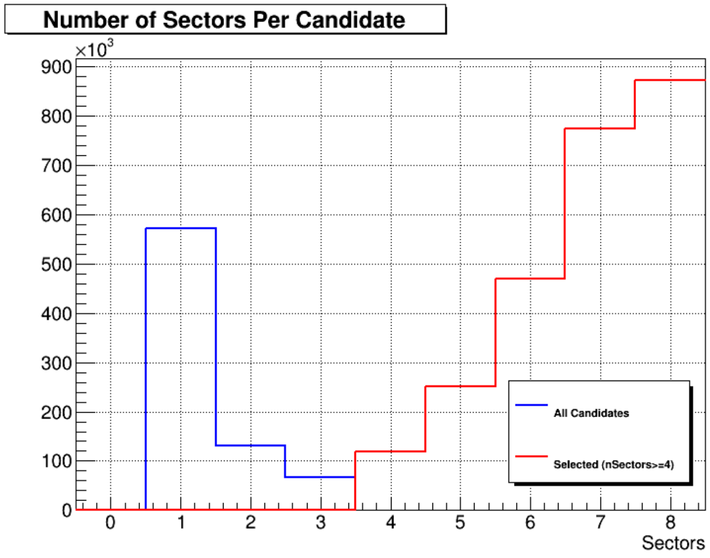


Nominal N_2 pressure for Kaons

Preliminary: single hit time resolution (~280 ps)

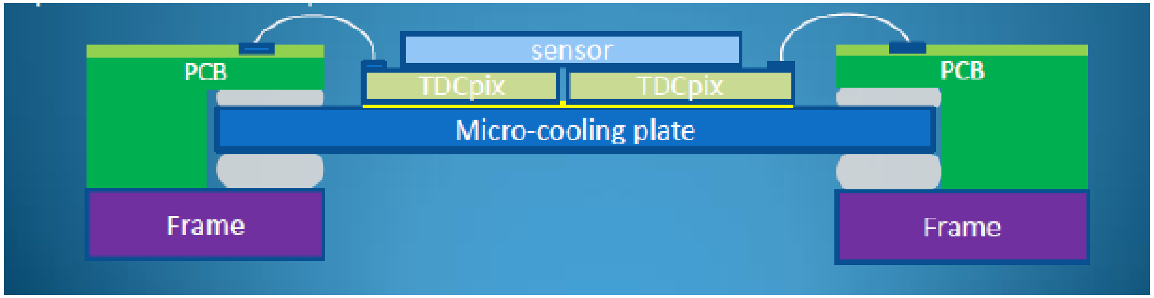
KTAG (PRELIMINARY)

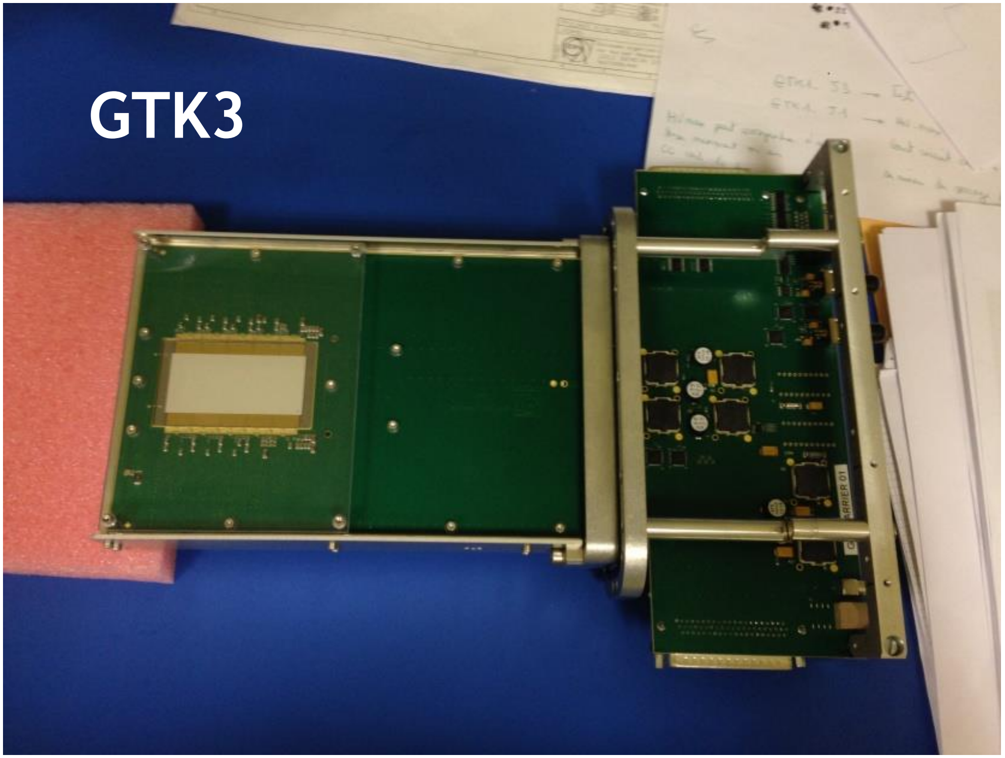


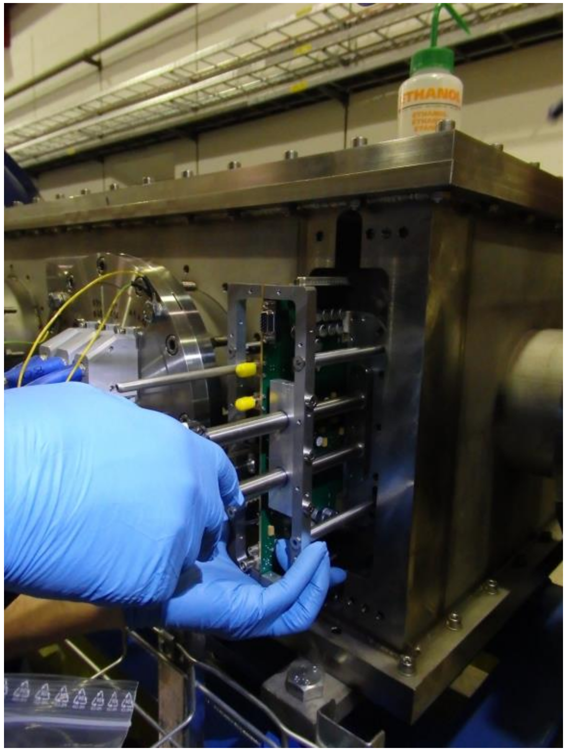


GIGATRACKER (GTK)

CERN (PH-DT, PH-ESE, PH-SME, EN,…)
Ferrara, Louvain-la-Neuve, Torino

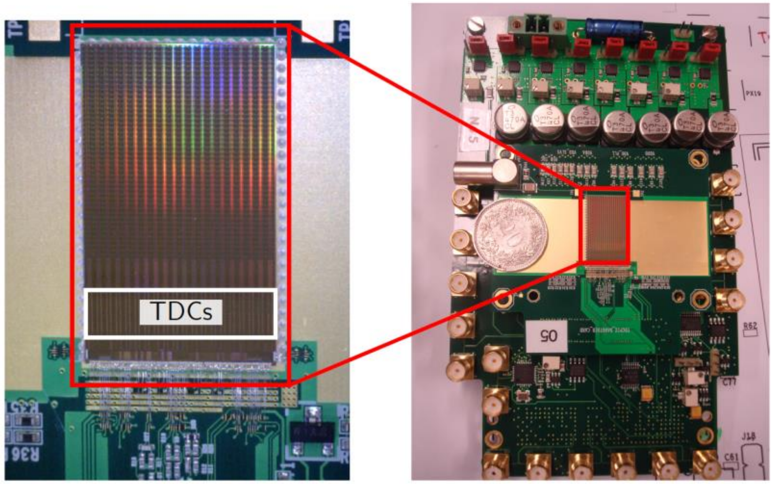






GTK READ OUT CHIP

TDCPix Wire Bonded to the Test Card



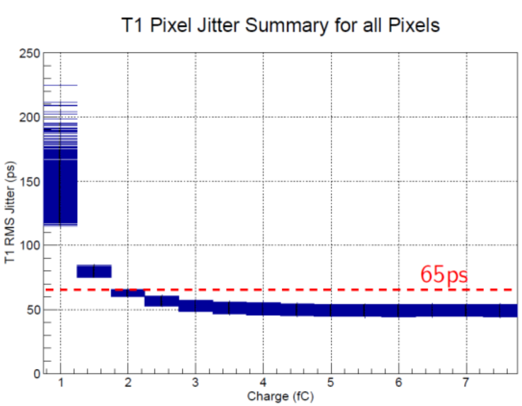
TDCPix

130 nm CMOS IBM

CERN
PH-ESE Design

Excellent performance
Major breakthrough for NA62

Full Chain Behaviour



T_1(RMS) $<$ 65 ps at 2.5 fC

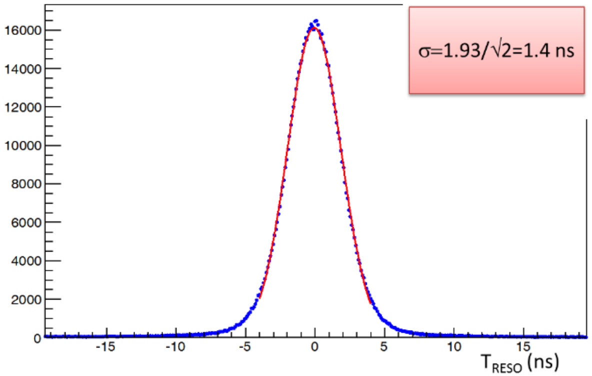
- trigger swept through full clk cycle
  - 32 phases
  - Step:100ps
- 10^4 triggers per phase
- No sensor present

