Status of the NA62 Experiment

Adam Conovaloff (George Mason University)
On Behalf of the NA62 Collaboration*

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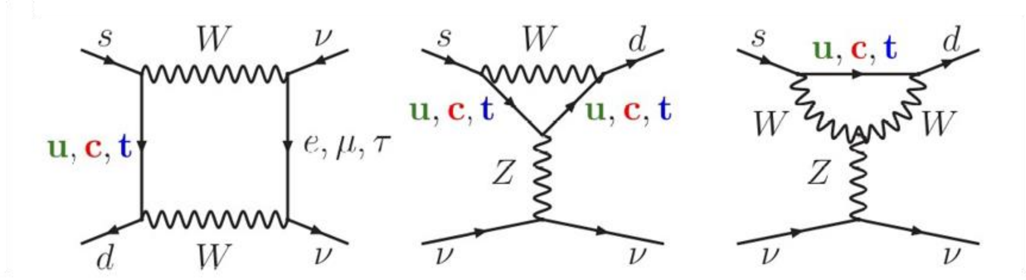
* Birmingham, Bratislava, Bristol, Bucharest, CERN, Dubna (JINR), Fairfax, Ferrara, Florence, Frascati, Glasgow, Liverpool, Louvain-la-Neuve, Mainz, Merced, Moscow (INR), Naples, Perugia, Pisa, Prague, Protvino (IHEP) , Rome I, Rome II, San Luis Potosi, SLAC, Sofia, TRIUMF, Turin, Vancouver (UBC)

Theoretical Considerations

Goal: Measure $K^+ \to \pi^+ \nu\nu$ to within 10% precision.

Three FCNC loop contributions: $s \to d$ couplings



Theoretically clean: All short-distance processes.

SM Predictions: (Buras et al. JHEP 1511 (2015) 33)

$$\mathrm{BR}(K^+ \to \pi^+ \nu\bar{\nu}) = (8.39 \pm 0.30) \cdot 10^{-11} \left(\frac{|V_{cb}|}{0.0407}\right)^{2.8} \left(\frac{\gamma}{73.2°}\right)^{0.74} = (8.4 \pm 1.0) \cdot 10^{-11}$$

$$\mathrm{BR}(K_L \to \pi^0 \nu\bar{\nu}) = (3.36 \pm 0.05) \cdot 10^{-11} \left(\frac{|V_{ub}|}{0.00388}\right)^{2} \left(\frac{|V_{cb}|}{0.0407}\right)^{2} \left(\frac{\sin\gamma}{\sin 73.2}\right)^{2} = (3.4 \pm 0.6) \cdot 10^{-11}$$

Previous Measurements:

$$\mathrm{BR}(K^+ \to \pi^+ \nu\bar{\nu}) = \left(17.3^{+11.5}_{-10.5}\right) \times 10^{-11}$$ Phys. Rev. D77, 052003 (2008), Phys. Rev. D77, 092004 (2009)

$$\mathrm{BR}(K_L \to \pi^0 \nu\bar{\nu}) < 2.6 \times 10^{-8}\ (90\%\ \mathrm{C.L.})$$ Phys. Rev. D81, 072004 (2010)

