CKM2016

9th International Workshop on the CKM Unitarity Triangle

TIFR, Mumbai

Nov. 28 – Dec. 2, 2016

Kaon Experiments

Augusto Ceccucci/ CERN

More *K* experiments than you think

- This presentation is an adapted (and shorter!) version of my "Experimental Summary" at KAON2016 Birmingham (UK), September 17, 2016
- Check here for references and credits: **KAON2016**
- I thank all the speakers and experiments, apologies for the many interesting results I cannot mention here because of time
- Kaon Physics includes many subjects, topics relevant to this workshop include, for instance:
  - Leptonic and Semi-leptonic Decays **(V_{us}, lepton universality)**
  - Very rare FCNC decays **(V_{td}, Physics beyond SM)**
- CP Violation in kaons (epsilon, epsilon') is very well measured experimentally, the onus is on the theory side to make the best use of these observables, I will not review these topics **(there is hope, see next slide)**

Re(Epsilon'/Epsilon)

***CP*-violation parameters** [ff] **PDG2016**

$A_L = (0.332 \pm 0.006)\%$

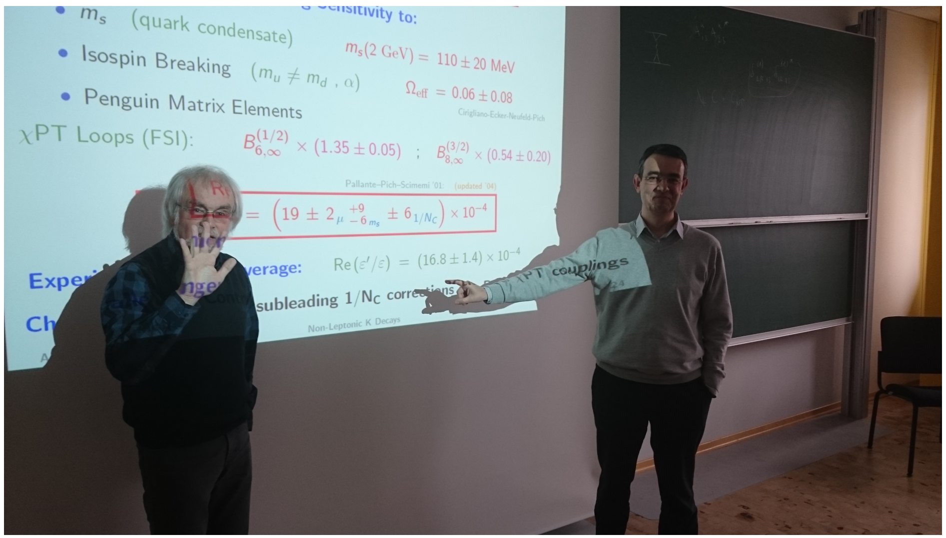
$|\eta_{00}| = (2.220 \pm 0.011) \times 10^{-3}$ (S = 1.8)

$|\eta_{+-}| = (2.232 \pm 0.011) \times 10^{-3}$ (S = 1.8)

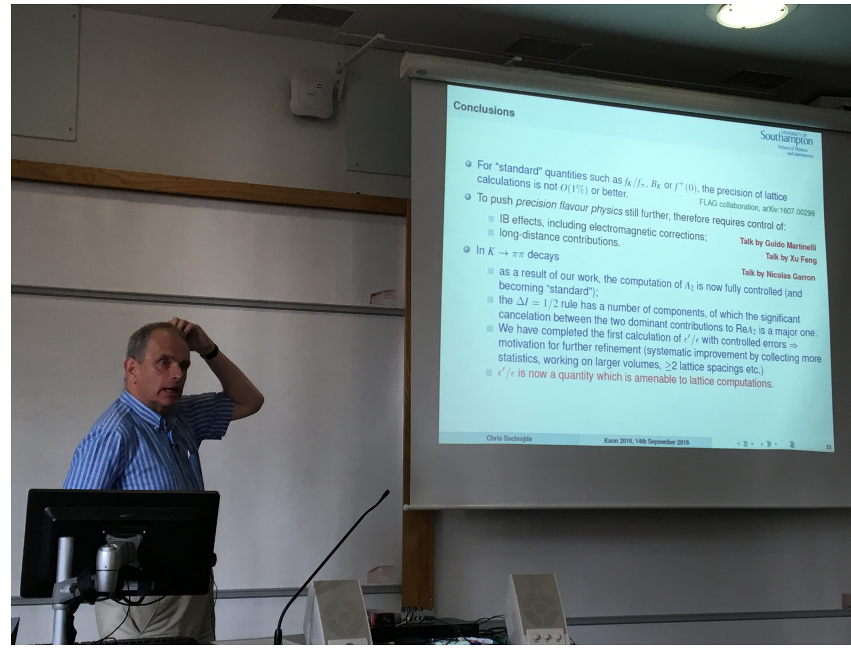
$|\epsilon| = (2.228 \pm 0.011) \times 10^{-3}$ (S = 1.8)

$|\eta_{00}/\eta_{+-}| = 0.9950 \pm 0.0007$ [ii] (S = 1.6)

$\mathrm{Re}(\epsilon'/\epsilon) = (1.66 \pm 0.23) \times 10^{-3}$ [ii] (S = 1.6)



A. Buras and T. Pich, MITP Mainz, "NA62 Physics Handbook"



C. Sachraida, Kaon2016:
"ε'/ε is now a quantity which is amenable to lattice calculations"

SM Prediction: 1, 5 or 19x10^{-4} ??

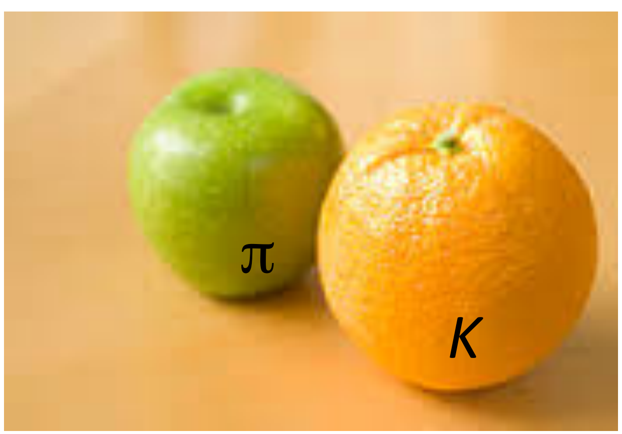
Leptonic & Semi-leptonic

Leptonic Decays & V_{us}

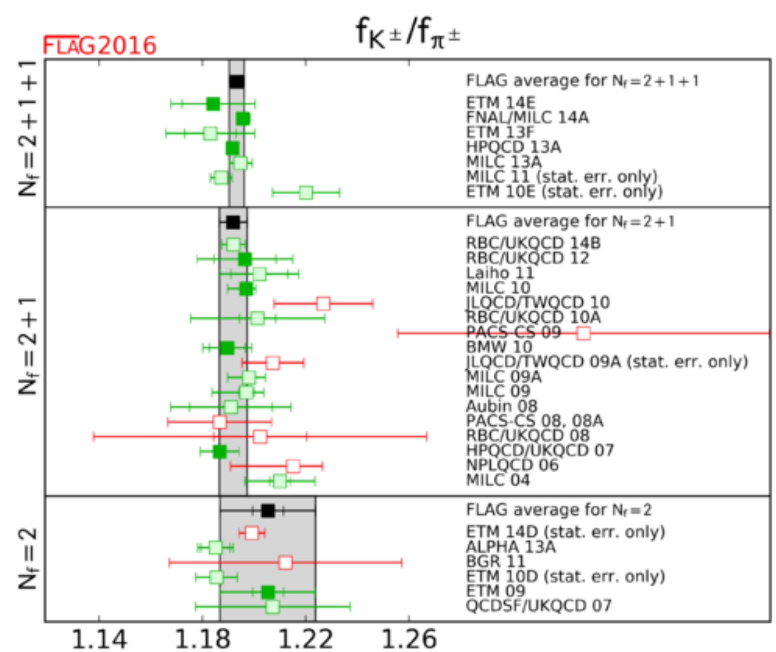
$$\frac{\Gamma(K \to \ell \bar{\nu}_\ell)}{\Gamma(\pi \to \ell \bar{\nu}_\ell)} = \left(\frac{|V_{us}|}{|V_{ud}|}\right)^2 \left(\frac{f_K}{f_\pi}\right)^2 \frac{m_K \left(1 - \frac{m_\ell^2}{m_K^2}\right)^2}{m_\pi \left(1 - \frac{m_\ell^2}{m_\pi^2}\right)^2} \left[1 + \frac{\alpha}{\pi}(C_K - C_\pi)\right]$$

Typical experimental input
(Blucher and Marciano, PDG2016)

$$\frac{\Gamma(K \to \mu\nu(\gamma))}{\Gamma(\pi \to \mu\nu(\gamma))} = 13367(29)$$



Typical theoretical input (FLAG2016)



V_{us} from semileptonic K decays

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

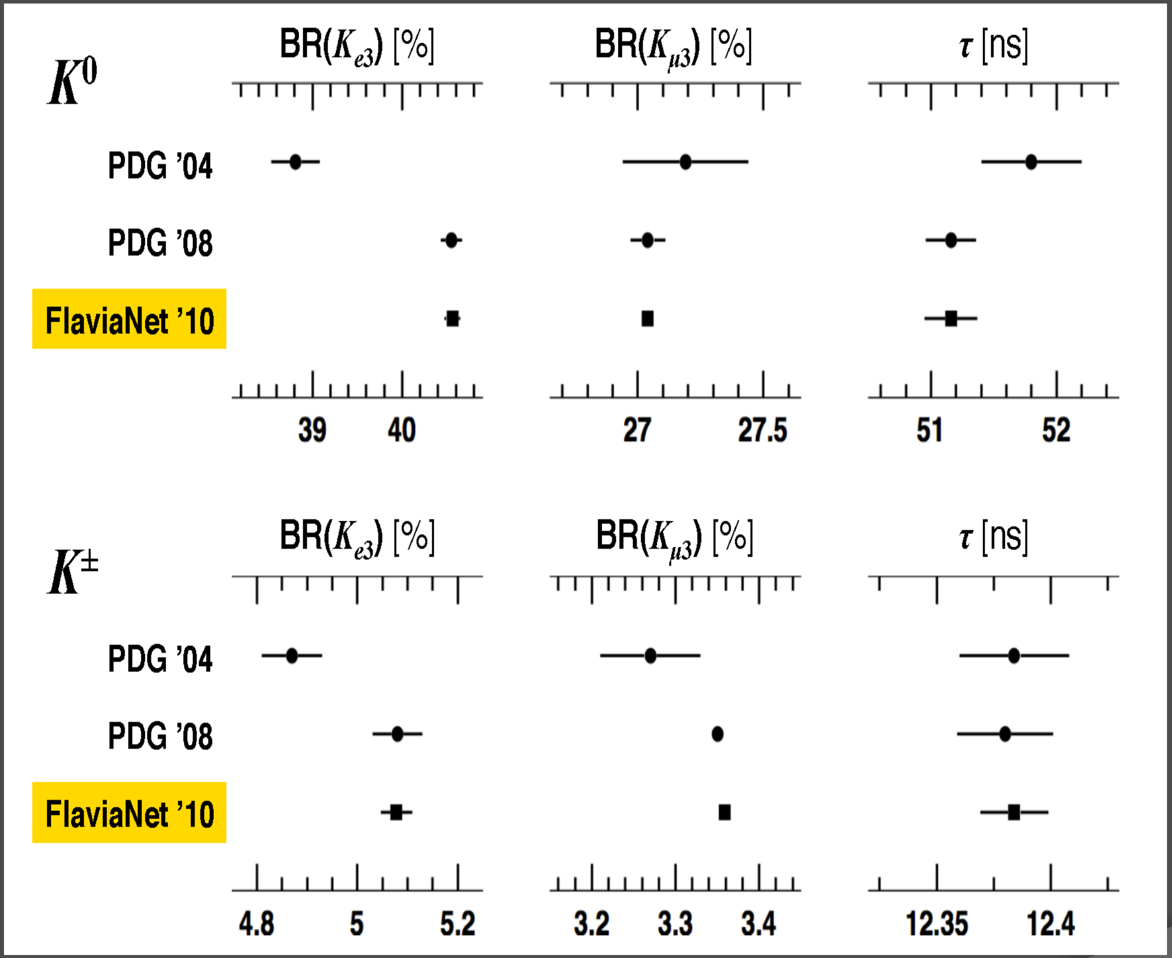
with $K \in \{K^+, K^0\}$; $\ell \in \{e, \mu\}$, and:

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

S_{EW} Universal SD EW correction (1.0232)

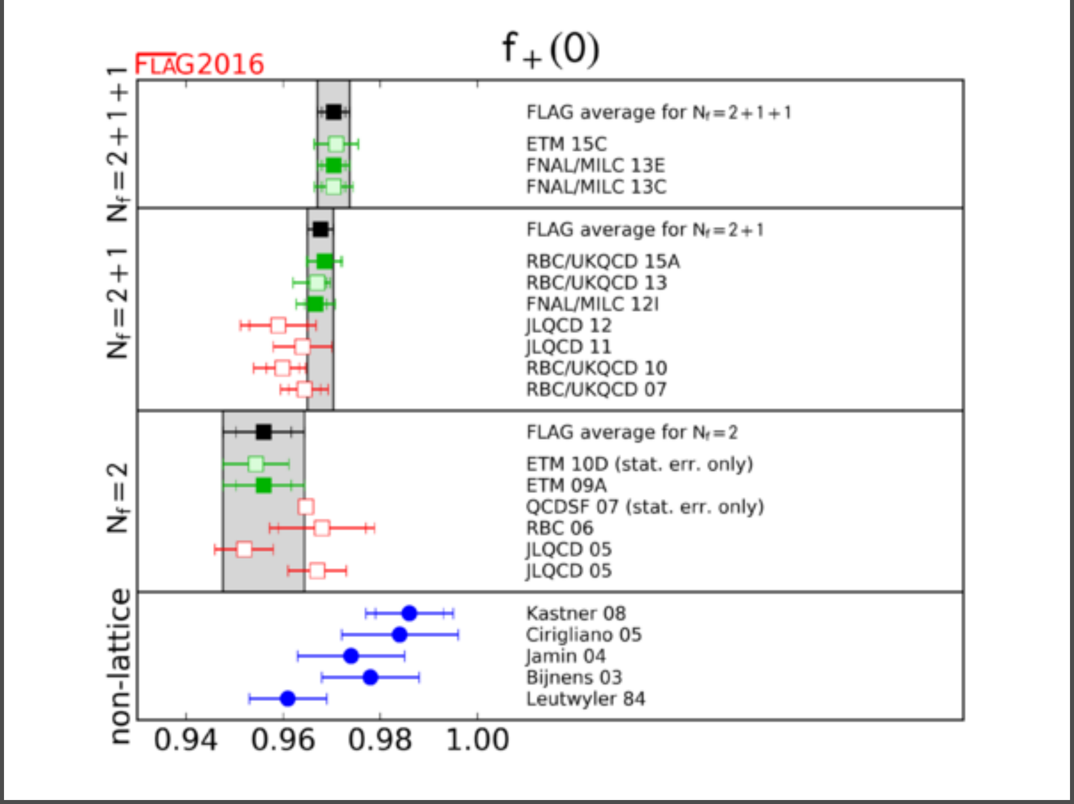
Input from Experiment		Input from Theory	
$\Gamma(K_{\ell 3(\gamma)})$	Rates with well determined radiative corrections	$f_+^{K0\pi^-}(0)$	Hadroni matrix element (form factor) at zero momentum transfer (t =0)
	•Branching Ratios	$\Delta_K^{SU(2)}$	Form factor correction for SU(2) breaking
	•Lifetimes		
$I_{K\ell}(\{\lambda\}_{K\ell})$	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_+'')		
	•$K_{\mu 3}$: Need λ_+ and λ_0		