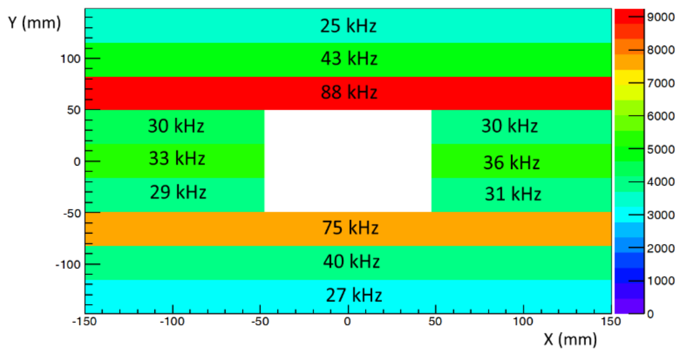
Block	Status	Remarks
Configuration	Working	5 chips tested
PLL	Working	3.2 GHz
Serialisers	Working	3.2 Gb/s
Bandgaps	Working	
Temperature Interlock	Working	
Column Biasing	Working	200 DACs
In-Pixel Threshold Trimming	Working	1800 DACs
# of bugs detected	0	

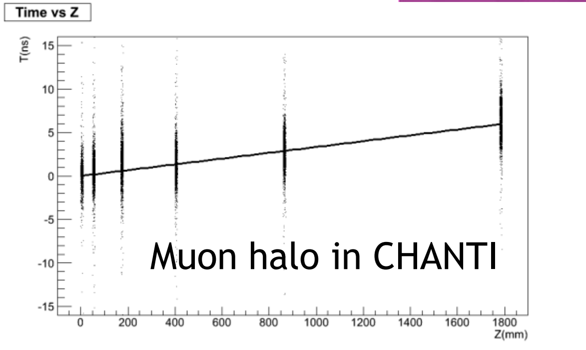
"Whole Chip" Resolution ~ 72 ps RMS

CHANTI

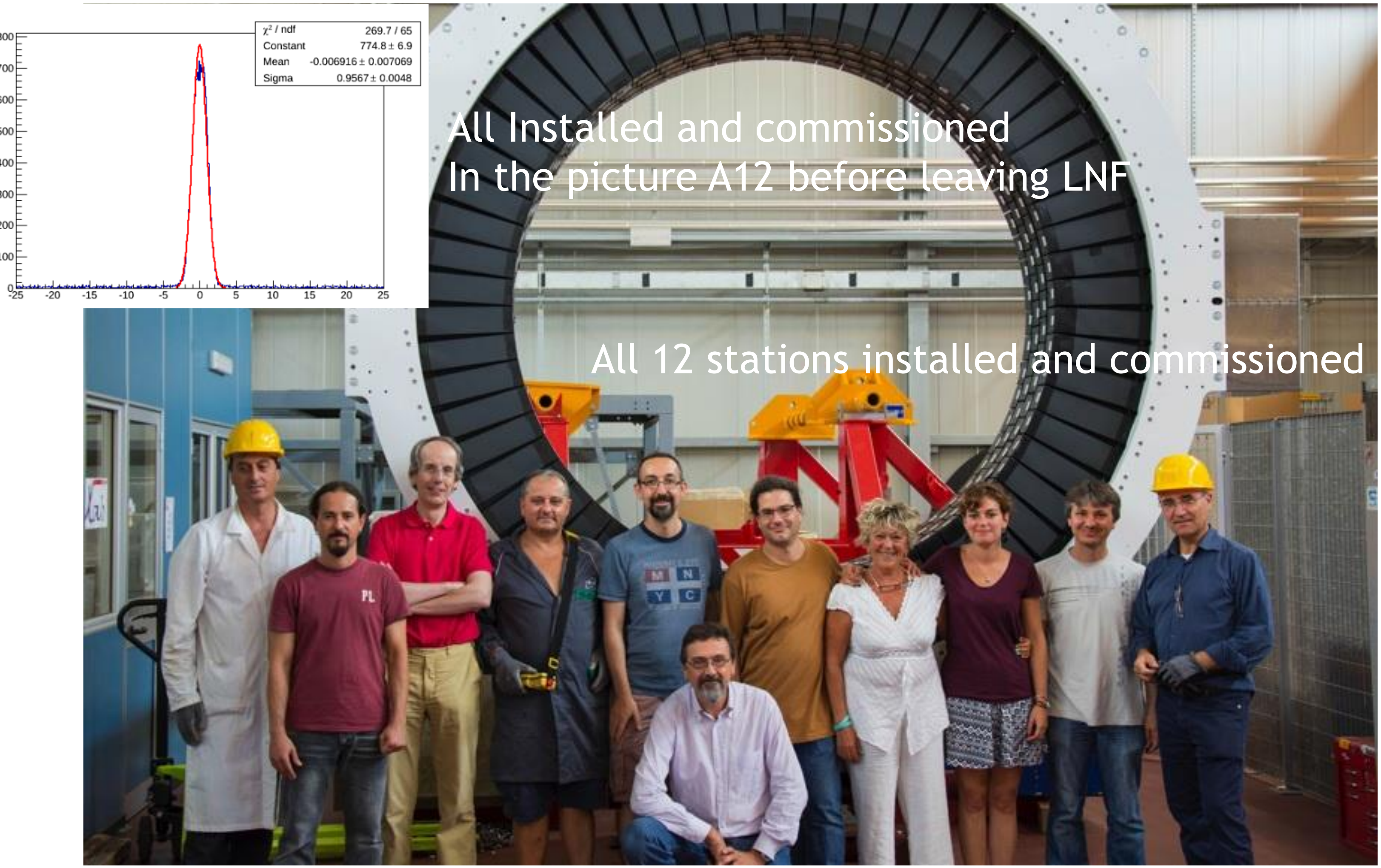
- The purpose of the CHANTI is to identify inelastic interactions occurring in the GTK3
- Six stations made by triangular scintillating bars read out via WLS fiber and SiPM
- 300 channels
- Installed and aligned to +/- 0.1 mm
- Typical rates O(10-100 kHz)/ch
- Very preliminary single hit time resolution (no single channel offset correction, no geometrical correction) = 1.4 ns







LARGE ANGLE VETOES (LAV)