Experimental Overview

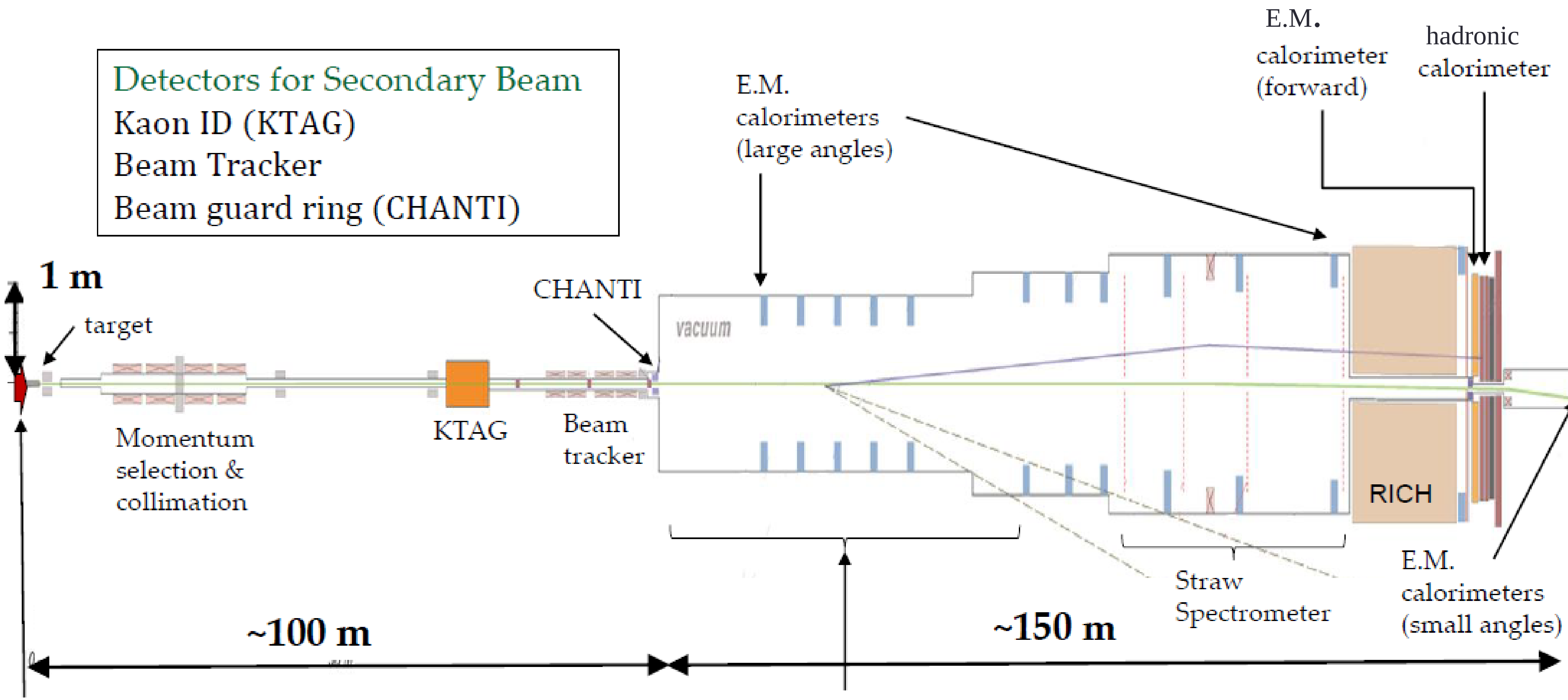
- Purpose
  - Measure $BR(K^+ \to \pi^+ \nu\nu)$ to 10% precision

- Requirements
  - Identify O(100) events
  - 10^{13} kaon decays with a signal acceptance of ~10%
  - Systematic uncertainty <10% precision background measurement
  - >10^{12} background rejection, <20% background in accepted events

- Experimental Method
  - In-flight K^+ decay

Experimental Apparatus

Detectors for Secondary Beam
Kaon ID (KTAG)
Beam Tracker
Beam guard ring (CHANTI)



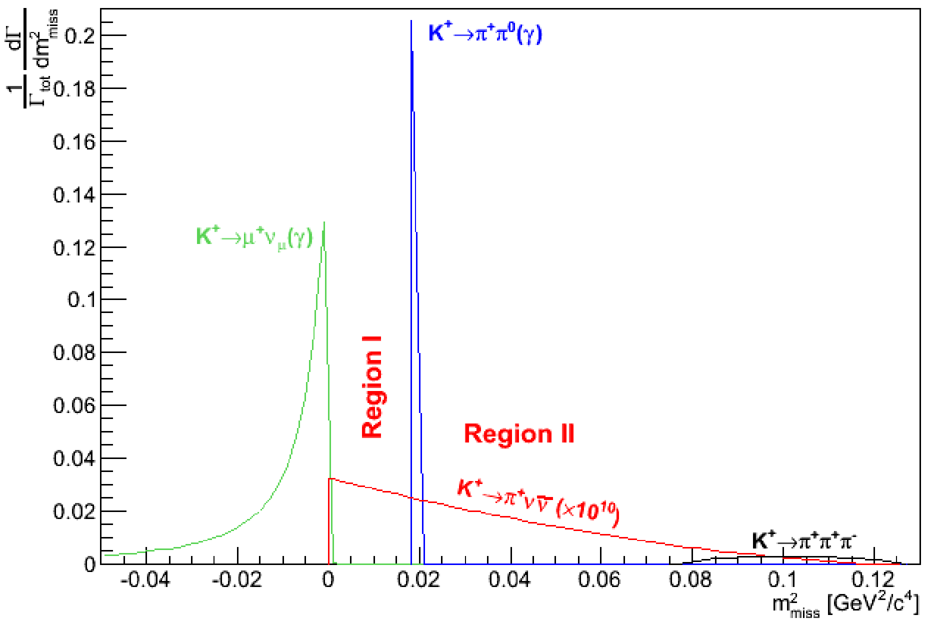
SPS proton
400 GeV
10^{12} p/s
3.5 s spill