Evolution of Experimental Input…

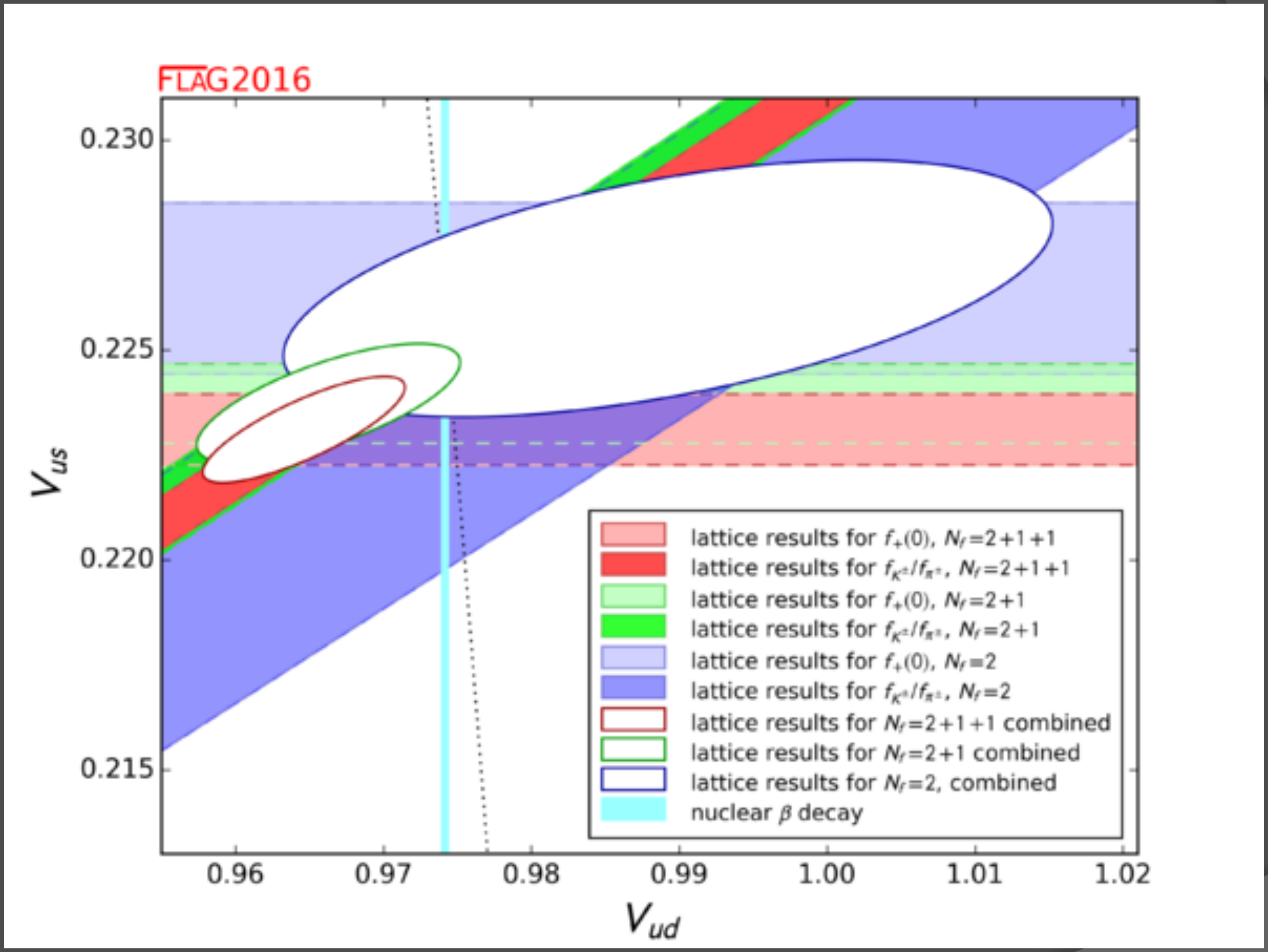


"V_{us} Revolution" with experimental input changing ~ 5% in some cases…..
Input from many experiments: **BNL865, KTeV, ISTRA+, KLOE, NA48, NA48/2**

...and of the Semi-leptonic Form-factor Calculation



Remarkable theoretical progress justifies the renewed experimental effort



Textbook example of interplay between theory and experiments

DAΦNE run with KLOE-2

After upgrade of several accelerator components, DAΦNE started a stable run with KLOE-2 in novembre 2014, delivering up to now 3.0 fb^{-1} (2.4 acquired)

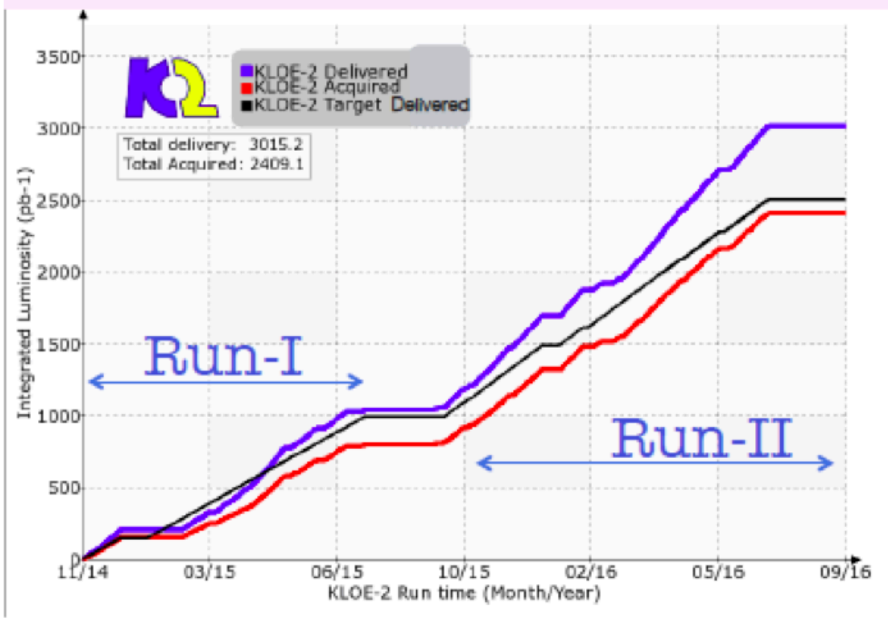
Peak Luminosity: **2.2 x 10^{32} cm^{-2} s^{-1}**

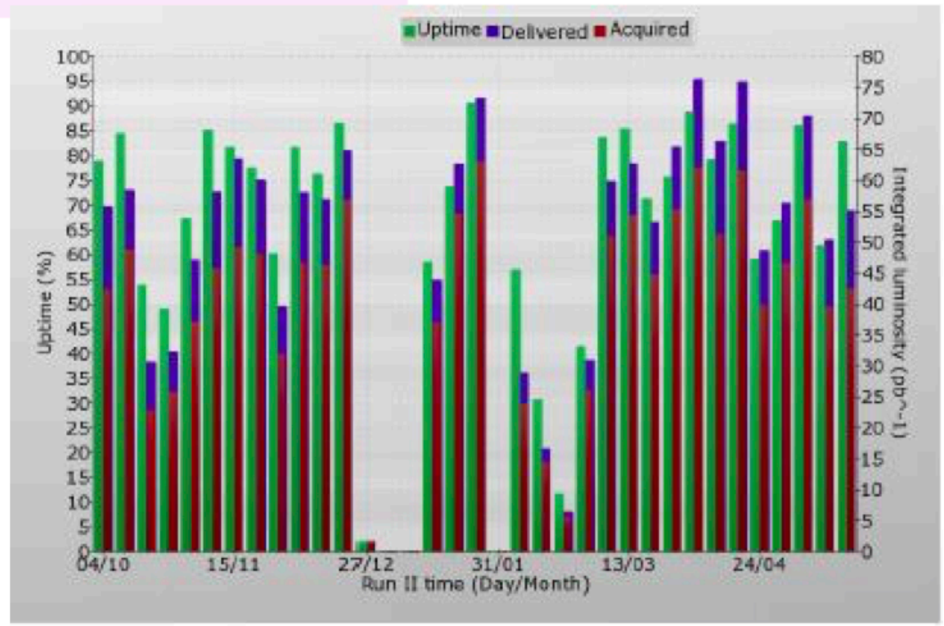
Best daily delivered integrated lumi: 13 pb^{-1} (11 acquired)

Average up-time : 80%

Expect to deliver another 3fb^{-1} by end of 2017.

Still room for improvement

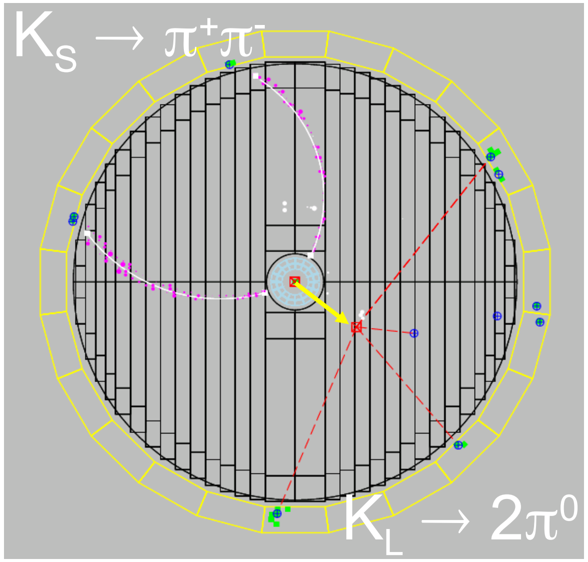


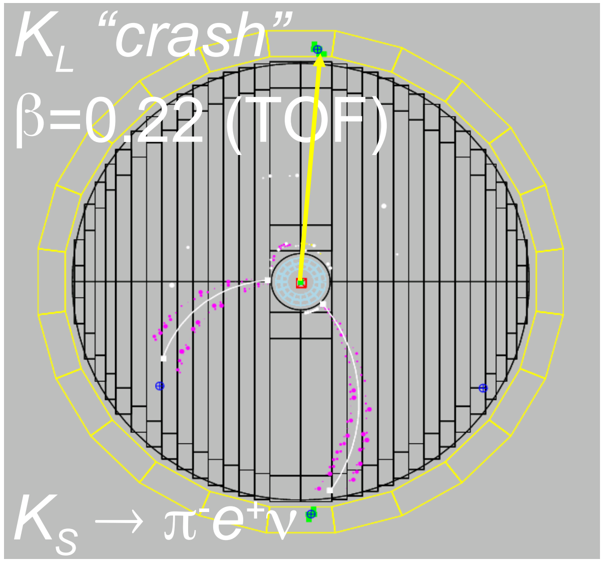


Unique Tagging Capability

Neutral kaons beams

UNIQUE





K_L tagged by
$K_S \to \pi^+\pi^-$ vertex at IP

K_S tagged by
K_L interaction in EmC

$f_+(0)|V_{us}|$

Present total error:

- value from KLOE	0.28%	*JHEP 0804 (2008) 059*
- world average	0.19%	
Expected at KLOE-2 with 5fb^{-1}	0.14%	with world average

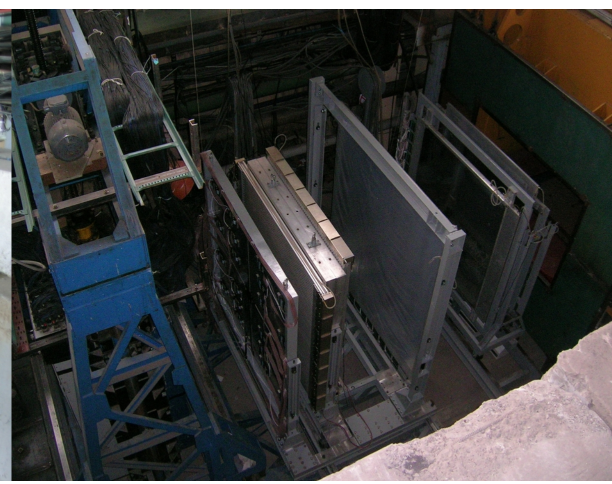
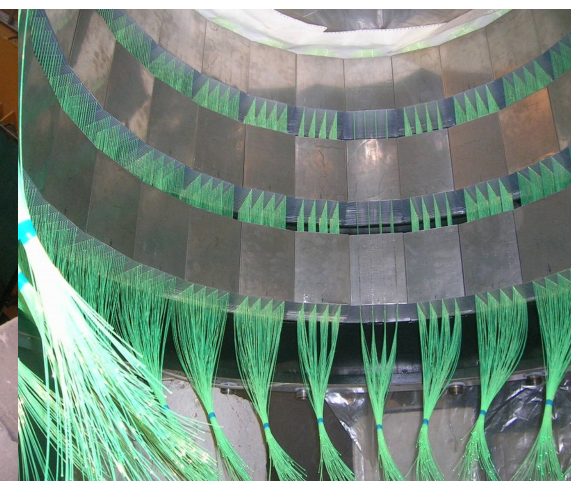
World average M.Moulson at CKM14

KLOE-2 prospects with 5fb^{-1}

	$f_+(0)\|V_{us}\|$	%err	BR	τ	δ	I_{Kl}	%err	BR	τ	δ	I_{Kl}
K_Le3	0.2163(6)	0.26	0.09	0.20	0.11	0.05	**0.20**	0.09	0.13	0.11	0.06
$K_L\mu3$	0.2166(6)	0.28	0.15	0.18	0.11	0.06	**0.24**	0.15	0.13	0.11	0.08
K_Se3	0.2155(13)	0.61	0.60	0.02	0.11	0.05	**0.32**	0.30	0.03	0.11	0.06
$K^\pm e3$	0.2172(8)	0.36	0.27	0.06	0.23	0.05	**0.48**	0.25	0.05	0.40	0.06
$K^\pm\mu3$	0.2170(11)	0.51	0.45	0.06	0.23	0.06	**0.48**	0.27	0.05	0.39	0.08
Aver	0.2165(4)	0.19					**0.14**				

OKA, IHEP Protvino

- RF separated K^+, up to 10^6 K/pulse, 20% purity
- Took data in 2010-2013, 1.34 x 10^8 $K \rightarrow \pi\pi$
- More data in Nov/Dec 2016

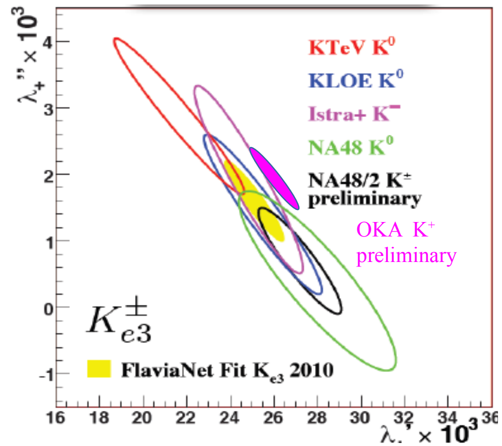




OKA Recent Results

K_{e3} Form Factors

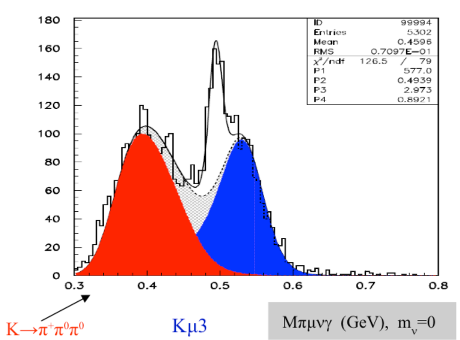
$\lambda'_+(\lambda_+)\times10^3$	$\lambda''_+\times10^3$	$F_S/f_+(0)\times10^2$	$F_T/f_+(0)\times10^2$
29.56±0.28			
26.1±0.45	1.94±0.24		
26.1±0.45	1.93±0.24	−0.44±0.7	0.16±2
26.1±0.45	1.93±0.24	−0.41±0.3	

Pole fit	Dispersive fit
M_v=890±3.7 MeV	Λ_+=(24.72±0.23)x10^{-3}



Radiative Corrections?