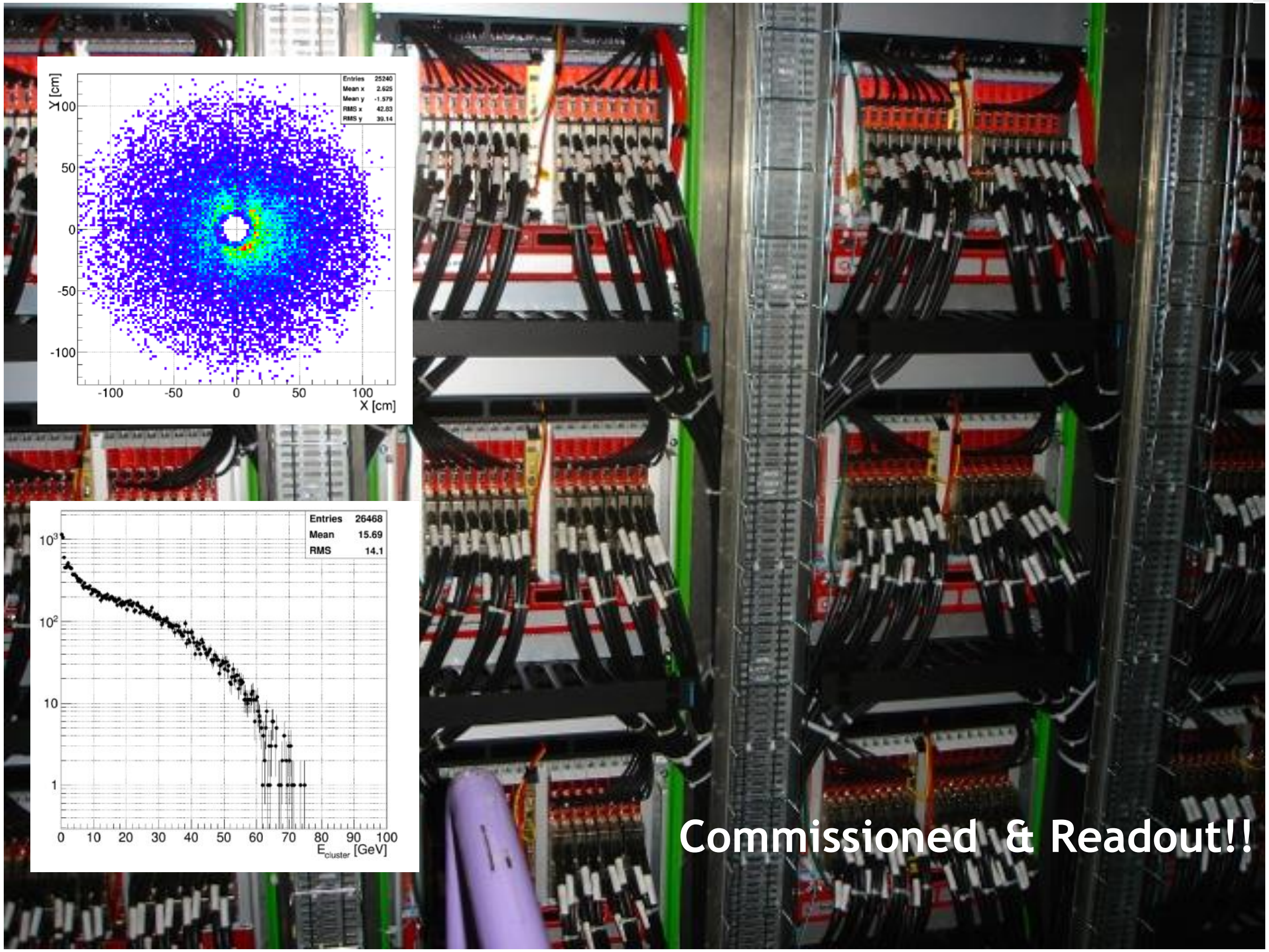


All Installed and commissioned
In the picture A12 before leaving LNF

All 12 stations installed and commissioned

Frascati, Naples, Pisa, Rome I

LIQUID KRYPTON READ OUT



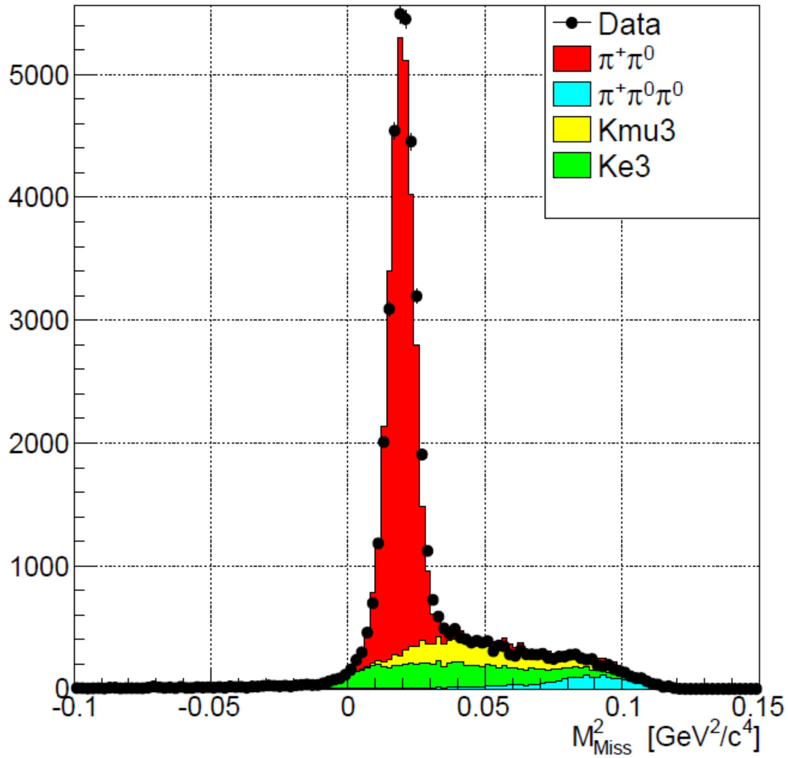
14 bit FADC, 40 Ms, 32 ch / module **432 modules, 28 VME crates**

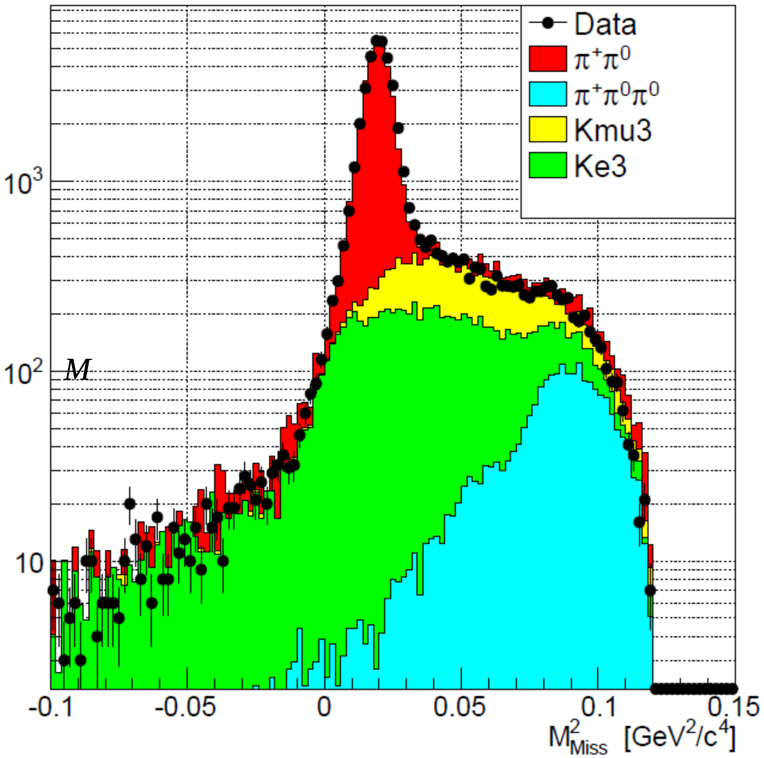
Specifications/Tender : CERN PH-ESE,PH-SME Manufacturer: CAEN (ITALY)

