ECN3
CERN North Area

STATUS OF NA62

CKM2016, TIFR, Mumbai, November 29, 2016
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on behalf of the NA62 Collaboration
NA62 COLLABORATION

29 Institutes, 230 Collaborators
Triumph of the CKM description

- All the flavour changing processes are described by the four parameters of the CKM mass mixing matrix ($\lambda, A, \rho, \eta$).

- From this plot, we know already either new physics energy scale is $\gg$ TeV (far beyond LHC) or the flavour structure of new physics is very special.
New generation of Kaon experiments

From I. Shipsey ICHEP 2016 “Vision and Outlook”

My comment: experimental dream not afflicted by large theoretical errors
NA62 NOVEL IN-FLIGHT TECHNIQUE TO MEASURE $K^+ \rightarrow \pi^+ \nu \bar{\nu}$

- ~100 ps timing for $K^+ - \pi^+$ association (KTAG, GTK, RICH)
- EM Calorimeters to veto photons (LAV, LKr, SAC, IRC), hadron calorimeters (MUV1, MUV2, HASC) and hodoscopes to veto muons (MUV0, MUV3), extra particles (CHOD, NewCHOD) and interactions (CHANTI)
- Very light, high rate trackers to reconstruct the $K^+$ and the $\pi^+$ momenta (GTK, STRAW)
- Full particle identification (KTAG, RICH)
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.)
For NA62 is essential to have a flat SPS slow extraction: both microscopically and macroscopically.

GTK: Si Pixel 300 micron * 300 micron

75 Gev/c beam

140 ps R.M.S.

RICH-KTAG
Three new detectors installed over the summer of 2016
All stations fully operational since 15/09/2016:

- Enabling technology: Si pixel (300 micron x 300 micron) with ~200 ps time resolution / station
- Flux up to one GHz of high energy hadrons over ~20 cm²
- Rate per mm² up to 1.4 MHz
- Triggerless readout

30/30 Cum Laude!
One track selection (OTS)

Single downstream track topology

Downstream track matching energy in calorimeters

Beam track matching the downstream track

Kaon ID

Beam track matching a K signal in Kaon ID

Decay vertex in the fiducial region (65 m).

Time resolutions:

Kaon ID < 100 ps

Beam track < 200 ps

Downstream track < 200 ps

Calorimeters 1-2 ns

Tracking Techniques:

Si-pixel tracker (beam);

Straw tube tracker in vacuum (downstream)

Goal:

$O(10^4 \div 10^5)$ suppression factor of the main kaon decay modes

$P_{\pi^+} < 35$ GeV/c: best $K^+ \rightarrow \mu^+ \nu$ suppression.

Kinematics studied on $K^+ \rightarrow \pi^+ \pi^0$ selected using LKr calorimeter.

$O(10^3)$ kinematic suppression factor measured.

K decay

$K^+ \rightarrow \pi^+ \pi^0$

$K^+ \rightarrow \mu^+ \nu$

$K^+ \rightarrow 3\pi$

$K^+ \rightarrow \pi^0 l^+ \nu$

2015 data

OTS + Kaon ID

OTS = One Track Selection

Single track tagged to originate from a kaon decay

Missing Mass Resolution for single track events
Technique: EM calorimeters exploiting correlations between $g$ from $\pi^0$.

Goal: O(10^8) rejection $p_0$ from K^+o+p_0.

$P_{\pi^+} < P^{\text{MAX}}_{\pi^+}$

In situ/continuous monitor of $\pi^0$ rejection performed selecting $K^+\pi^+\pi^0$ events purely on kinematics.

Measured on data using K^+o+p_0 selected kinematically.

2015 measurement statistically and background limited.
• All the ingredients are in place to launch the assault to $K^+ \rightarrow \pi^+ \nu \nu$
• Moved from construction/commissioning to data taking/analysis
IMPROVED SHIELDING AND INTERLOCKS

- Proper shielding is crucial for the safety of the NA62 equipment and operation
- Several NA62 systems operate at rates where Single Event Effects due to HEH are expected

2015

2016

2.9x10^8 High Energy Hadrons (HEH)/cm²
Progress on 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 (no noise, 30/30 chips since September 15)

K-decays: extrapolation to end of 2018:
5*10^{11} / month * 12 months \approx 6 \times 10^{12}
\rightarrow With improved extraction and incremental improvements to the efficiency we can reach our target of 10^{13} K decays before LS2
Dimuon trigger, few % of the data, BR~9 $10^{-8}$

$K^+ \to \pi^+ \mu^+ \mu^-$

**NA62 preliminary**

700 $K_{\pi\mu\mu}$ events

$\sigma_M = 1.3$ MeV/c$^2$

Mass resolution better by a factor $\sim 2$ with respect to NA48/2
Heavy neutral leptons in $K^+ \rightarrow l^+ N$

- Can also search for **HNL** in $K^+ \rightarrow l^+ N$ where $N$ does not decay inside the detector fiducial volume.
- $K^+ \rightarrow l^+ N$ events would appear as peaks in the $K^+ \rightarrow l^+ \nu$ squared missing mass distribution.
- Searches are model independent.

Analysis underway with NA62 data from 2015.
Heavy neutral leptons in $K^+ \rightarrow l^+ N$

- Current experimental status: **most stringent constraints from kaon measurements**
- Expected SES with 2015 NA62 data at the level of $10^{-8}$ (similar for $K \rightarrow eN$ and $K \rightarrow \mu N$)

![Graph showing limits on $|\mu_{l\nu}|^2$ vs. $m_l$ (GeV) and heavy neutrino mass GeV/c²)

- KEK (1982) - Expected sensitivity
- E949 (2015) - Single event sensitivity

2007 data
Approx. $10^{12}$ kaon decays collected in 2016
- Performed transition from commissioning to data taking/analysis
- Need stable FT extraction (no 10-30 Hz bump) and as many proton days as possible before LS2
- Incremental improvements to data taking efficiency, trigger and beam intensity planned for 2017 in order to fulfil our objective to collecting approx. $10^{13}$ kaon decays before LS2 \( \mathcal{O}(100) \) PNN SM events
- Several triggers collected simultaneously to address a broad physics portfolio
- There are plans to extend the experiment after LS2 to also explore the “Dark Sector” using the NA62 setup