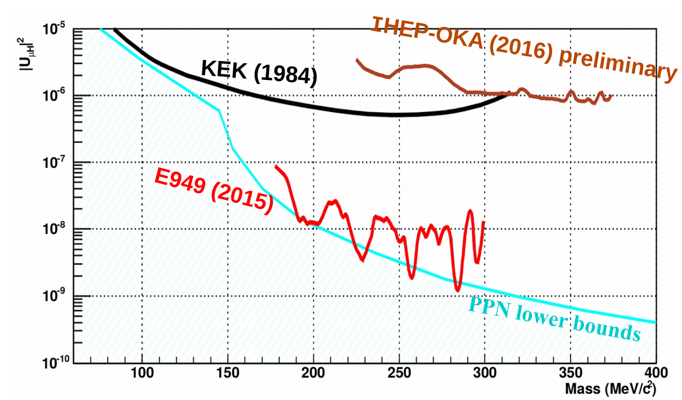
Radiative $K_{\mu3}$



R=Br(Kμ3γ, 30 <Eγ < 60 MeV)/Br(Kμ3) =
(4.85±0.2(stat)±0.5(syst)) ×10^{-4} R(O(p^4)) = 4.7×10^{-4}
T-odd asymmetry A_ξ= (−0.19±0.051±0.09) ~3 ×10^{-4}
Space asymm. A(cos$\theta^*_{\mu\gamma}$)=(0.61±0.05±0.1) ~0.05 ?

Heavy Neutrino Search

$K^+ \rightarrow \mu\nu_H$



Presented by V. Obraztsov @KAON2016

Possible Experimental Progress

- Improvements on the determinations of BRs and form factors
- KLOE2 to improve also determination of K^0_L lifetime
- K-tagging capability may pave the way to absolute BR measurements also in NA62
- Can one Measure K and π in the same experiment?

Lepton Flavour Violation & Lepton Universality

NA62 sensitivity for LFNV decays

NA62

Decays in FV in 2 years of data: 1×10^{13} K^+ decays; 2×10^{12} π^0 decays

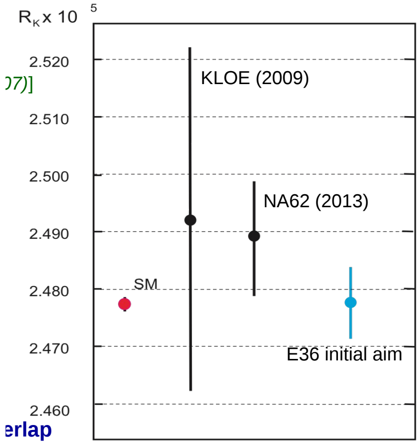
Single-event sensitivity 1/(decays × acceptance)

Mode	UL at 90% CL	Experiment	NA62 acceptance*
$K^+ \to \pi^+\mu^+e^-$	1.3×10^{-11}	BNL 777/865	~10%
$K^+ \to \pi^+\mu^-e^+$	5.2×10^{-10}	BNL 865	
$K^+ \to \pi^-\mu^+e^+$	5.0×10^{-10}	BNL 865	~10%
$K^+ \to \pi^-e^+e^+$	6.4×10^{-10}	BNL 865	~5%
$K^+ \to \pi^-\mu^+\mu^+$	1.1×10^{-9}	NA48/2	~20%
$K^+ \to \mu^-\nu e^+e^+$	2.0×10^{-8}	Geneva Saclay	~2%
$K^+ \to e^-\nu\mu^+\mu^+$	no data		~10%
$\pi^0 \to \mu^+e^-$	3.6×10^{-10}	KTeV	~2%
$\pi^0 \to \mu^-e^+$			

* From fast Monte Carlo simulation with flat phase-space distribution. Includes trigger efficiency.

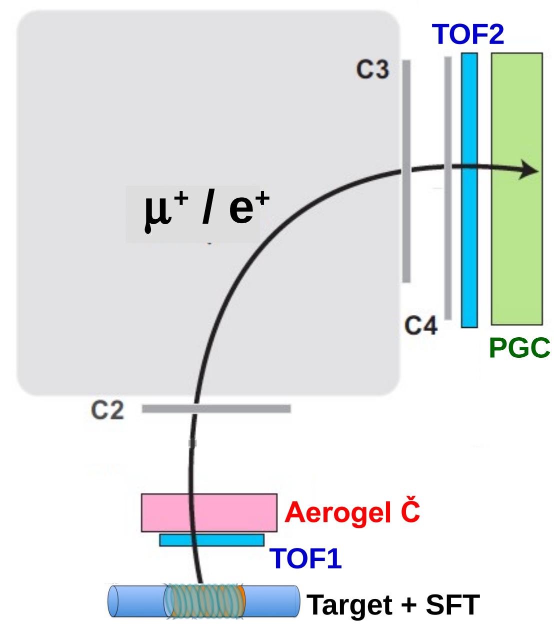
NA62 single-event sensitivities:
~10^{-12} for K^+ decays
~10^{-11} for π^0 decays

E36 @JPARC



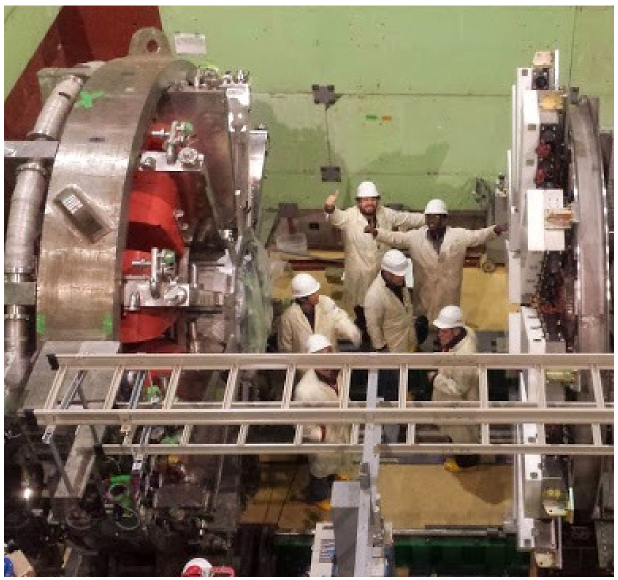
- TREK=
  - E06 (Time reversal in transverse muon polarization polarization, requires Hadron Hall extension)
  - **E36** (Lepton Universality, HNL, Dark Photons)
- Stopped Kaons decays,
  E36 aims to improve by a factor of 2 (**~0.25%**) the test of lepton universality in *K* leptonic decays
- K1.1BR Beamline (J-PARC)
- Expect **μ-e separation >>10^6** by TOF, Aerogel Cherenkov and kinematics

Bianchin



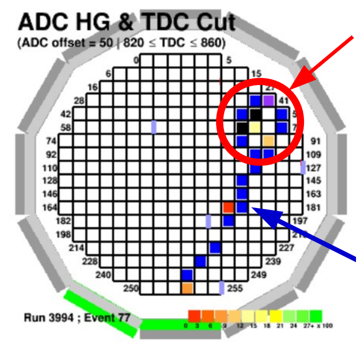
E06 Commissioning and Preliminary Results

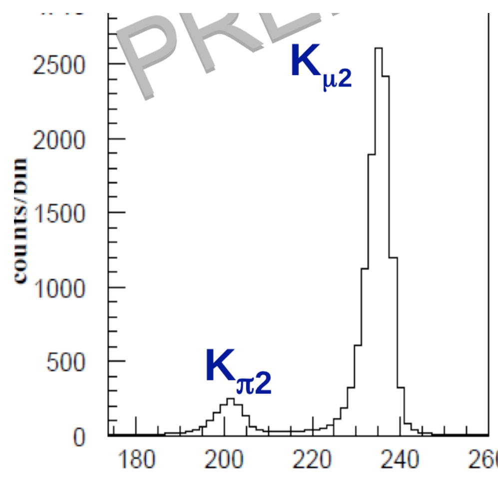
Detector with toroidal magnet

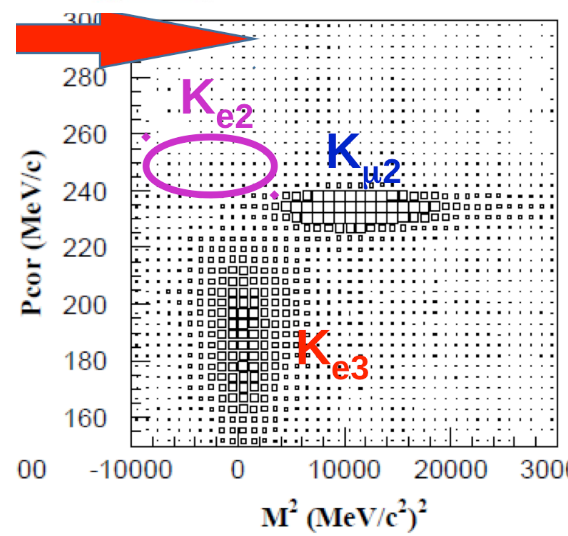


Nice data!

K-stop







Heavy Neutrinos, Dark Photons and other Exotics from Kaon Decays

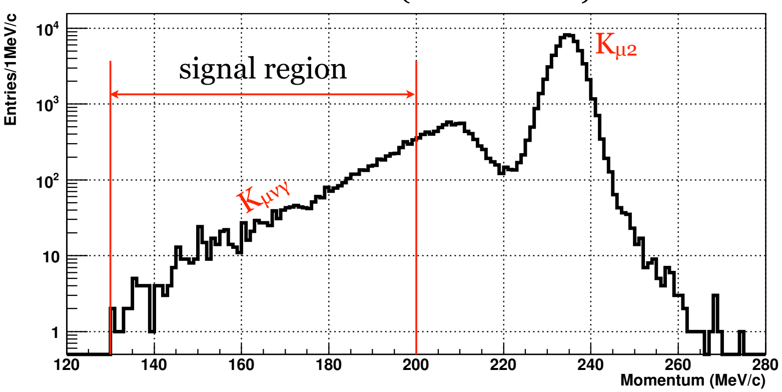
E949: $K^+ \rightarrow \mu^+ \nu_H$ and $K^+ \rightarrow \mu^+ \nu\nu\nu$

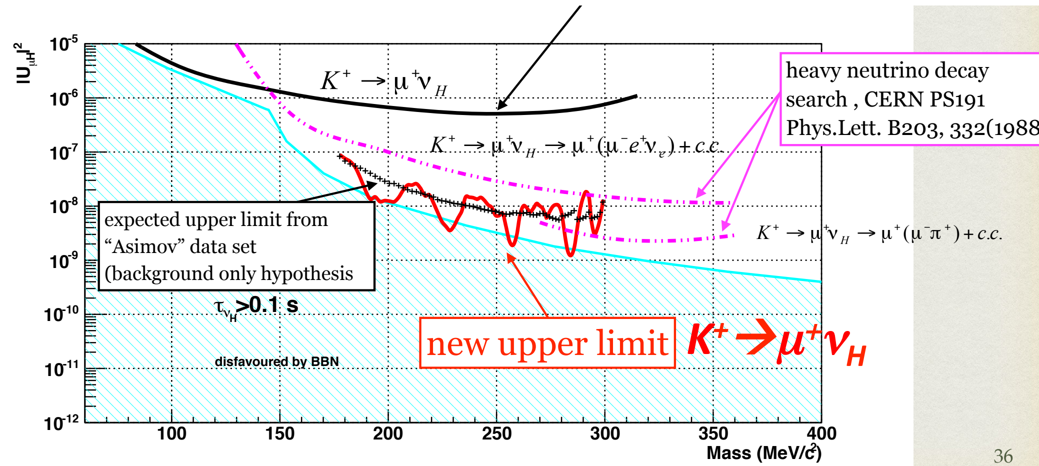
$$BR(K^+ \to \pi^+ \nu\bar{\nu}) = (1.73^{+1.15}_{-1.05}) \times 10^{-10}$$

- World Renowned for $K^+ \rightarrow \pi^+ \nu\nu$
- The huge stopped kaon sample of **E949** is a gold mine for $K^+ \rightarrow \pi^+ X$
- $K^+ \rightarrow \mu^+ X$ searches are limited by the muon rejection applied in the trigger but still yield best world results

E949: $K^+ \rightarrow \mu^+ \nu_H$ and $K^+ \rightarrow \mu^+ \nu\nu\nu$

after all selection criteria (100% of data)





2. Neutrino-neutrino interaction.

$$\frac{\Gamma(K^+ \to \mu^+ \nu \bar{\nu} \nu)}{\Gamma(K^+ \to \text{all})} < 2.4 \times 10^{-6}$$

3. Six-fermion interaction:

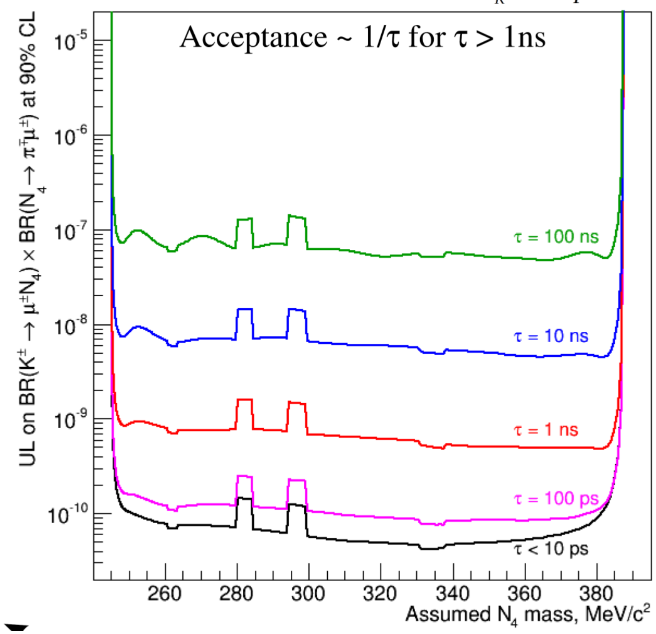
$$\frac{\Gamma(K^+ \to \mu^+ \nu \bar{\nu} \nu)}{\Gamma(K^+ \to \text{all})} < 2.7 \times 10^{-6}$$

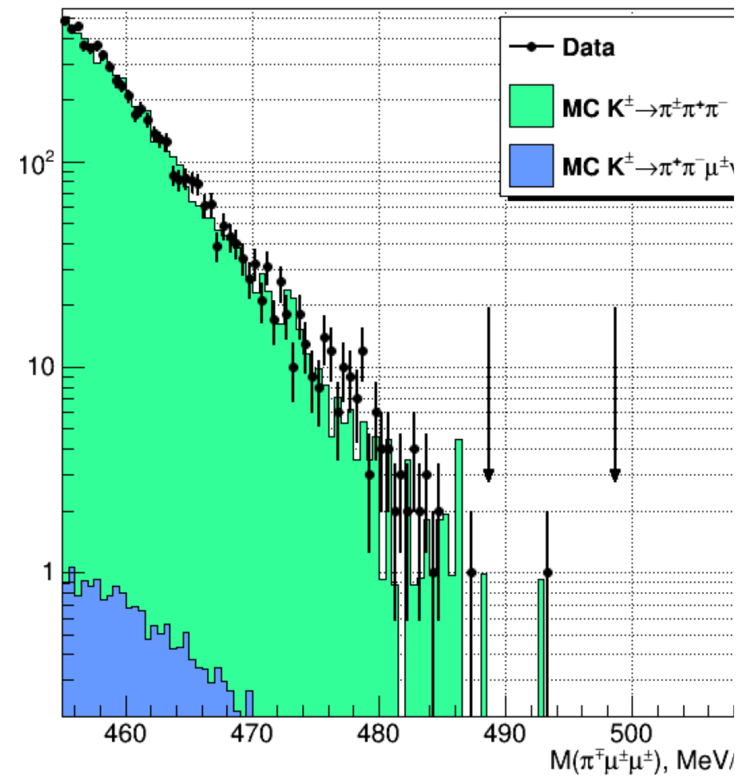
- Search for heavy neutrinos: $K^+ \rightarrow \mu^+ \nu_H$, Phys. Rev. D 91, 052001 (2015)
- Search for rare decay $K^+ \rightarrow \mu^+ \nu\nu\nu$, Phys. Rev. D 94, 032012 (2016)