FIRST LOOK AT THE 2014 LKR DATA…

Squared missing mass spectrum

$M^2_{miss} = (P_{K+} - P_{\pi 0})^2$

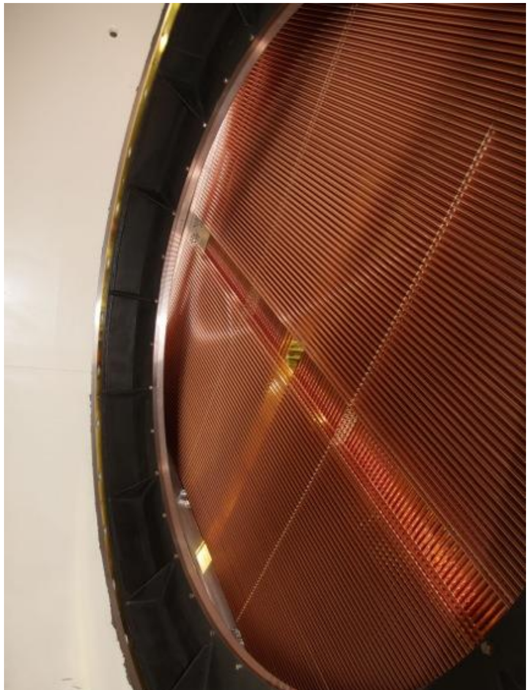


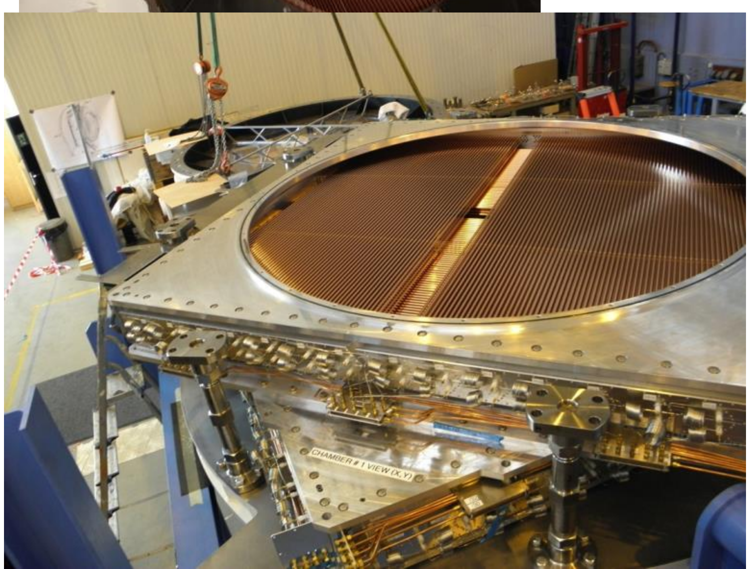


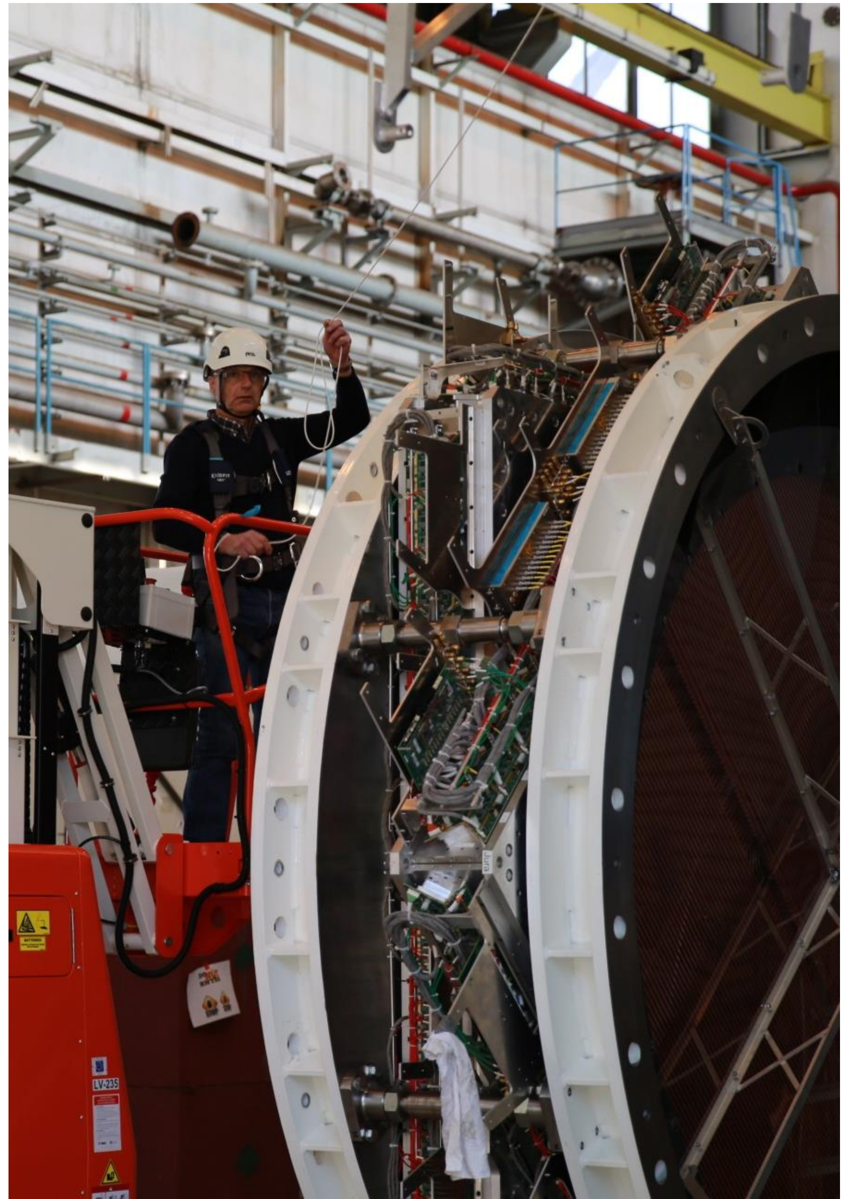
Not even Preliminary

NA62 STRAW TRACKER

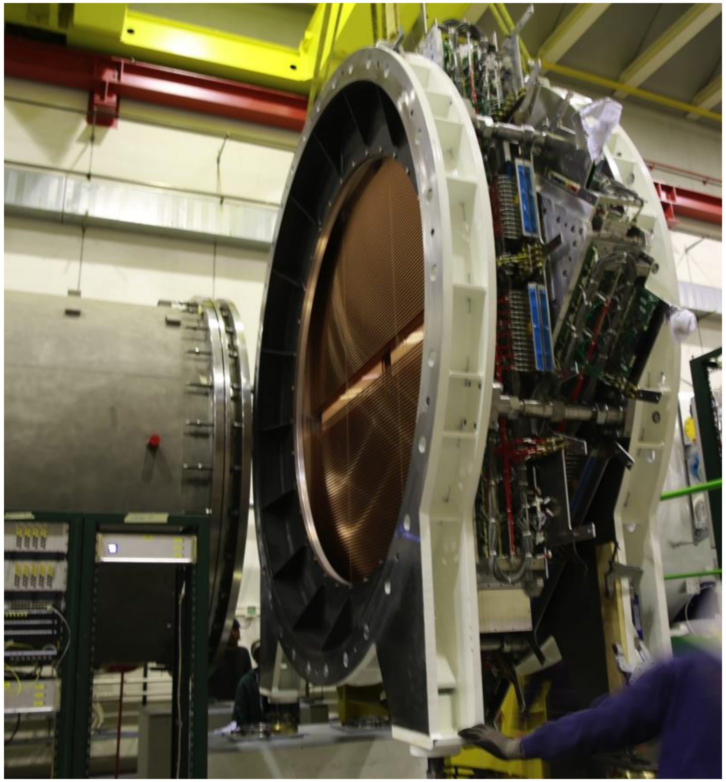
CERN (PH-DT, PH-ESE,PH-SME) – JINR

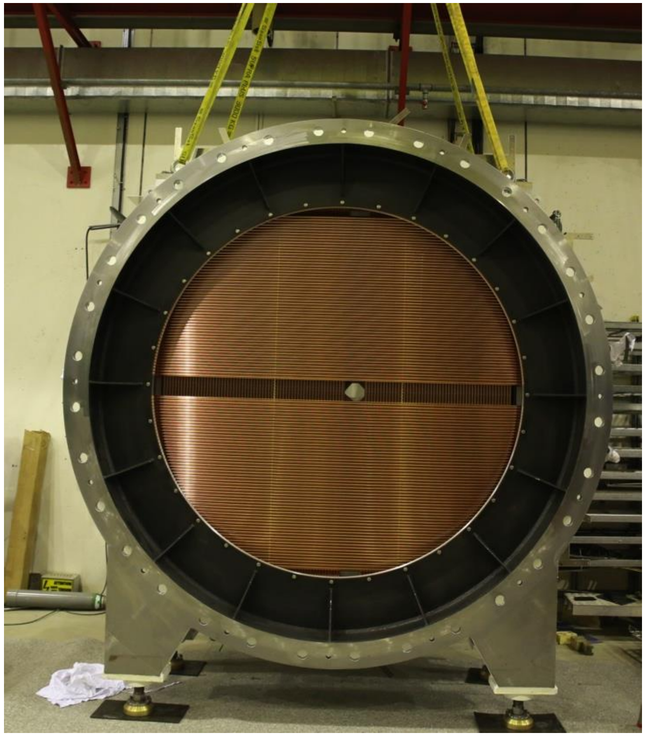






COMPLETION OF THE STRAWS

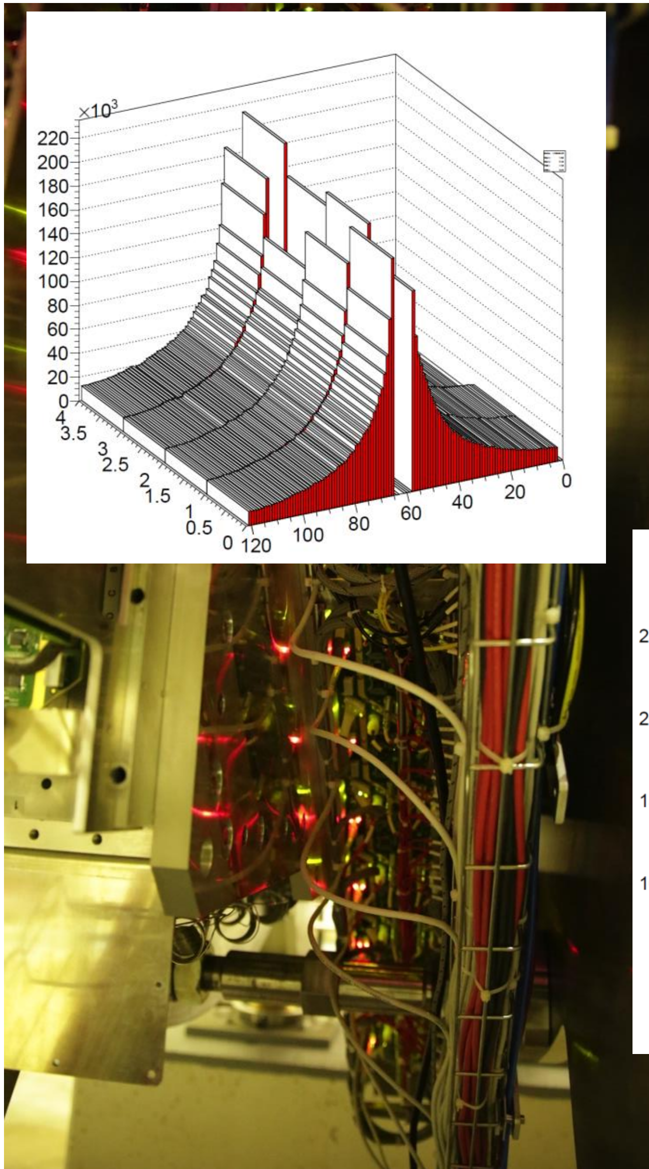




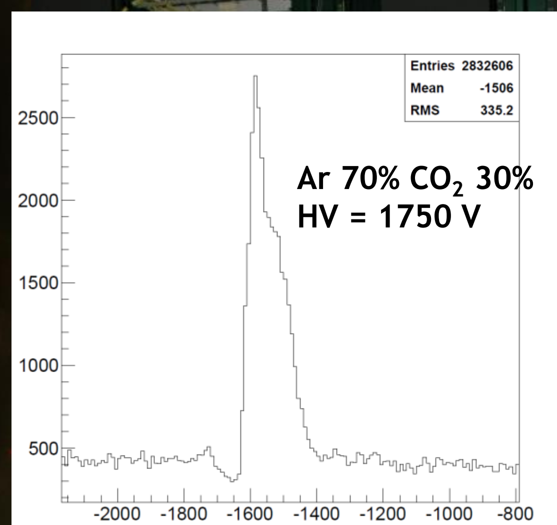
Number (Ch/Mod/ Coordinates)	Start of assembling	End of assembling	End of testing	Delivered to CERN	Assembling and testing time (months)
CH2 M1 U-V	**09.2012**	04.2013	10.2013	11.2013	14
CH2 M2 X-Y	07.2013	01.2014	02.2014	04.2014	8
CH4 M1 U-V	12.2013	02.2014	03.2014	04.2014	4
CH4 M2 X-Y	02.2014	05.2014	**06.2014**	07.2014	5