NA48/2: $K \rightarrow \pi\ \mu\ \mu$

- **Same sign** di-muon sample:
  - BR($K^{+/-} \rightarrow \pi^{-/+}\ \mu^{+/-}\ \mu^{+/-}$)<8.6 x 10^{-11} 90%CL
- Search for $K^{+/-} \rightarrow \mu^{+/-} N_4 (N_4 \rightarrow \pi^{-/+} \mu^{+/-})$

$$UL(BR(K^{\pm} \rightarrow \mu^{\pm} N_4) BR(N_4 \rightarrow \pi^{\mp} \mu^{\pm})) = \frac{UL(N_{sig})}{N_K * Acceptance}$$

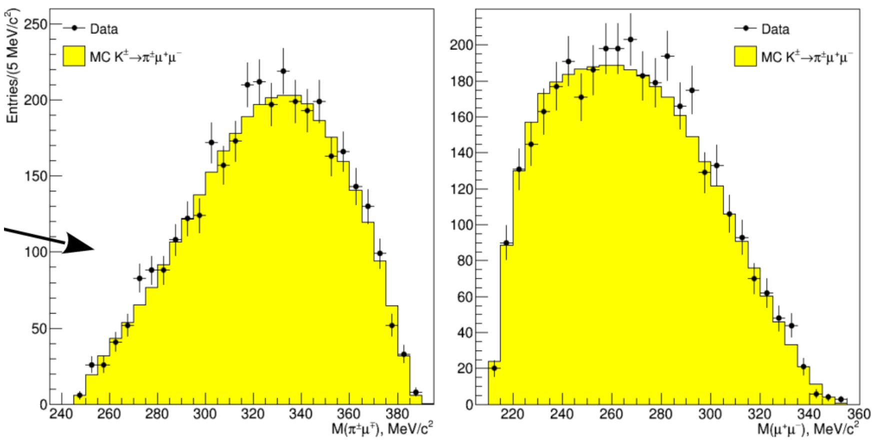


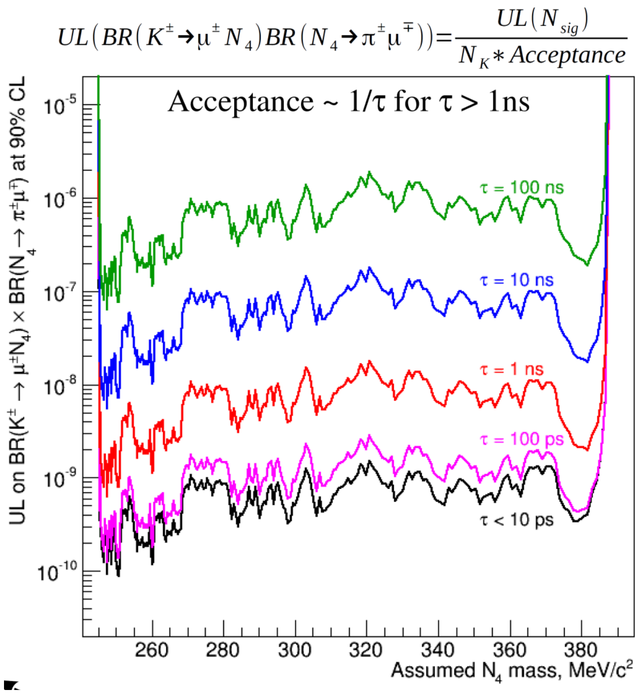


NA48/2: $K \rightarrow \pi\, \mu\, \mu$

- **Opposite sign** muon sample: 3489 events; ~.36% K→3π background
- Scan the πμ and μμ invariant masses

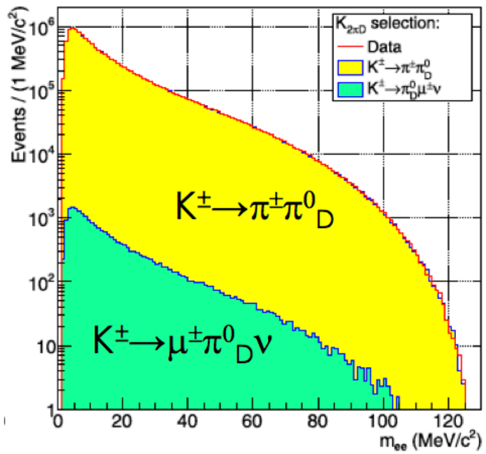
  looking for resonances in *K* decays

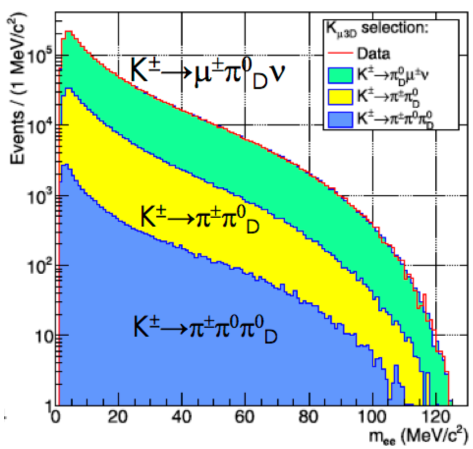




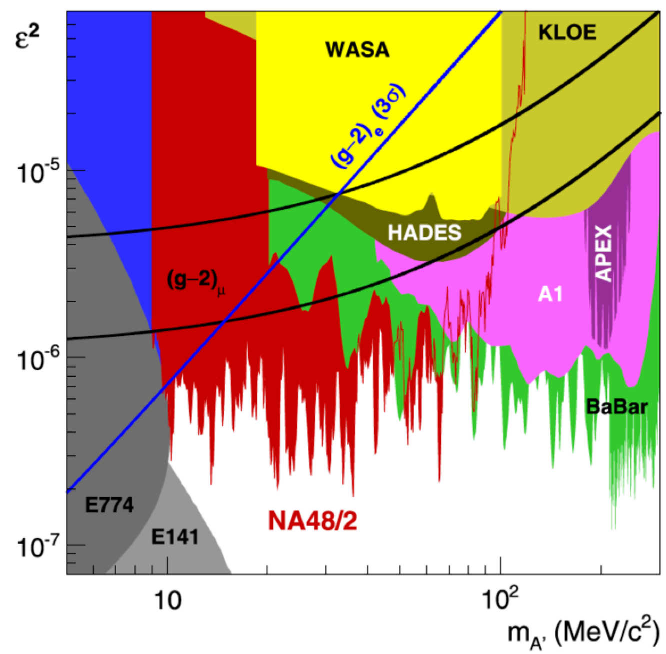
NA48/2: Dark Photon Search

From huge 1.7 x 10^7 sample of NA48/2 $K\rightarrow\pi\pi^0_D$ and $K\rightarrow\pi_D\mu\nu$





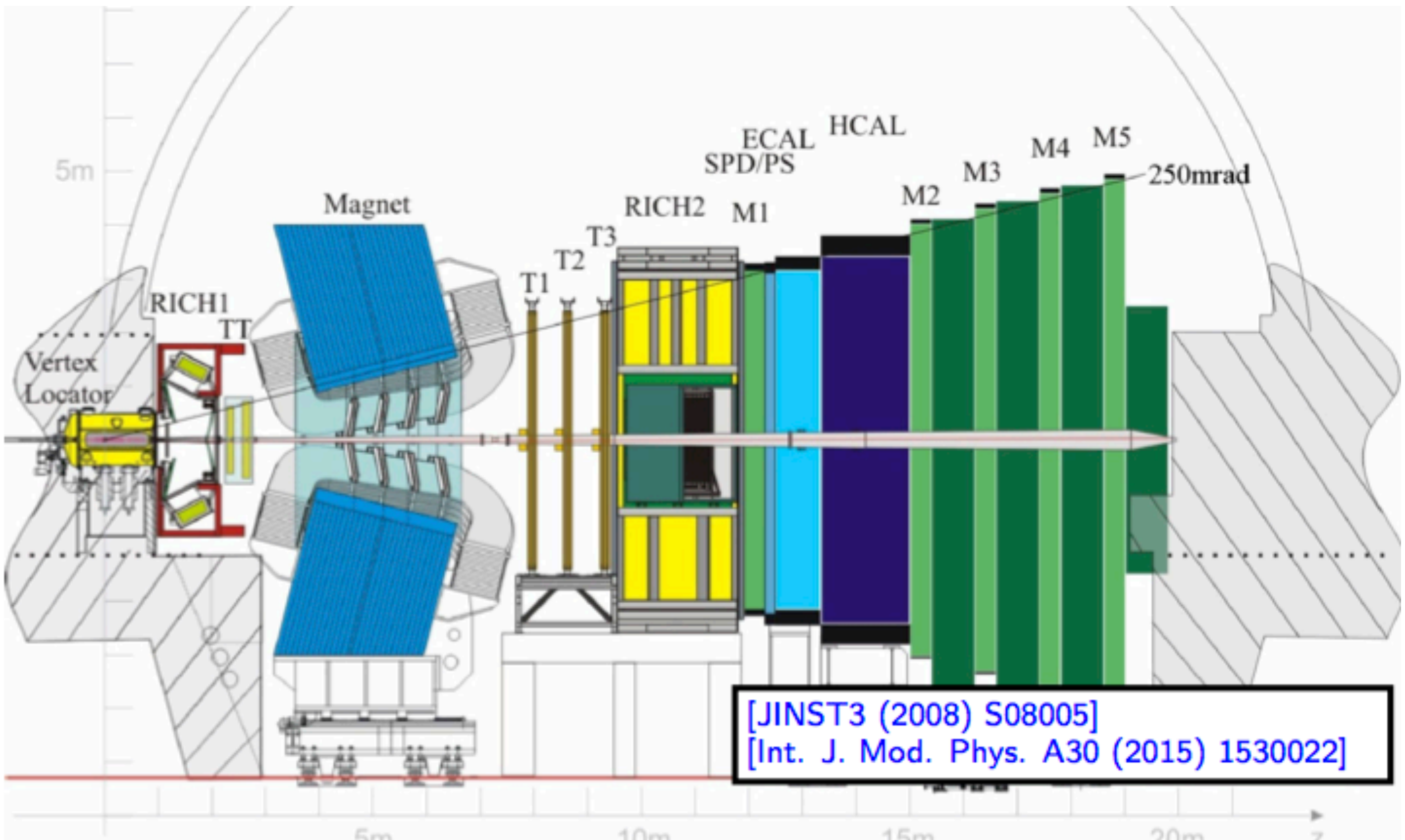
DP exclusion summary
Final result: **PLB746 (2015) 178**



Among the applications:

- Rule out DP as explanation of $(g\text{-}2)_\mu$ anomaly (under some hypotheses)
- Proto-phobic 5th forces…

LHCb as K^0_S / Σ Factory



LHCb: $K^0_S \to \mu^+\mu^-$

- **10^{13} K^0_S/fb^{-1} !!!**
- Can use "long tracks" to reconstruct K^0_S
- Trigger limitation (ε~2%) will be overcome

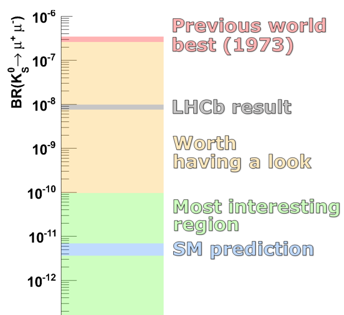
Results so far (90%CL)

- $\mathcal{B}\left(K^0_S \to \mu^+\mu^-\right) < 3.1 \times 10^{-7}$ CERN PS*
- $\mathcal{B}\left(K^0_S \to \mu^+\mu^-\right) < 9 \times 10^{-9}$ LHCb Coll.†

All distant from the SM prediction‡:

$$\mathcal{B}\left(K^0_S \to \mu^+\mu^-\right) = (5.0 \pm 0.2) \times 10^{-12}$$

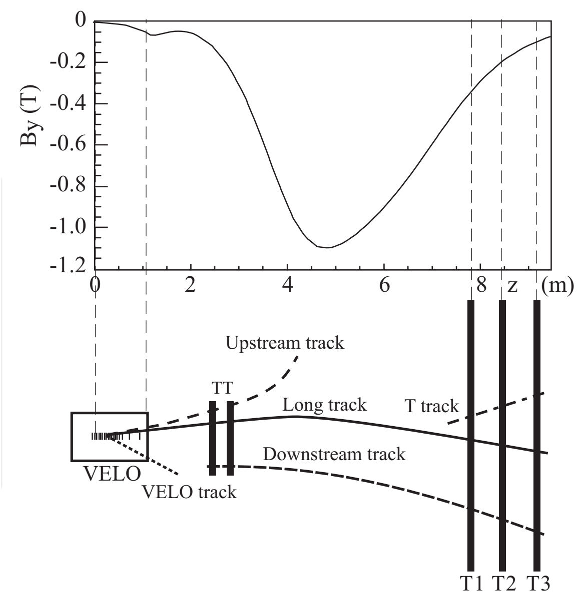
*CERN PS [PLB44 (1973) 217]
†LHCb Coll. [JHEP 01 (2013) 090]
‡[NPB366 (1991) 189] , [JHEP 01 (2004) 009]



$$\mathcal{B}\left(K^0_S \to \mu^+\mu^-\right) < 6.9(5.8) \times 10^{-9} \text{ at } 95(90)\% \text{ CL}$$

This result improves the previous LHCb limit by a factor 1.6, becoming the new world best result.

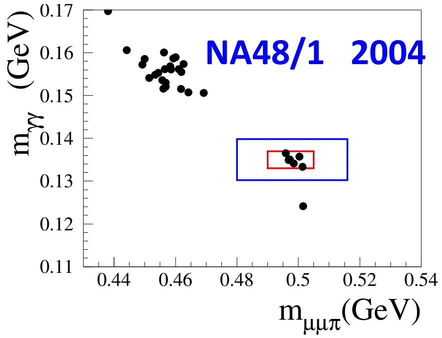
2 fb^{-1}



[Int. J. Mod. Phys. A30 (2015) 1530022]

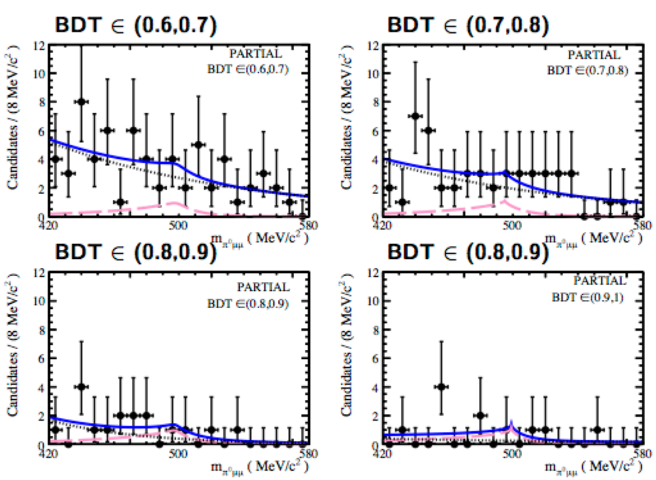
LHCb: $K^0_S \rightarrow \pi^0\mu^+\mu^-$ feasibility study

$\mathcal{B}(K^0_S \to \pi^0\mu^+\mu^-) = 2.9^{+1.5}_{-1.2} \times 10^{-9}$
(Phys. Lett. **B599** (2004) 197)

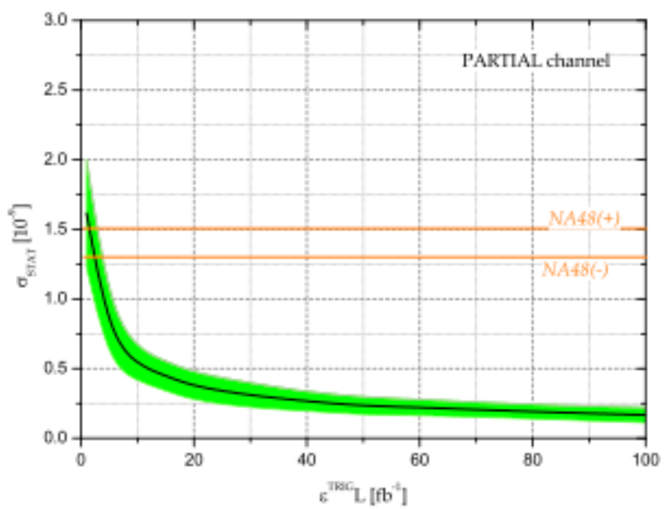


Improvements on the K^0_S BR determination
Would lead to better prediction for the
CP-Violating K^0_L mode

$N_{K^0_S \to \pi^0\mu^+\mu^-} = 24^{+15}_{-14}$ events



Excellent prospects for the LHCb upgrade!

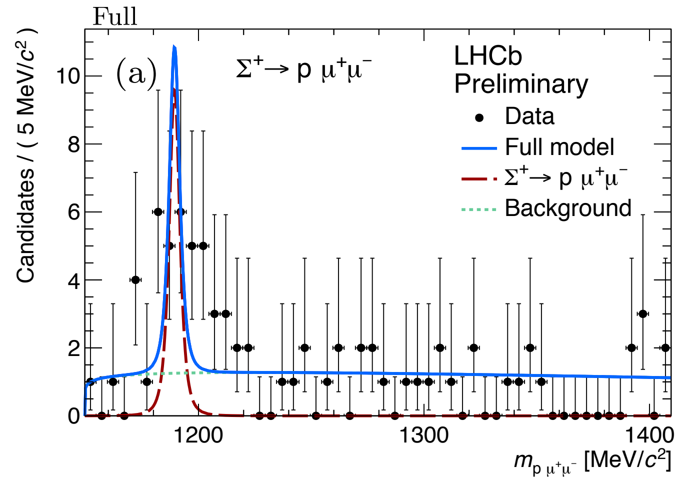


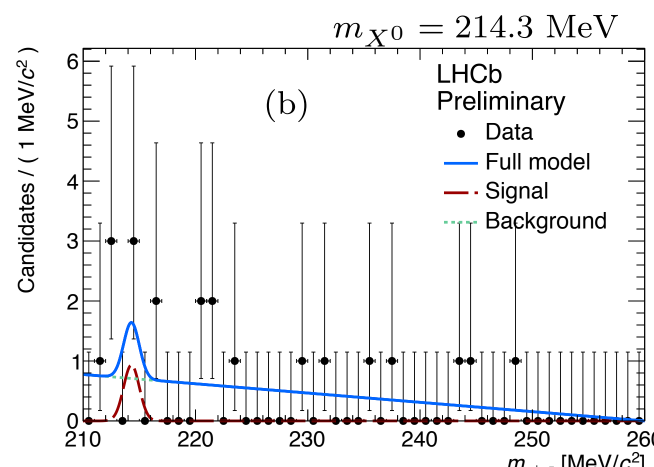
LHCb: Evidence of $\Sigma^+ \rightarrow p\mu^+\mu^-$

- Long standing puzzle from HyperCP:
  - 3 events clustered at $M(\mu^+\mu^-)$~214 MeV
- Very nice LHCb analysis shows evidence for $\Sigma^+ \rightarrow p\mu^+\mu^-$ with ~13 events
- **No bumpy feature** in $M(\mu^+\mu^-)$
- From the subset of the events for which a normalization could be made:

$BR(\Sigma^+ \rightarrow p\mu^+\mu^-) < 6.3\times10^{-8}$ at 95% CL

2011+2012 data 3 fb^{-1}





$K \to \pi\nu\nu$

Decay	Exp	Theory
$K_L^0 \to \pi^0 \nu\bar{\nu}$	$< 2.6x10^{-8}$ E391a	$(3.4 \pm 0.6)x10^{-11}$ *
$K^+ \to \pi^+ \nu\bar{\nu}$	$17.3^{+11.5}_{-10.7}x10^{-11}$ E949	$(8.4 \pm 1.0)x10^{-11}$

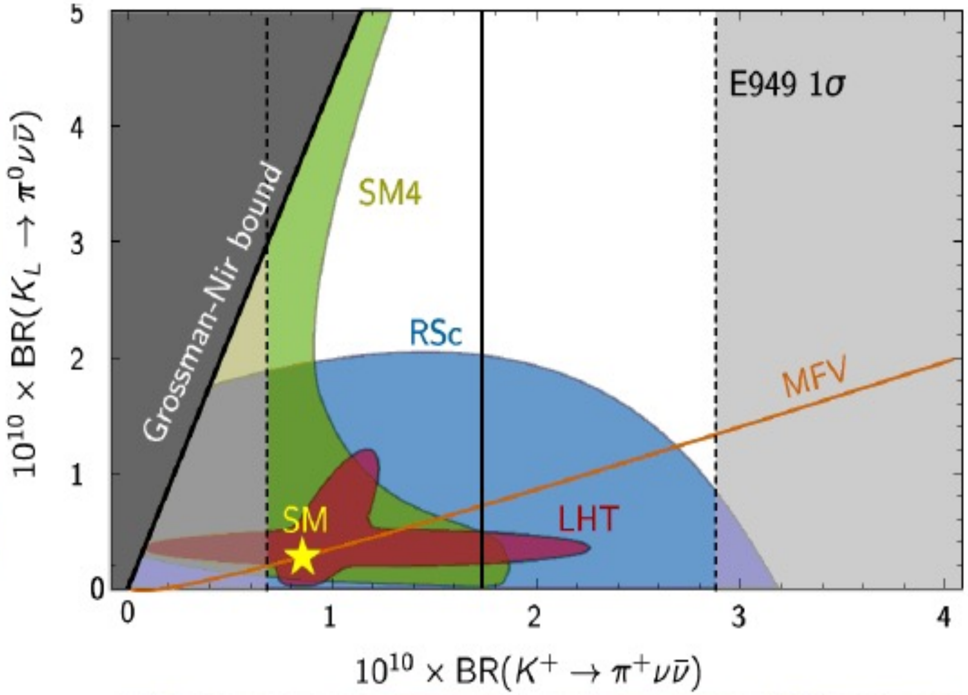
Theory : A. Buras et al. JHEP 1511 (2015) 33

* A ~0.3 μm speck of dust compared to the 8586 m of Kangchenjunga

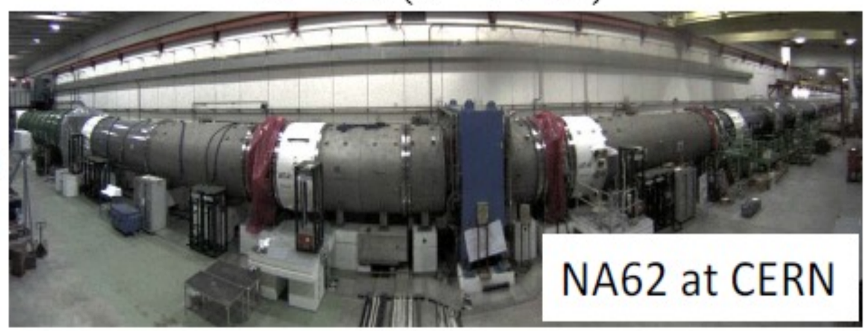
Credit: Wikipedia

New generation of Kaon experiments

O(1) SM $K_L \rightarrow \pi^0 \nu\nu$ events



O(100) SM $K^+ \rightarrow \pi^+ \nu\nu$ events

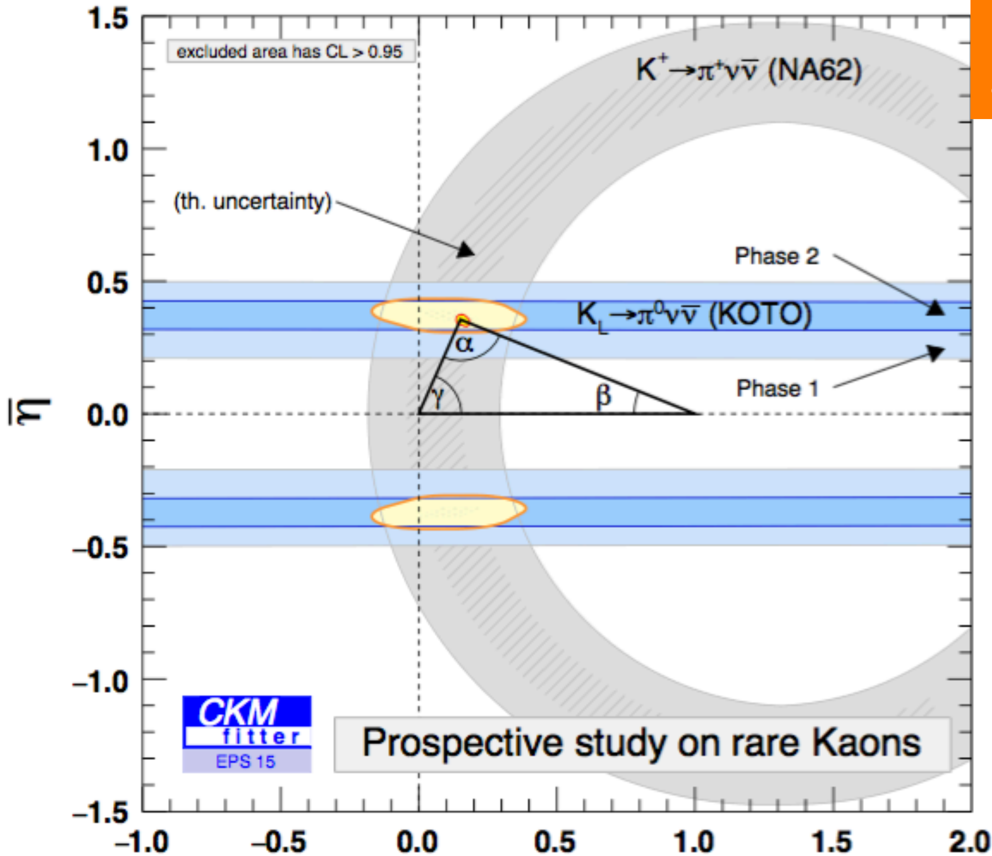


From I. Shipsey ICHEP 2016
"Vision and Outlook"

My comment (AC): an experimental dream not afflicted by large theoretical errors

Prospective

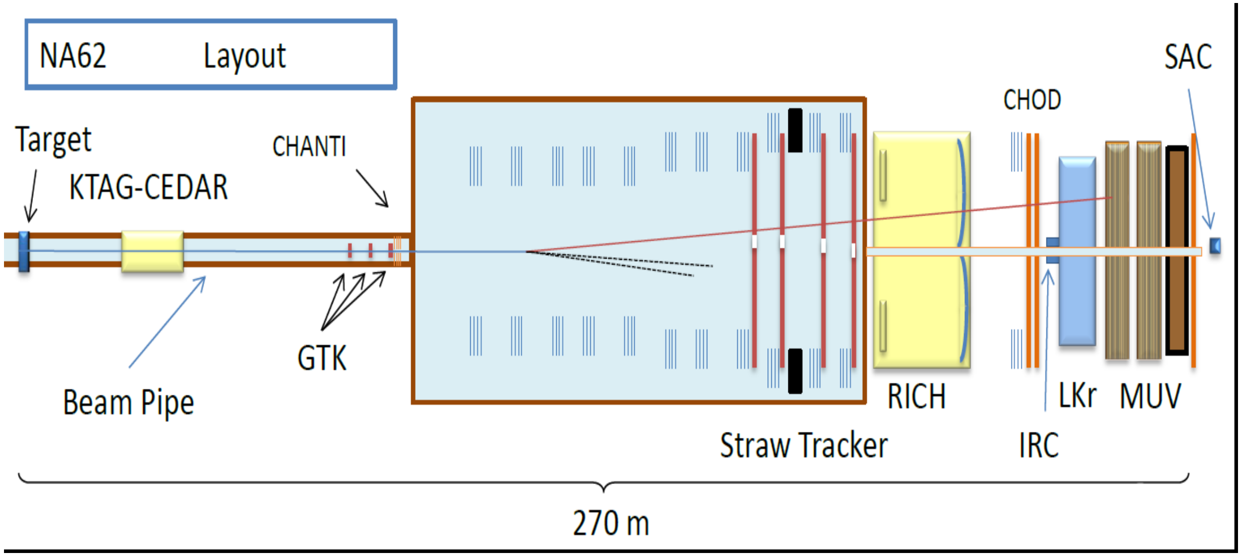
- NA62 : $Br(K^+ \to \pi^+ \nu \bar{\nu})$ at 10% accuracy
- KOTO : Phase 1 $\sim 3\sigma$ constraint on the branching ratio (SM), Phase 2 stage with $Br(K_L \to \pi^0 \nu \bar{\nu})$ at 10% accuracy



My (AC) comment: these experiments are exploratory tools

- NA62: in grey the role played by theoretical uncertainties
- KOTO : phases 1 and 2 indicated

NA62 SCHEMATIC LAYOUT



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

SPS K12 Beam: 750 MHz, 75 GeV/c
•Positive polarity
•Kaon fraction ~6%
•Δ p/p ~ 1%
•Useful kaon decays ~10% (5 MHz)

Residual pressure in decay tank ~10^{-6} mbar

NA62 is built 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

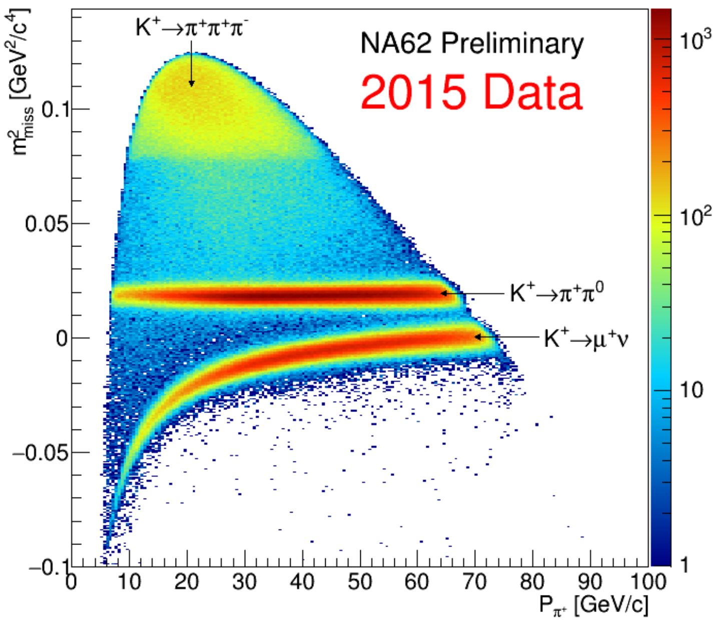
It paves the way to a broad physics program in kaon decays (LFV, LU, CHPT) and beyond (HNL, Exotics, Dark Sector etc.)