STRAW COMMISSIONING

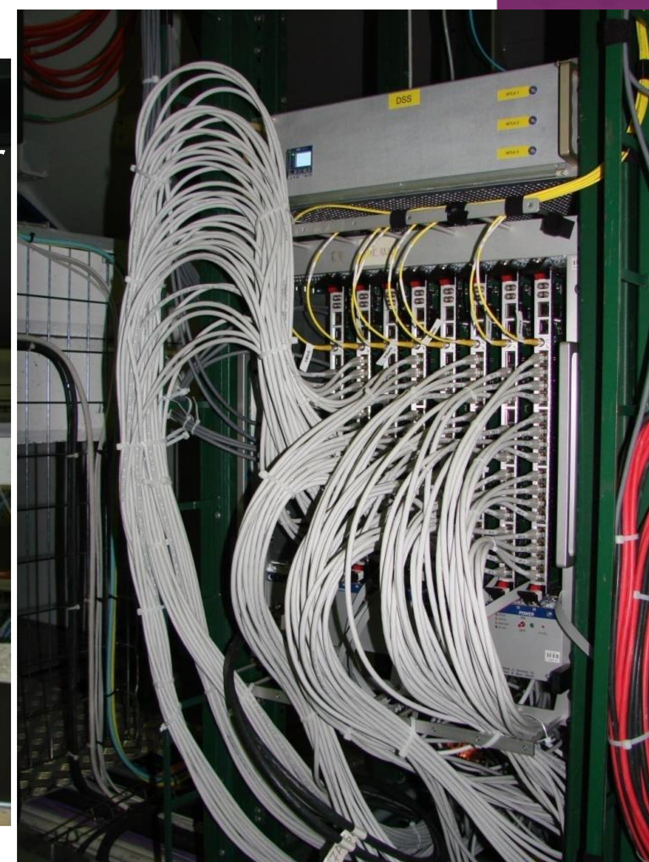
Full NA62 Straw Spectrometer installed and readout



Residual pressure in the Decay tank ~ 3 10^{-6} mbar

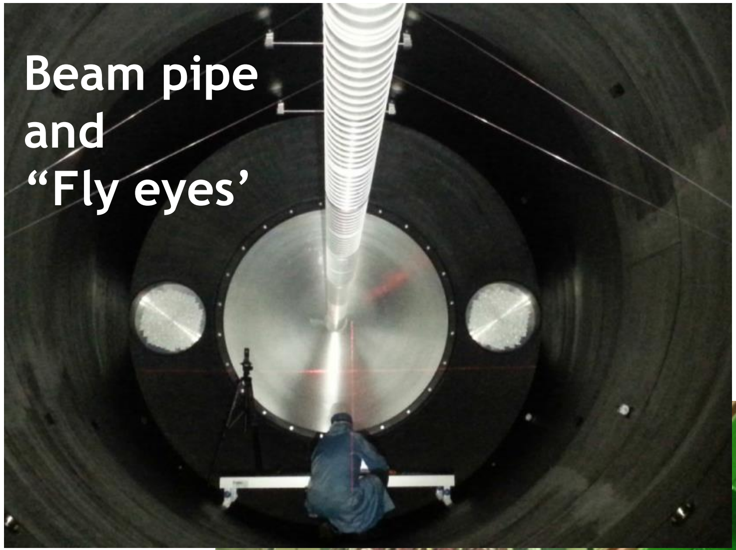


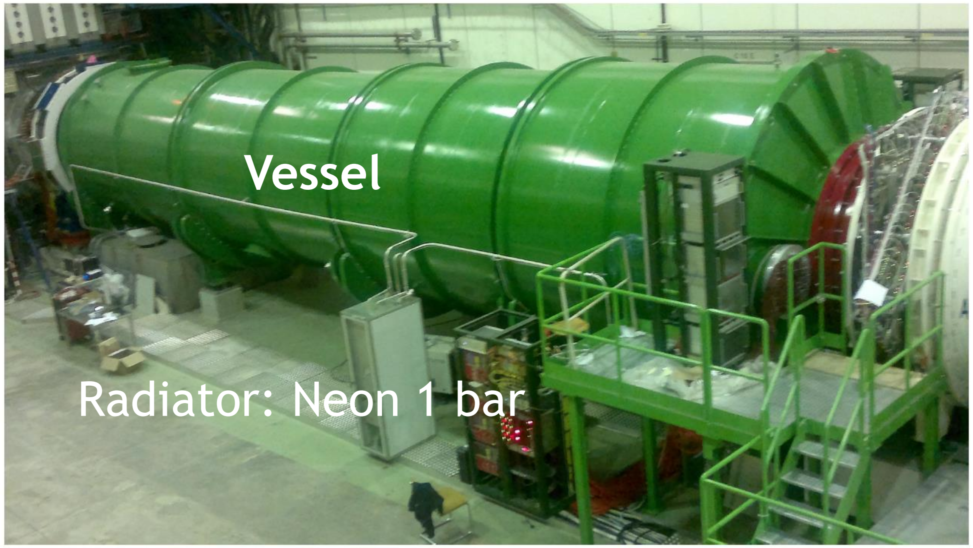
Raw Leading times (ns)