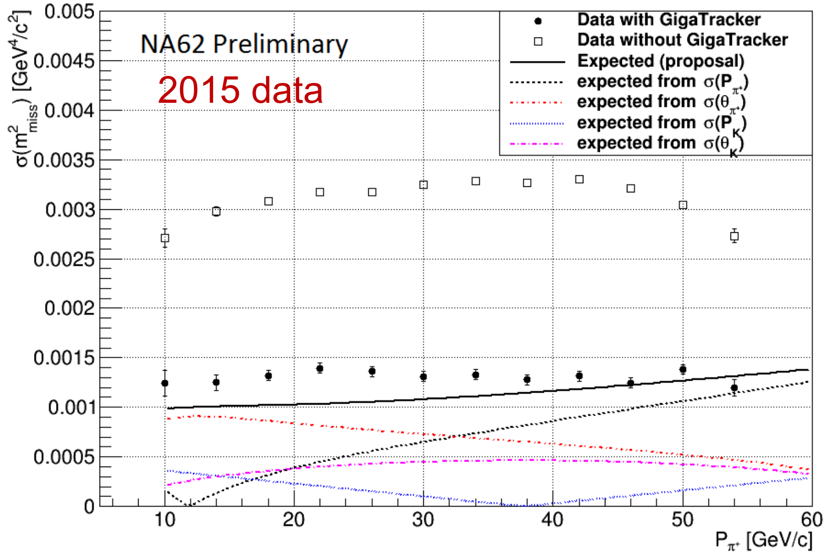
Status of NA62: Data Taking

Data taking until the end of 2018; plans for the future

NA62: Kinematics

OTS + Kaon ID



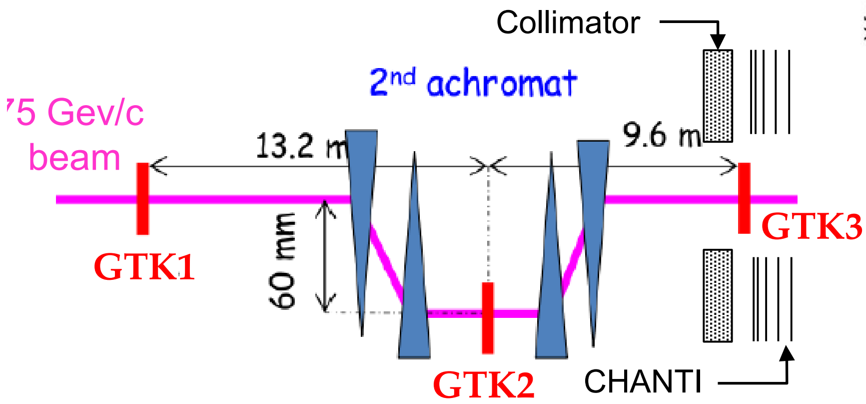


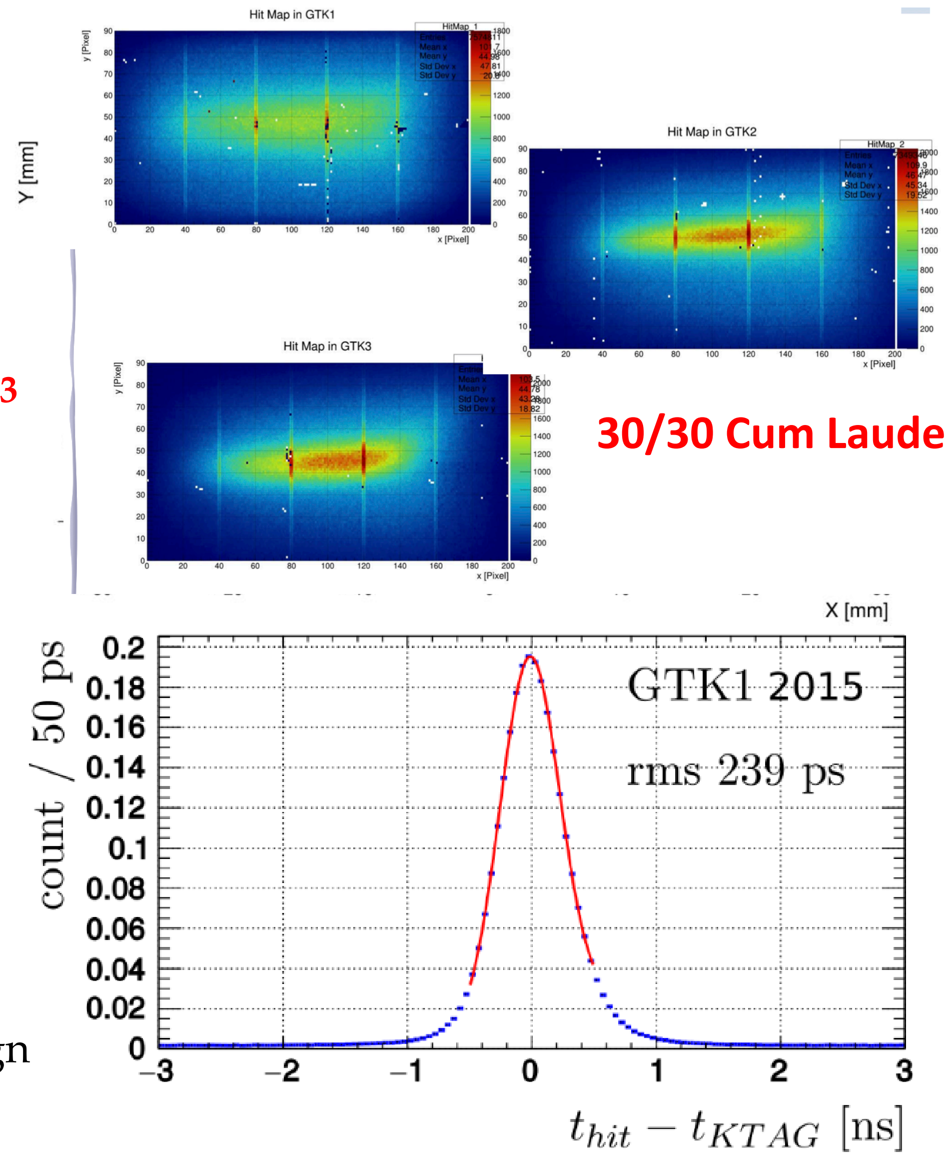
Single track tagged to be a Kaon

Missing Mass Resolution

NA62: Gigatracker

ENABLING NEW TECHNOLOGY

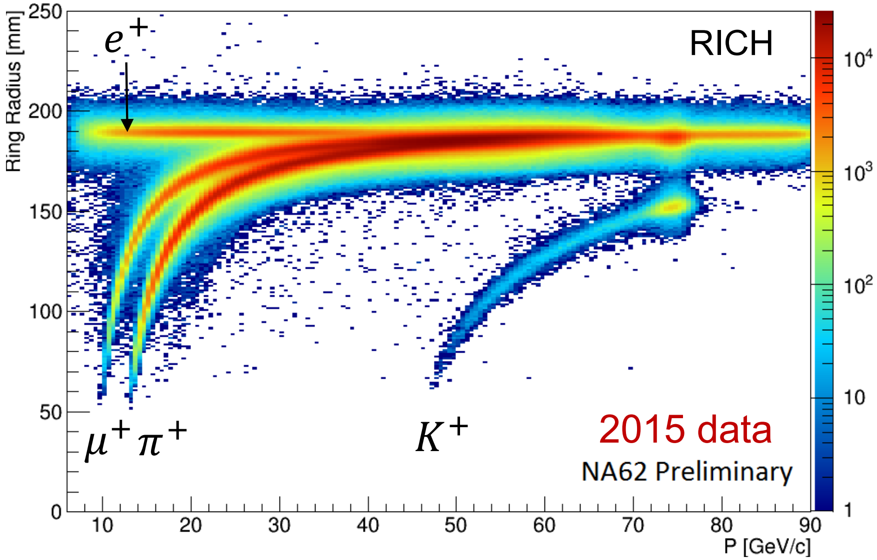




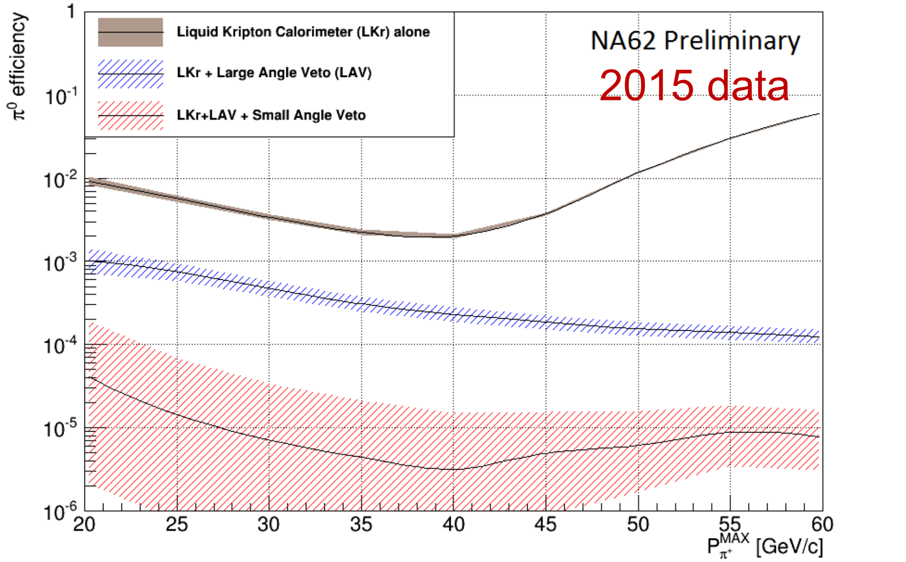
30/30 Cum Laude

- 3 Si pixel stations on the beam
- 300 × 300 μm^2 pixels, ~54000 pixels
- Cooling using microchannel technique
- On-sensor TDC readout chip
- $X/X_0 < 0.5\%$ / station
- Commissioned in 2015-2016
- Measured performances match the design
  - $\sigma(t_{beam\ track}) \leq 200$ ps

NA62: PID & π^0 Rejection

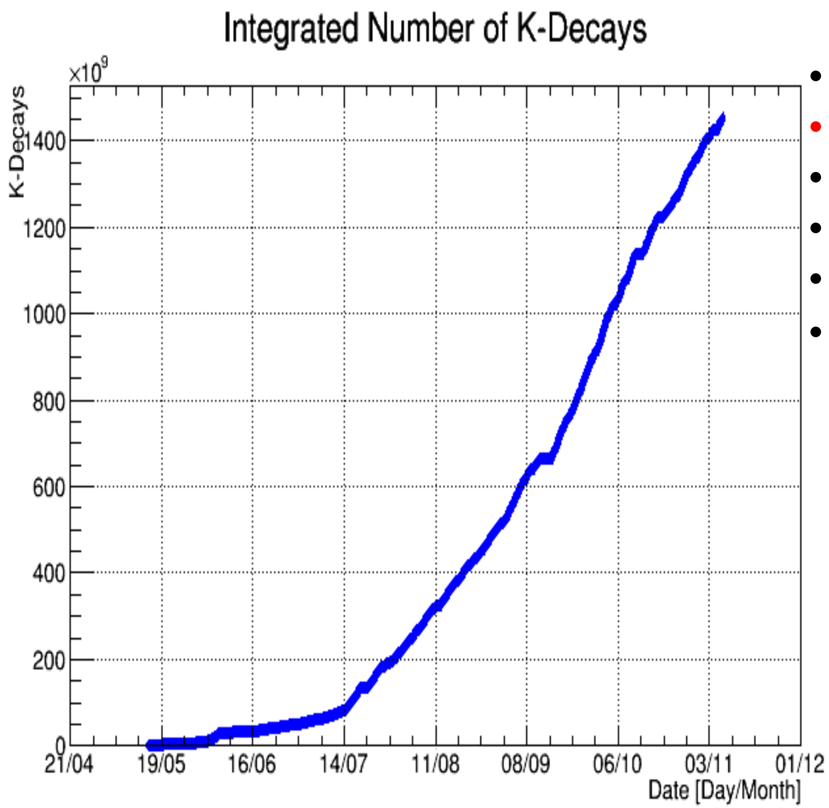


$15 < P_{\pi^+} < P_{\pi^+}^{MAX}$

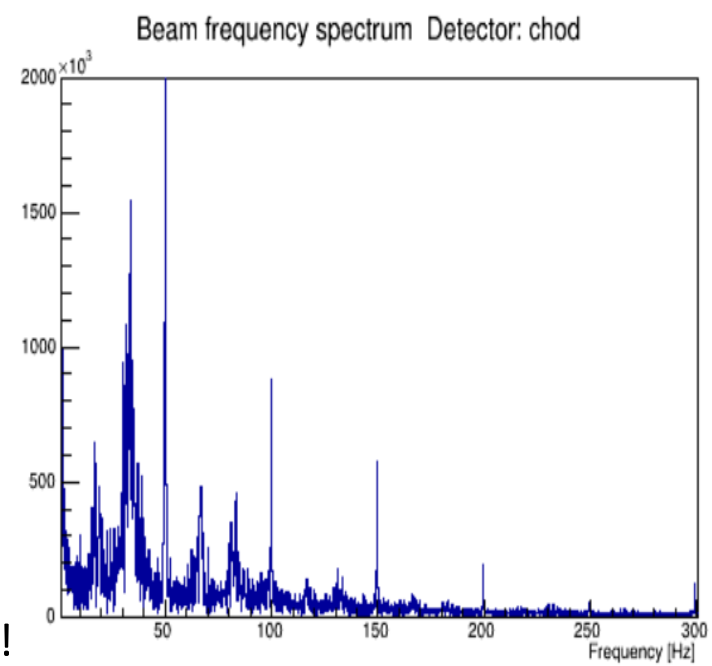


- **All the ingredients are in place to launch the assault to the** ***$K^+ \rightarrow \pi^+ \nu\nu$***
- **Moved from construction/commissioning to data taking/analysis**
- **A lot of non-$\pi\nu\nu$ physics to be done concurrently**

NA62 Data Taking 2016



- Running consistently at about **40%** of nominal intensity
- **Limited by beam "Structures" (e.g. 10-30 Hz, 50 Hz, etc.)**
- Data taking for PNN + EXOTICS simultaneously
- 250 ktrigger / pulse on tape (corresponding to 14 KHz DC)
- Second SPS spill since ~mid July
- Three full GTK (30/30 chips)since September 15)



K-decays: extrapolation to end of 2018:

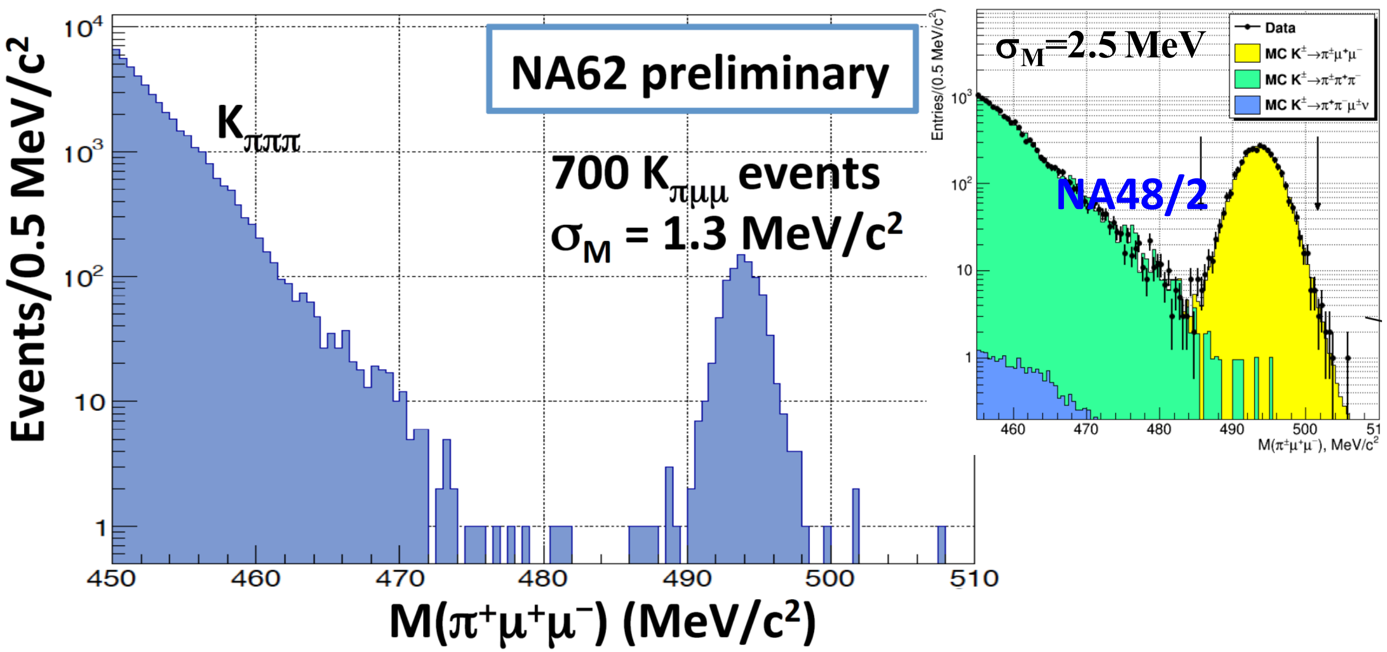
$5*10^{11}$ / month * 12 months ~ 6 10^{12}

→ With better beam and incremental improvements it can reach the target of 10^{13} K decays before LS2

→ It needs as many good Fixed Target days as possible!