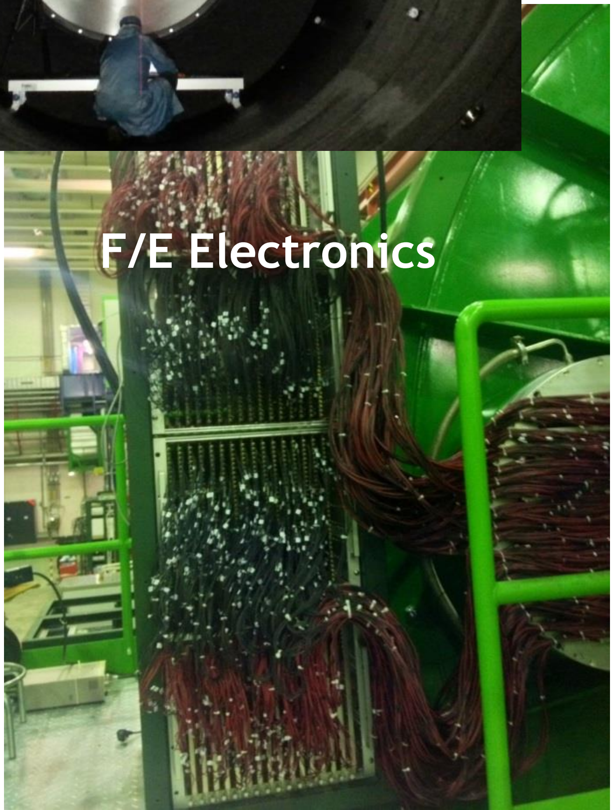


NA62 RICH

CERN (PH-DT,..), Firenze, Perugia

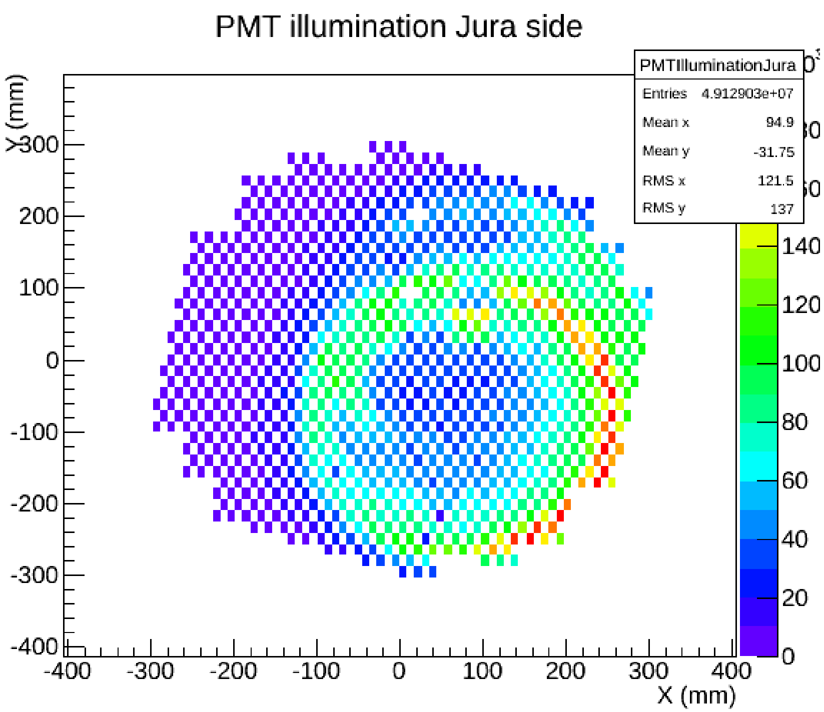


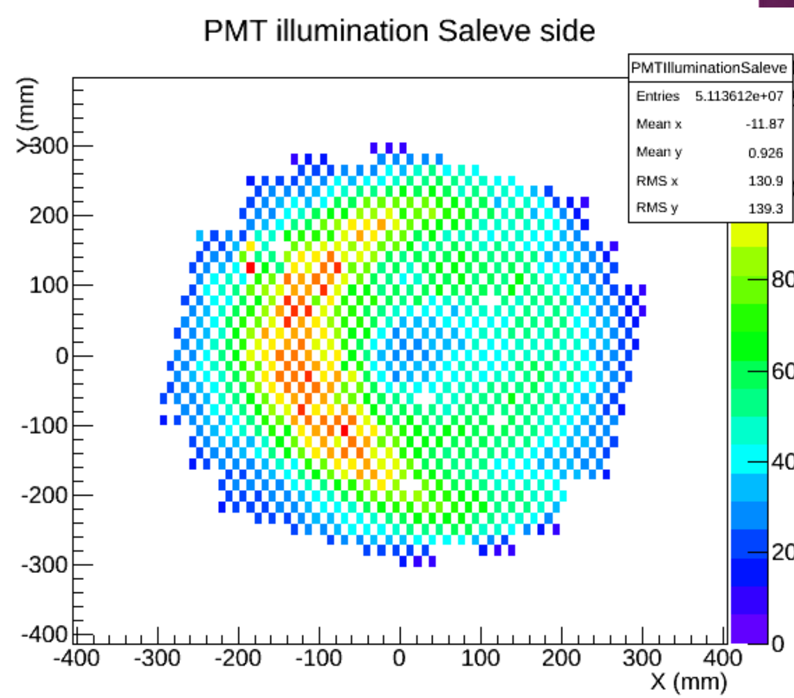




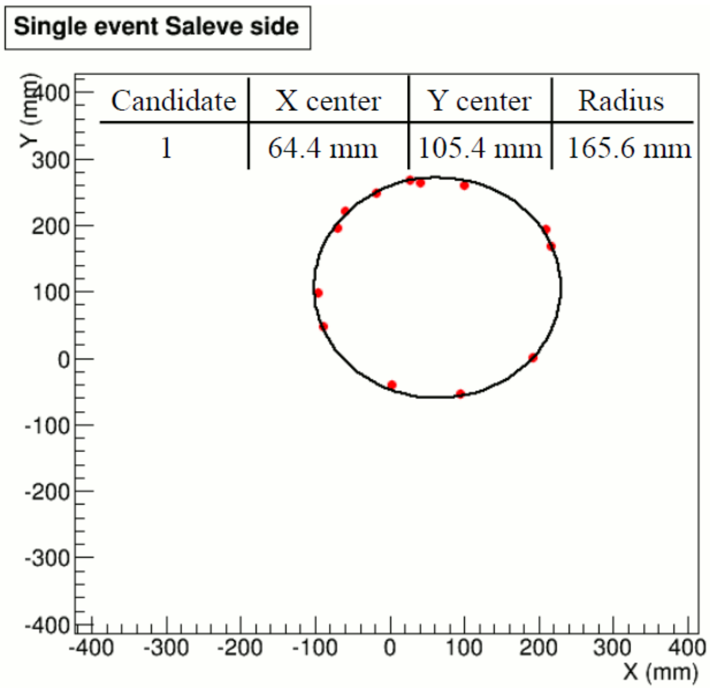
RICH COMMISSIONING

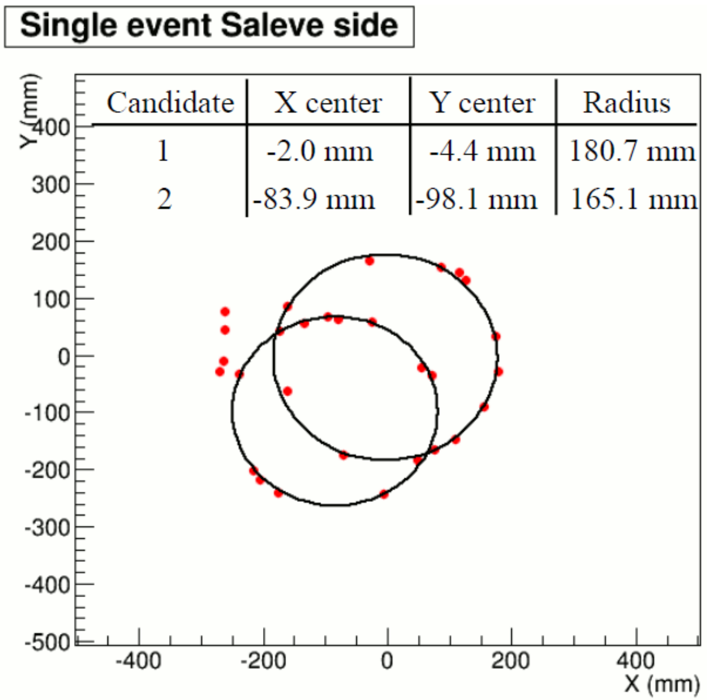
RUN 1068 (Q1×MUV3) 1170 bursts





RICH RINGS

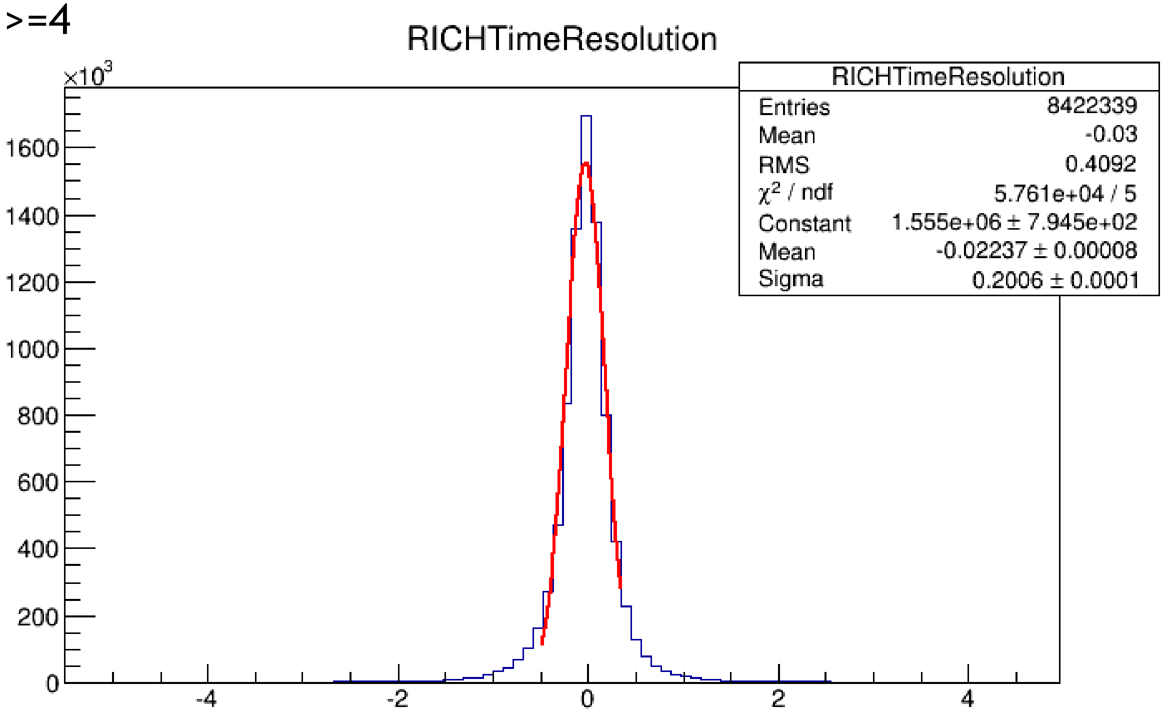

Single event Saleve side
Candidate | X center | Y center | Radius
1 | 64.4 mm | 105.4 mm | 165.6 mm
Y (mm)
X (mm)


Single event Saleve side
Candidate | X center | Y center | Radius
1 | -2.0 mm | -4.4 mm | 180.7 mm
2 | -83.9 mm | -98.1 mm | 165.1 mm
Y (mm)
X (mm)

RICH TIME RESOLUTION (PRELIMINARY)

For each event, average time of half of the hits – average time of the other half σ = 200 ps = 2 * event time resolution