NA62: $K \rightarrow \pi\ \mu\ \mu$

- **Factor of two improvement in mass resolution over NA48/2**
- Order of magnitude improvement in statistics



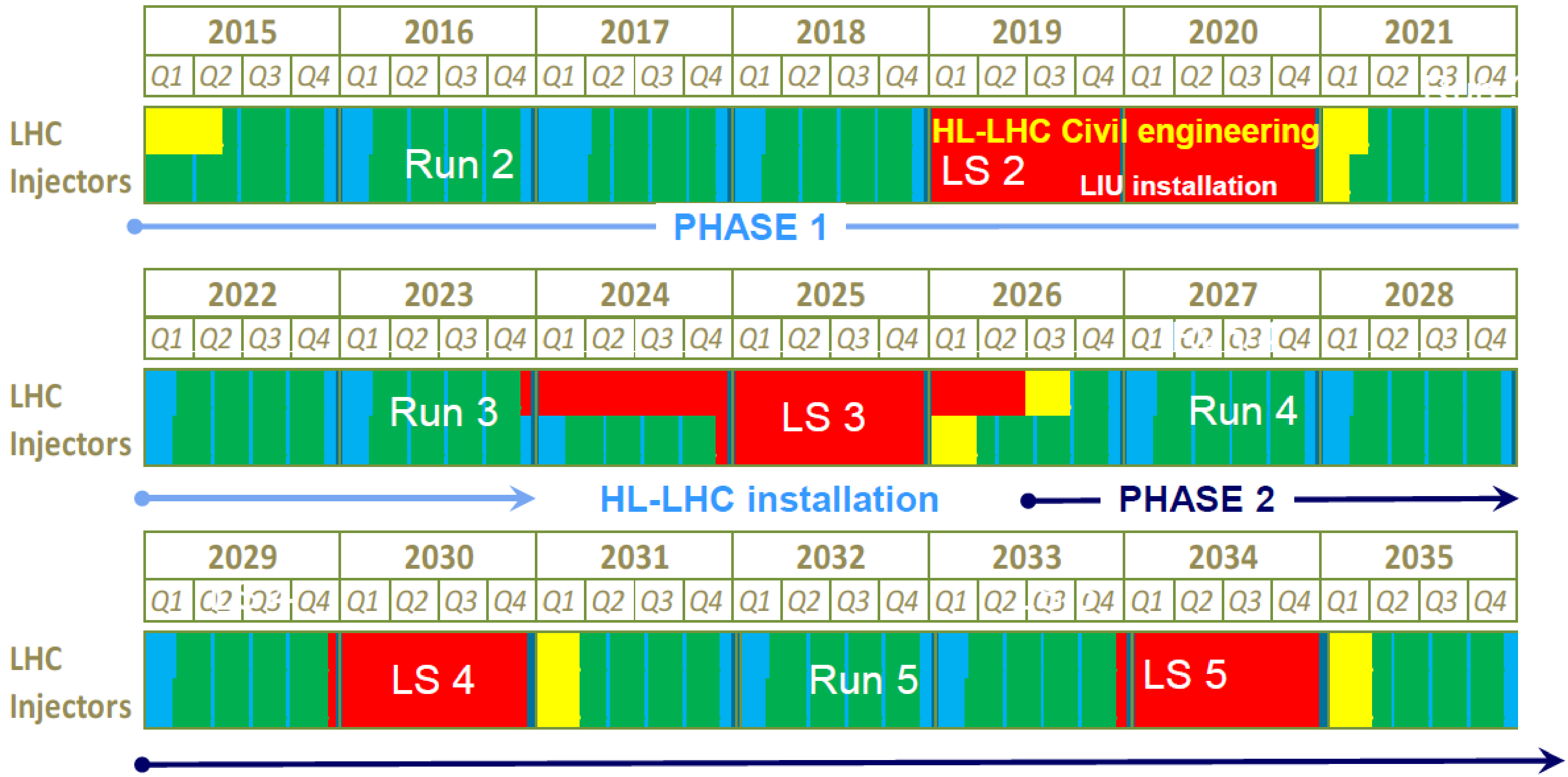
LHC roadmap: according to MTP 2016-2020

LS2 starting in 2019 => 24 months + 3 months BC

LS3 LHC: starting in 2024 => 30 months + 3 months BC

Injectors: in 2025 => 13 months + 3 months BC

- Physics
- Shutdown
- Beam commissioning
- Technical stop



NA62 Future

Conclusions

- There are planned and current searches for exotic processes at NA62:

  K^+ decays: LNV/LFV modes, HNL production searches (already under analysis with 2015 data)
  π^0 decays: rare and forbidden LFV, dark photon production

- Assuming fulfillment of main goal, BR($K^+ \to \pi^+ \nu\bar{\nu}$) at 10% precision, broad physics program at NA62 after LS2 (to start in 2021)
- Present beam and detector setup: LFV/LNV/forbidden π^0/K^+ decays for SES ~10^{-12}
- Year-long data-taking in "beam-dump" mode. Sensitivity to various NP models: Dark photons, Axions, Heavy neutral leptons, etc.
- Background rejection power studied for the searches proposed, up to ~10^{15} POTs
- The current NA62 run will be exploited to:
  evaluate the background rejection up to ~10^{18} POTs;
  understand if the current apparatus needs any optimisations or modifications for a future "beam-dump" operation

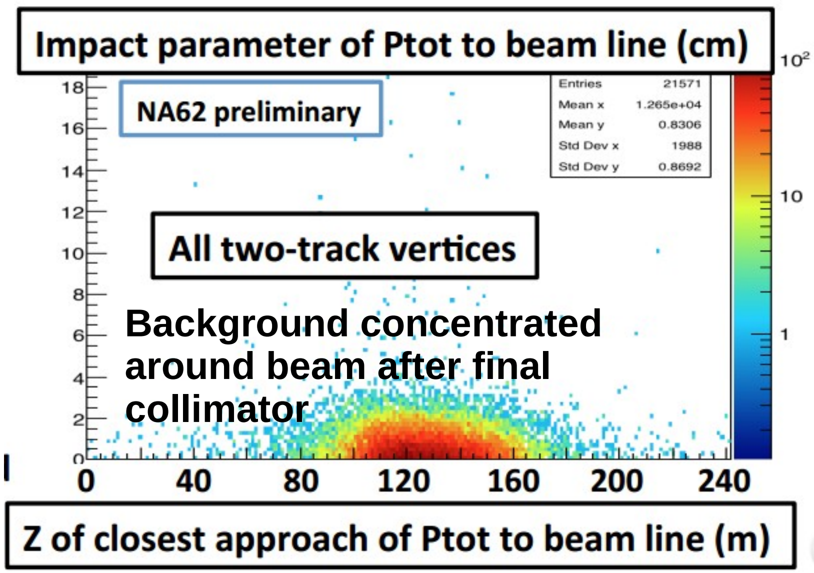
Stay tuned!

NA62-DUMP

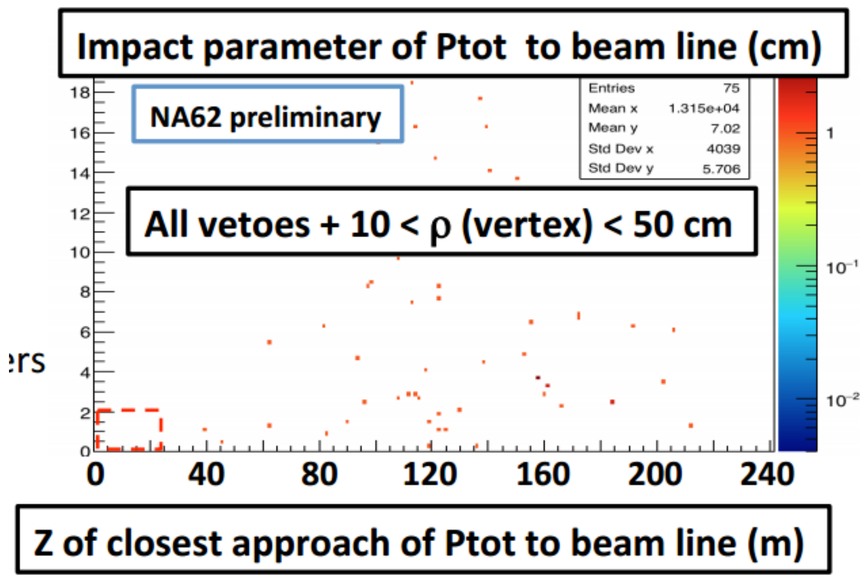
Test of the zero background assumption

- **Event selection: track quality + acceptance cuts**
  two track vertex: cda < 1 cm
  position 105 < Z < 165 m

  Stat. corresponds to ~10^{15} POT



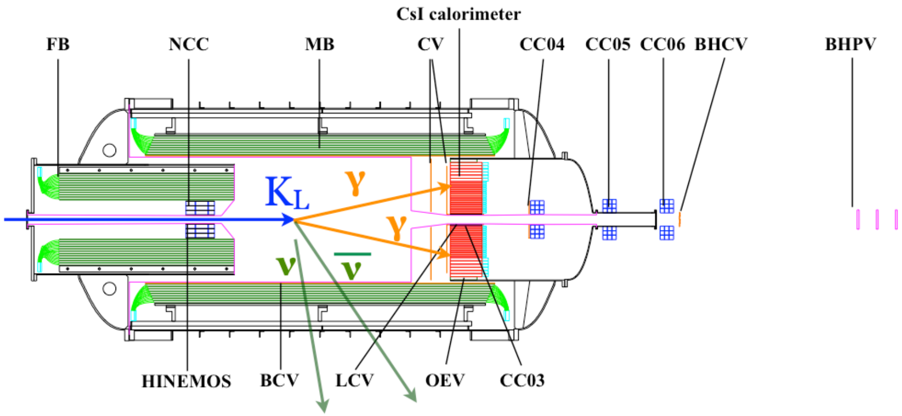
- **Event-level veto conditions:**
  energy in LKr <2 GeV
  veto on forward/large angle calorimeters
  veto on charged anti-counter
- **Total momentum stems from target**

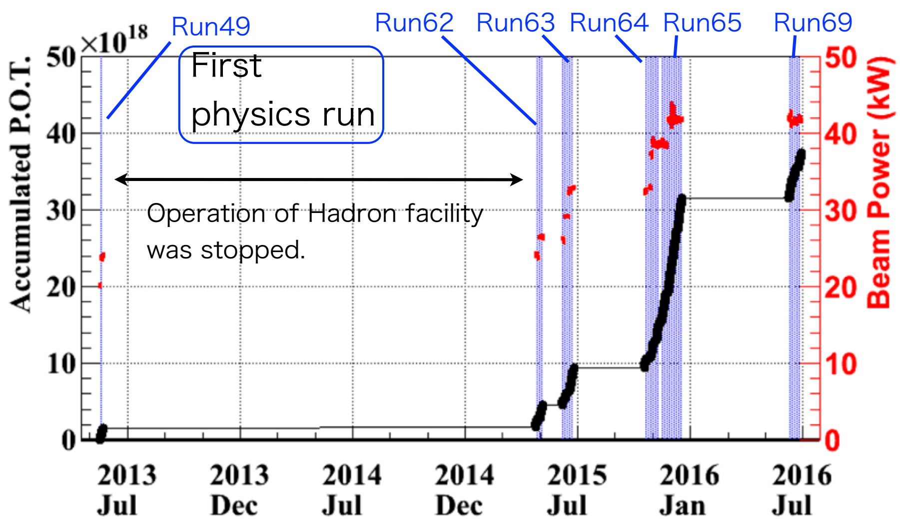


No events selected in the signal region!

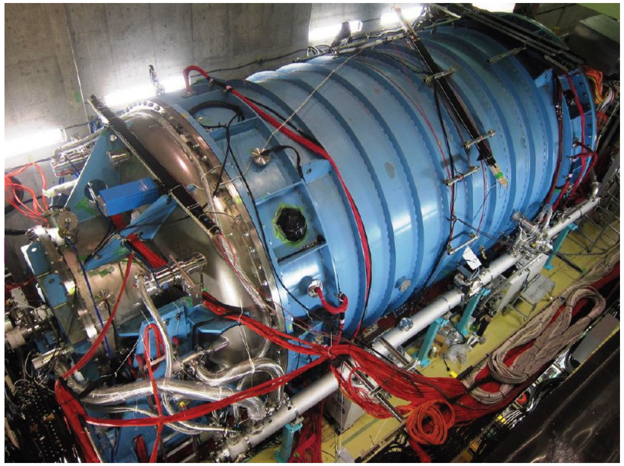
Status of KOTO: Data Taking

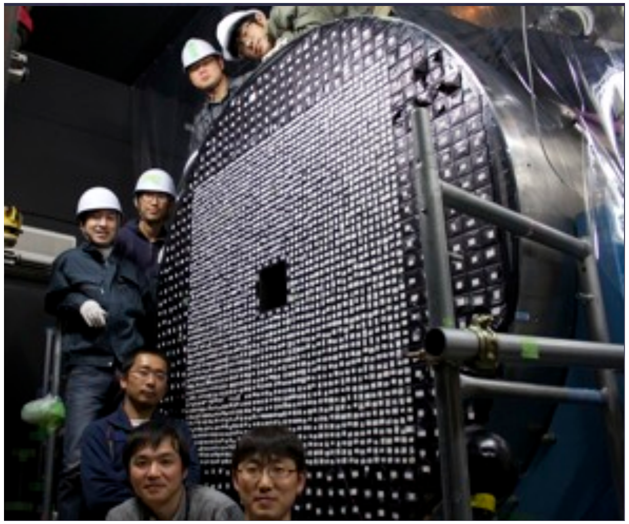
CsI calorimeter + Hermetic veto system





…a blessing in disguise

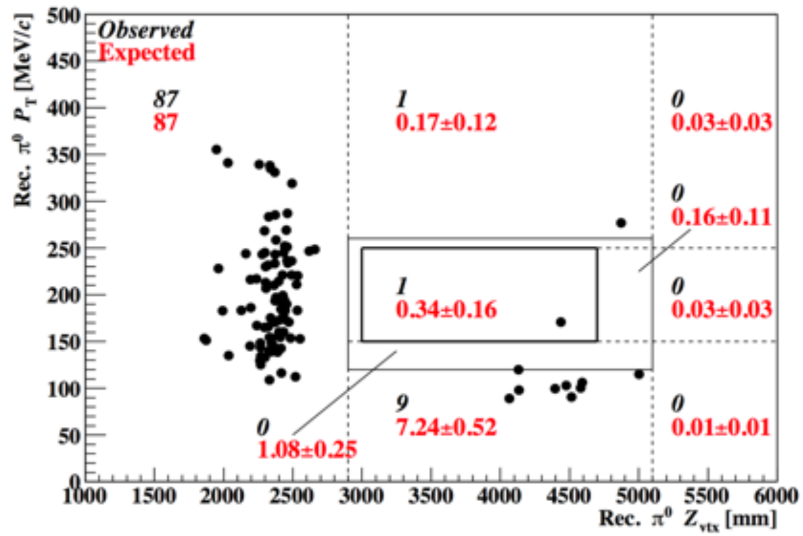




Result of the first physics run

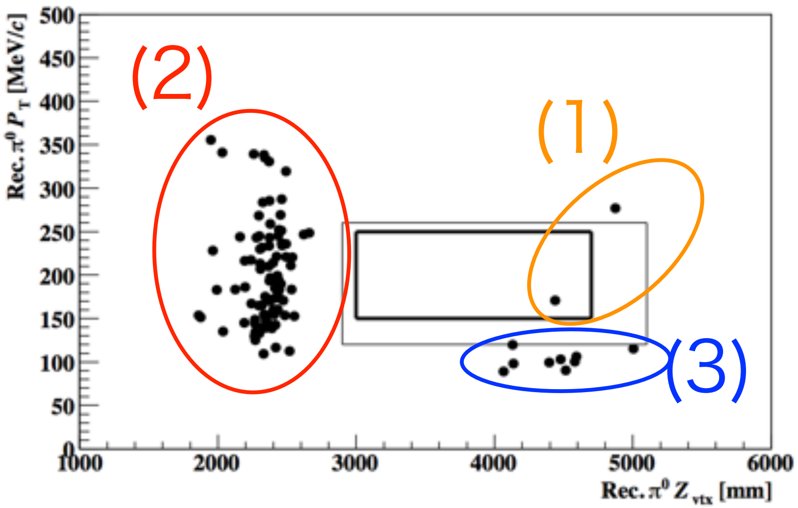
- Set the upper limit on $Br(K_L \to \pi^0 \nu \bar{\nu})$
  - $<5.1\times10^{-8}$ (90% C.L.)
- Set the upper limit on $Br(K_L \to \pi^0 X^0)$ $(M_X = M_\pi)$
  - $<3.7\times10^{-8}$ (90% C.L.)
- Submitted a paper to PTEP

  arXiv:1609.03637

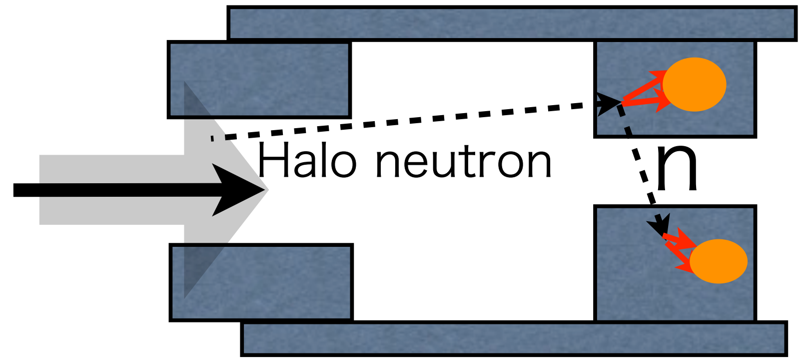


BG source	#BG
Halo neutrons hitting the CsI Calorimeter	0.18±0.15
Kaon decay events	0.10±0.04
Halo neutrons hitting the NCC	0.056±0.056
Sum	0.34± 0.16

Lessons from the first physics run

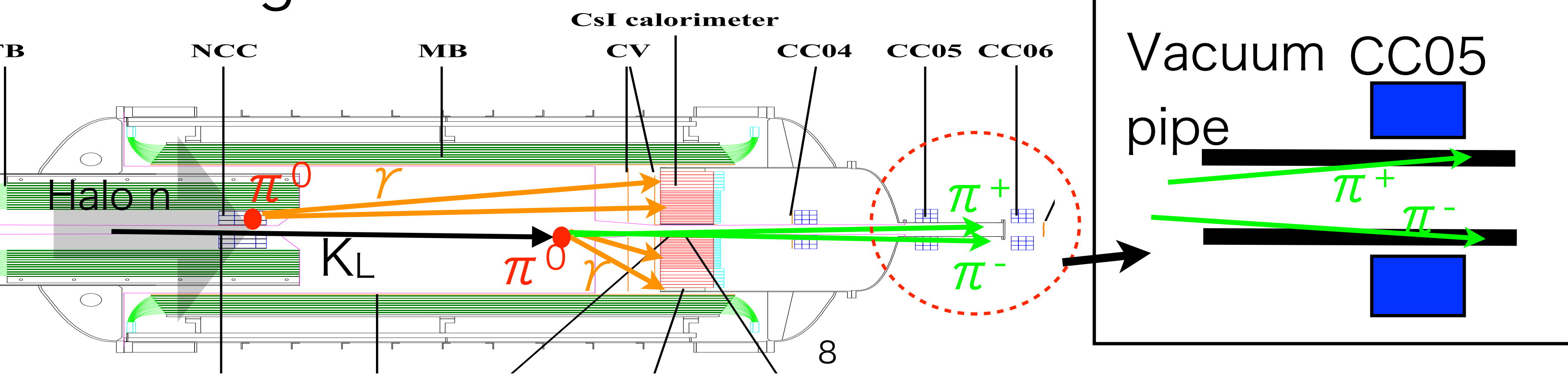


(1)Halo neutrons hitting the CsI Calorimeter



(2)Halo neutrons hitting the NCC

(3)$K_L \rightarrow \pi^+\pi^-\pi^0$ BG



KOTO Run62: Preliminary results After imposing all selection cuts

-Summary of
#BG inside the signal box

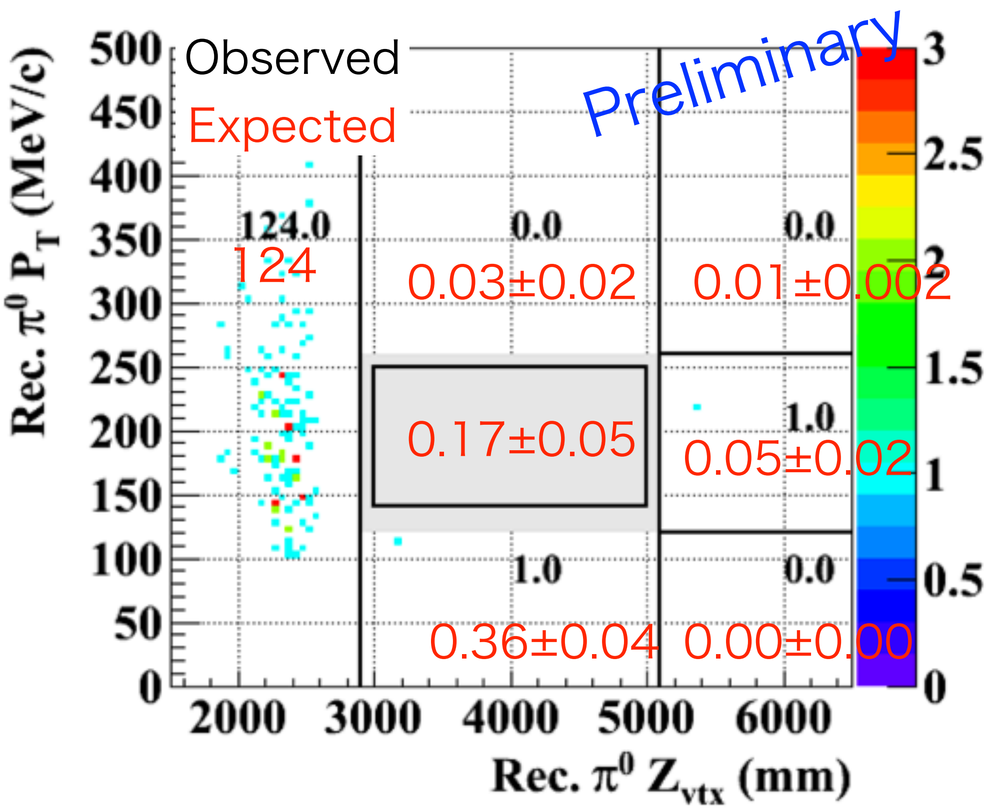
Preliminary

BG source	#BG
$K_L \to 2\pi^0$	0.04±0.03
$K_L \to \pi^+\pi^-\pi^0$	0.04±0.01
Upstream events	0.04±0.04
Hadron cluster events	0.05±0.02
Other BG sources	Under estimation

-S.E.S

5.9×10^{-9}

Apply all selection cuts



KLEVER: $K_L \to \pi^0 \nu\bar{\nu}$ at the SPS

Can a competitive measurement of BR($K_L \to \pi^0 \nu\bar{\nu}$) be made at the SPS?

NA62-16-03

Status report on design studies for an experiment to measure BR($K_L \to \pi^0 \nu\bar{\nu}$) at the CERN SPS

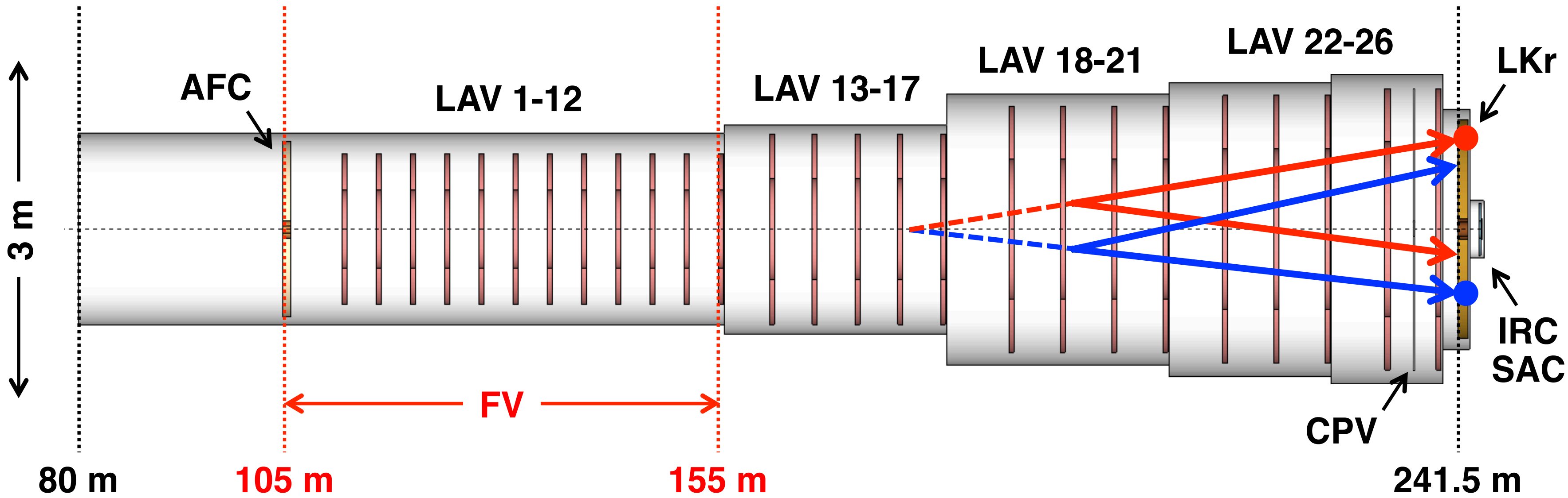
A. Bradley, M.B. Brunetti, F. Bucci, A. Cassese, N. Doble, D. Di Filippo, E. Gamberini, L. Gatignon, A. Gianoli, E. Imbergamo, M. Lenti, S. Martellotti, A. Mazzolari, M. Moulson[1], I. Neri, F. Petrucci, P. Rubin, R. Volpe

April 27, 2016

Preliminary design studies indicate that an experiment to measure BR($K_L \to \pi^0 \nu\bar{\nu}$) can be performed at the SPS in Run 4 (2026-2029)

- Many issues still to be addressed!
- Expected sensitivity: ~ 60 SM events with $S/B \sim 1$
- Comparable in precision to KOTO Step 2, with complementary technique (high vs. low energy) and different systematics

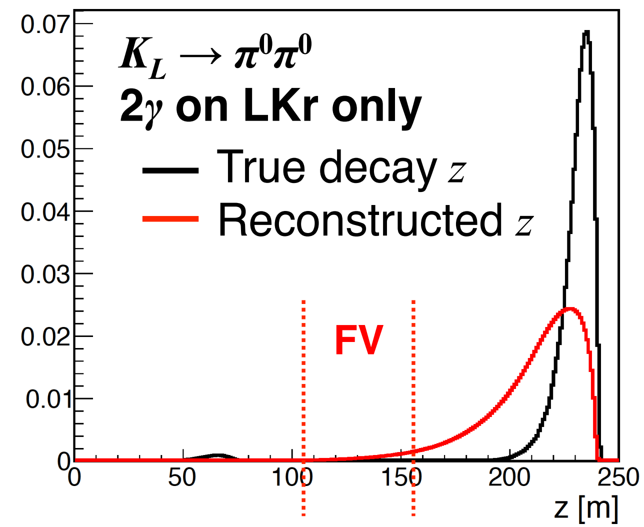
Detector layout for $K_L \to \pi^0 \nu\bar{\nu}$



Vacuum tank layout and FV similar to NA62

90-m distance from FV to LKr significantly helps background rejection

- Most $K_L \to \pi^0\pi^0$ decays with lost photons occur just upstream of the LKr
- "π^0s" from mispaired γs are mainly reconstructed downstream of FV



Summary: Homework for CKM2018

- Once this round of ***K*→ *πνν*** experiments will have bridged the current window of opportunity (~10% precision for K^+, SM sensitivity for K^0_L), the exploitation of these modes for CKM trigonometry can start, **BUT** we are still missing an experiment for **O(1000)** events
  - How far can one push the NA62 technique for K^+?
  - Who has got the protons for K^0_L?
- No new ideas yet on how to make progress on $K^0_L \rightarrow \pi^0 \mu^+ \mu^-$ and $K^0_L \rightarrow \pi^0 e^+ e^-$
  - Accept inferior signal over background ratio and extract signal from sheer statistics?
  - Precise determination of the K^0_S modes would allow one to consider more options (e.g. measure the interference term). There is hope from LHCb for the muonic channel
- Tests of V_{us} approaching 0.1% precision…
  - How far can the theory be pushed?
  - And the experiments?
  - Could one improve the V_{ud} measurement from pion beta decays to the level of the neutron one?
- **ε'/ε** as quantitative constraint: what is, finally, the SM prediction for it?