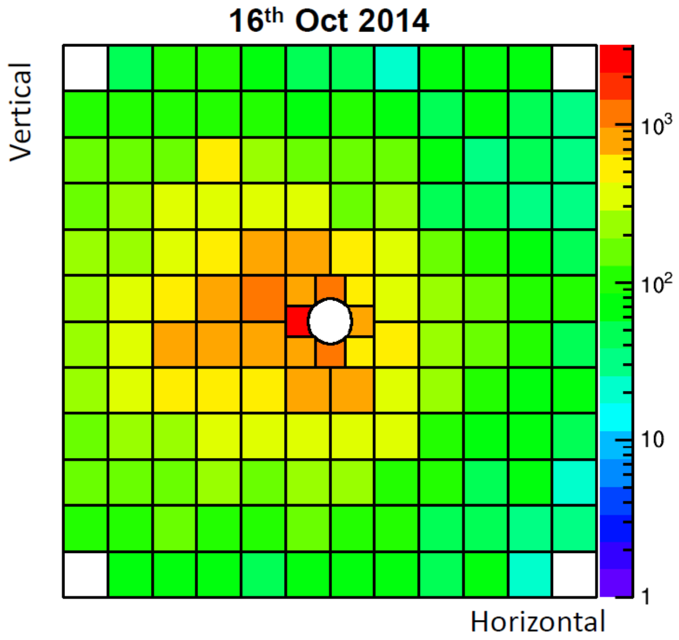
only cut: nHits >=4

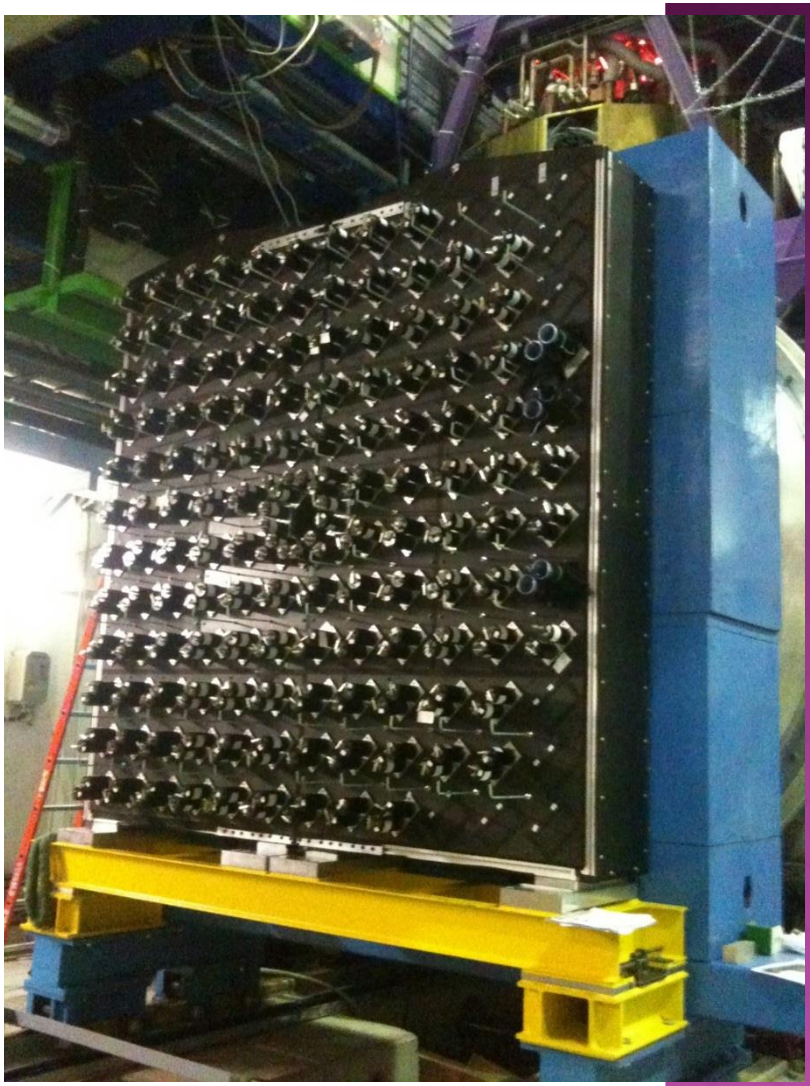


event time resolution = 100 ps

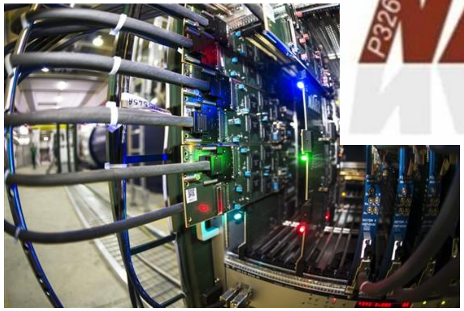
MUV3

- MUV3 already running in technical run 2012.
- Now: all scintillator tiles equipped with PMTs.
- Still old NA48-AKL CFD read-out → Will be renewed for 2015 run.



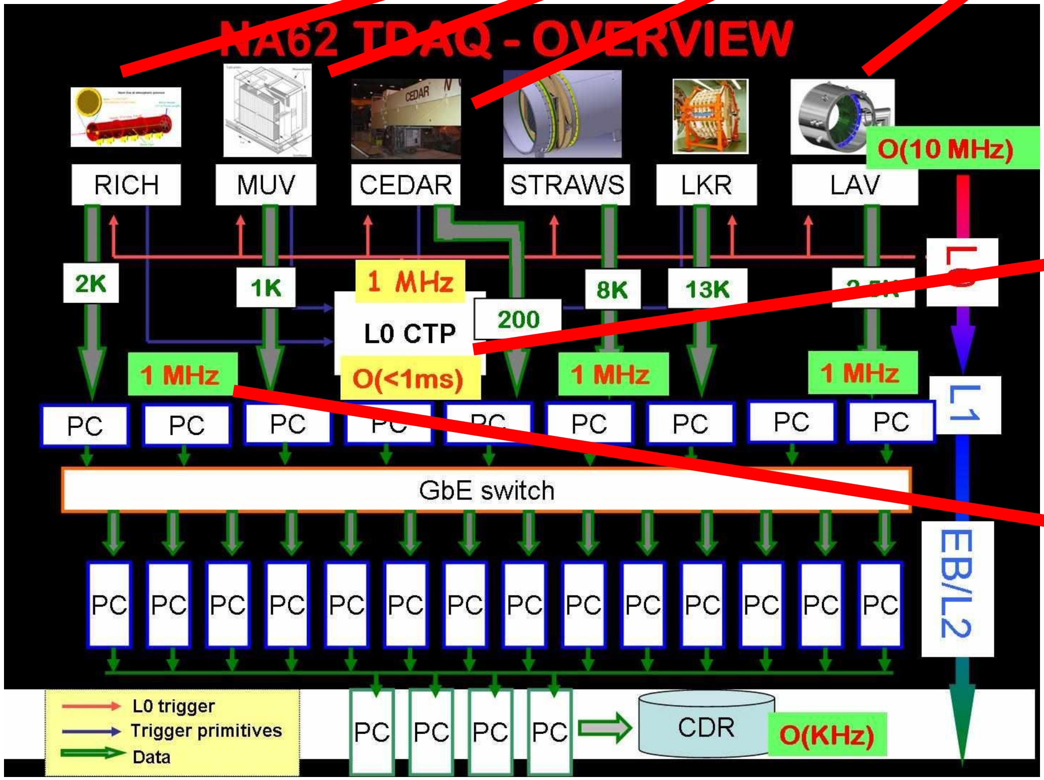


TRIGGER AND DATA ACQUISITION (TDAQ)

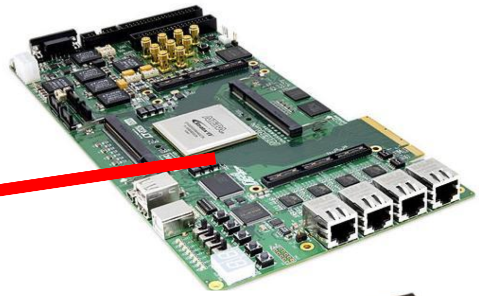


Key element for high-rate rare decay search

Several innovative solutions



Full-digital integrated L0 hardware trigger on 10 MHz main data to 1 MHz readout

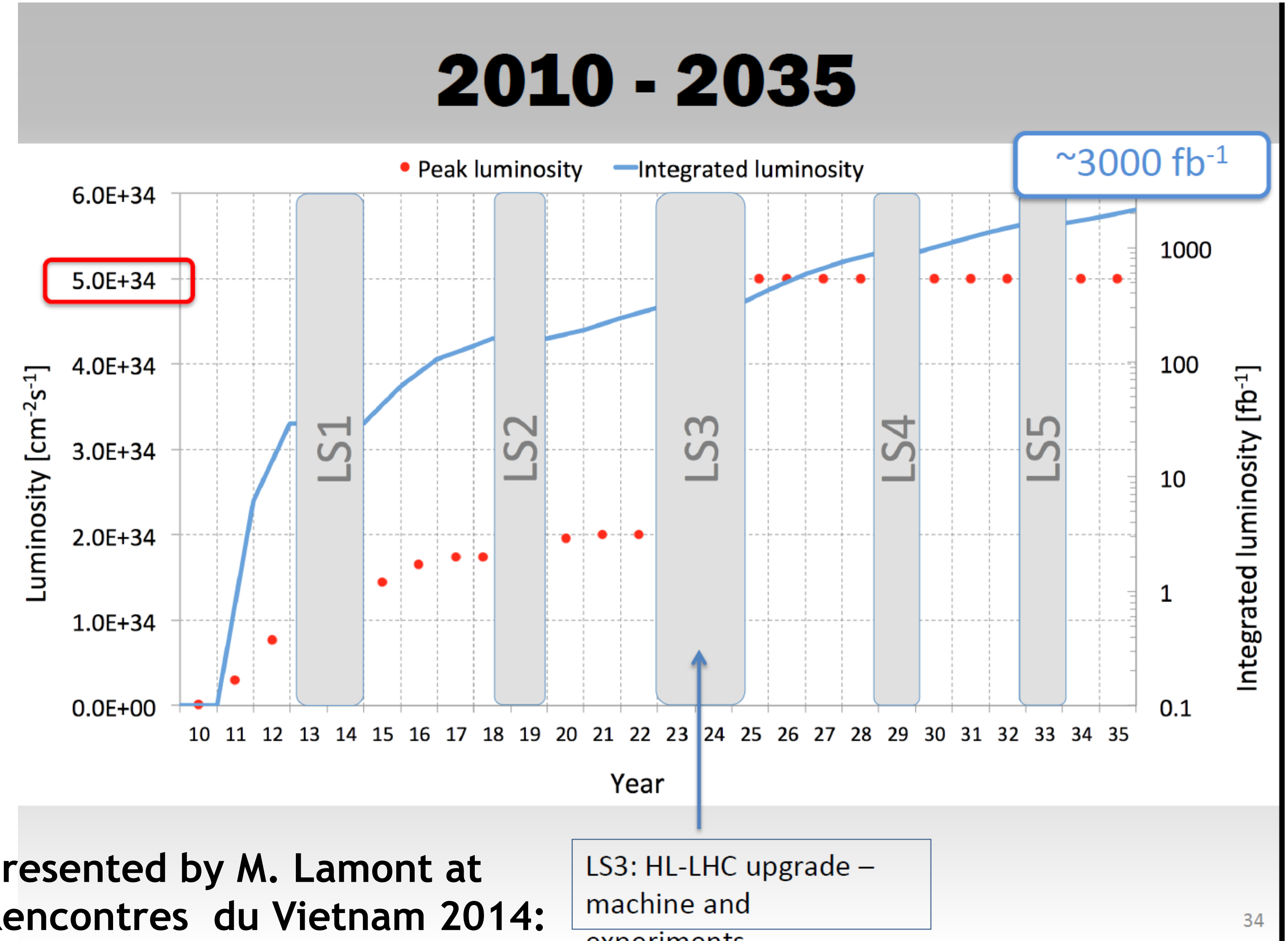


First test of real time use of GPUs in hardware trigger

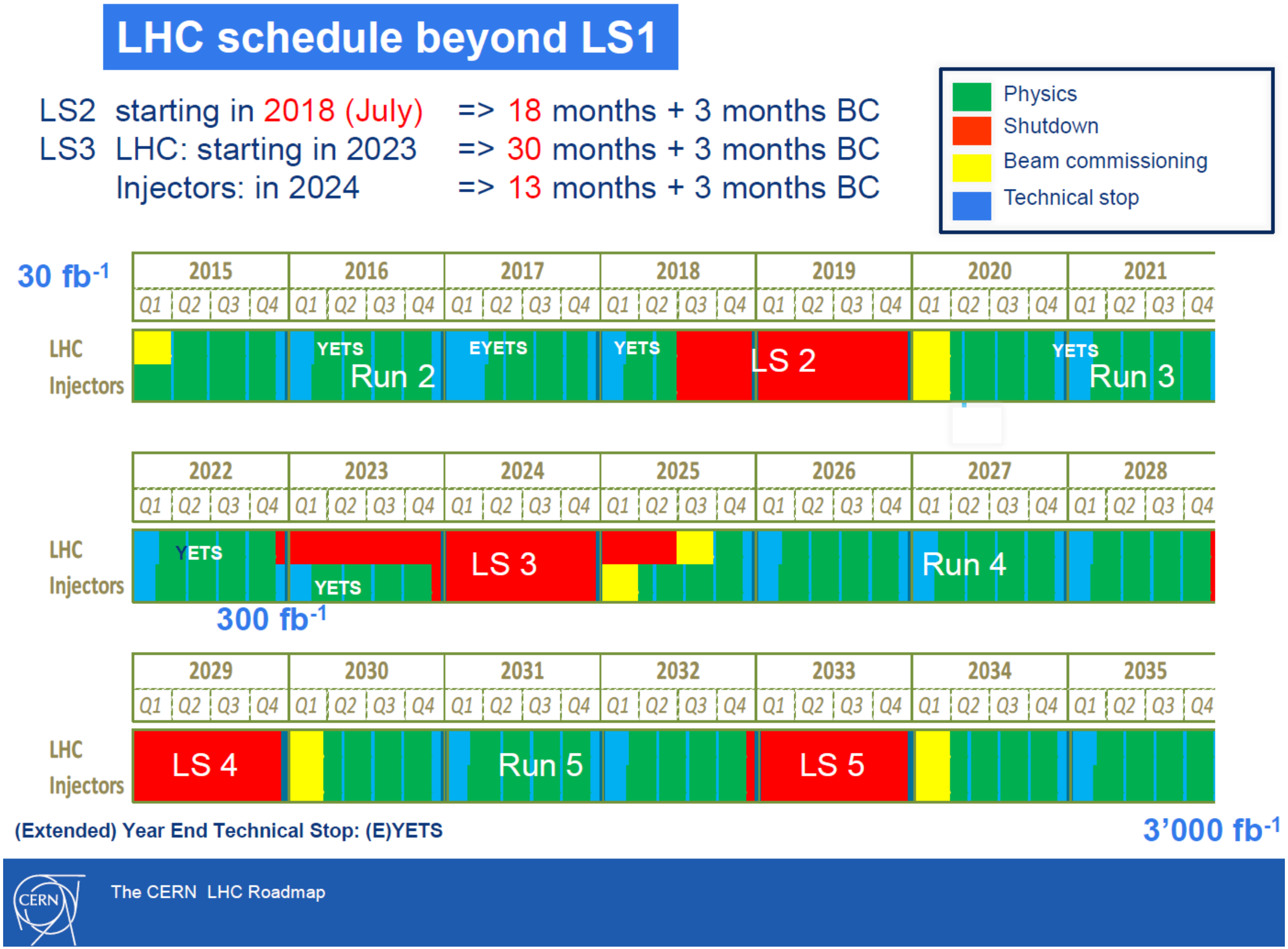
STATUS OF NA62: OUTLOOK

- The baseline detector is being commissioned with beam
- With NA62 starting, CERN is again exploring the Standard Model using high intensity Kaon beams. This newly built apparatus is an attractive long-term facility to search for new physics
- Accumulate and analyze $O(10^{13})$ good kaon decays before Long Shutdown 2 (LS2)
- Evaluate ultimate reach

LHC FUTURE RUNNING



Presented by M. Lamont at Rencontres du Vietnam 2014: Physics at LHC and beyond



Availability of the LHC injectors (R. Heuer, March 2014 Council)

A NICE INTERPLAY BETWEEN KAONS AND BEES IN THE SM

$$\frac{\Gamma(K_L^0 \to \pi^0 \nu\bar{\nu})}{\Gamma(K_S^0 \to \pi^0 \nu\bar{\nu})} = \tan^2(\beta - \beta_s)$$

$$\frac{\Gamma(K_L^0 \to \pi^0 \nu\bar{\nu})}{\Gamma(K^+ \to \pi^+ \nu\bar{\nu})} = r_{is} \sin^2(\beta - \beta_s)$$

Summary: Outlook in 2025

New physics at LHC	**No new physics at LHC**
Explore flavor structure of "new" SM	Explore extremely high mass scales with indirect probes

Either way, $K_L \to \pi^0 \nu\bar{\nu}$ will still be quite interesting!

In 2025, the experimental situation will have progressed:

- NA62 may have BR($K^+ \to \pi^+ \nu\bar{\nu}$) to < 5%
- KOTO will have evidence for $K_L \to \pi^0 \nu\bar{\nu}$ events
- KOTO-2 will be starting up with 10 event/sly sensitivity

Will a 100-event $K_L \to \pi^0 \nu\bar{\nu}$ experiment at CERN be in the works?

- At an upgraded T10 facility using NA62 infrastructure?
- At a new high-intensity facility at PS or SPS?
- As part of an FCC injector upgrade?

More questions than answers, but a 100 event $K_L \to \pi^0 \nu\bar{\nu}$ experiment is surely a worthwhile endeavor!

Time to look forward!!

FLAVOUR: INTERPLAY OF THEORY, EXPERIMENTS AND ACCELERATORS

- Effective theories, Lattice QCD, phenomenology, exclusive decays
- Flavour “factories”
- CKM trigonometry
- FCNC, Rare decays, CP-Violation
- Maximal Flavour Conservation (or Minimal Flavour Violation)
- Yukawa couplings of the Higgs, masses of fermions

- **…Pipeline full for ten exciting years at least!**
- **A.D. circa 2025: Crossroad for Flavour Physics**