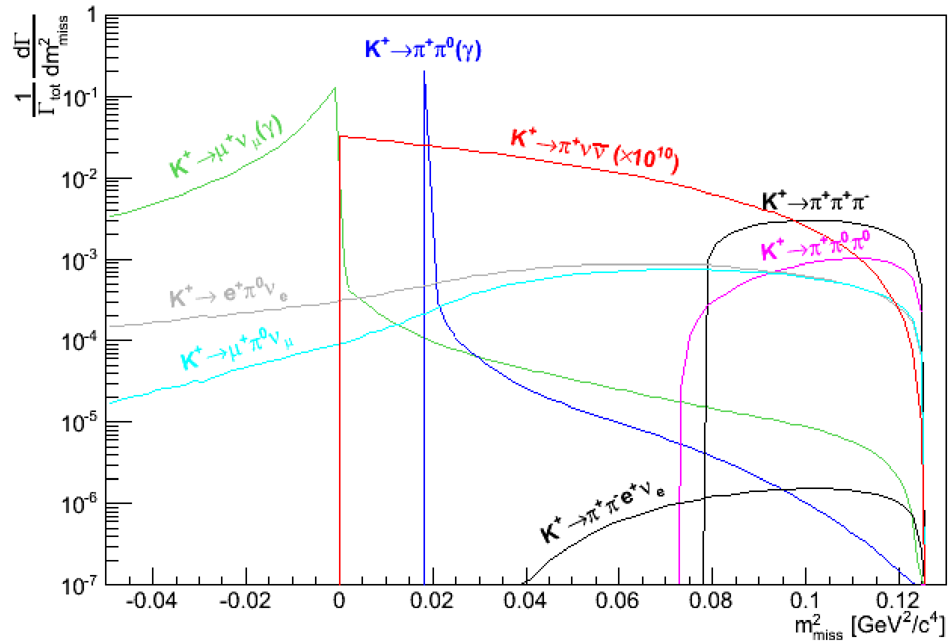
Secondary Beam
75 GeV/c, $\Delta p/p \sim 1\%$
X,Y Divergence < 100 μrad
K(6%), π(70%), p(23%)
Total rate: 750 MHz
Beam size: $6.0 \times 2.7\ cm^2$

Kaon Decay
~5 MHz
$4.5 \times 10^{12}/year$
60 m length
10^{-6} mbar vacuum

Detectors for decay products
Charged particle tracking
Charged particle time stamping
Photon detection
Particle ID

Analysis Method





Experimental Methods:

Two missing mass sq signal regions

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

Hermetic Photon Suppression

Particle ID: kaon upstream, μ/π downstream

Sub ns timing

Backgrounds:

K^+ decays

Beam Particles

Sensitivity/Background Suppression

- Required Background Suppression:

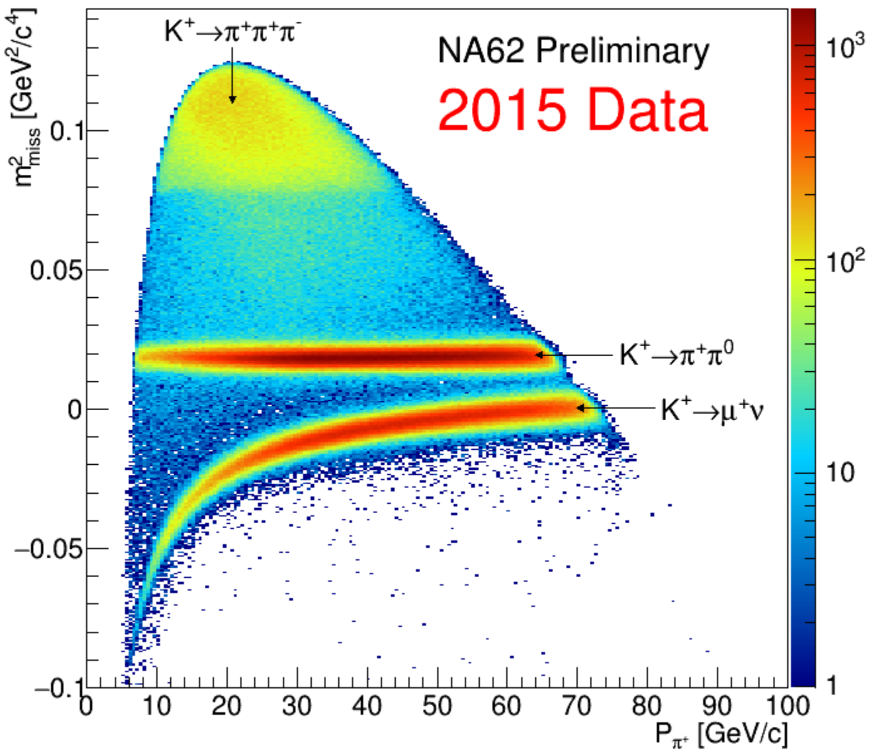
Kinematics	$O(10^4 - 10^5)$
Particle ID (charged)	$O(10^7)$
γ suppression	$O(10^8)$
timing	$O(10^2)$

Sensitivity

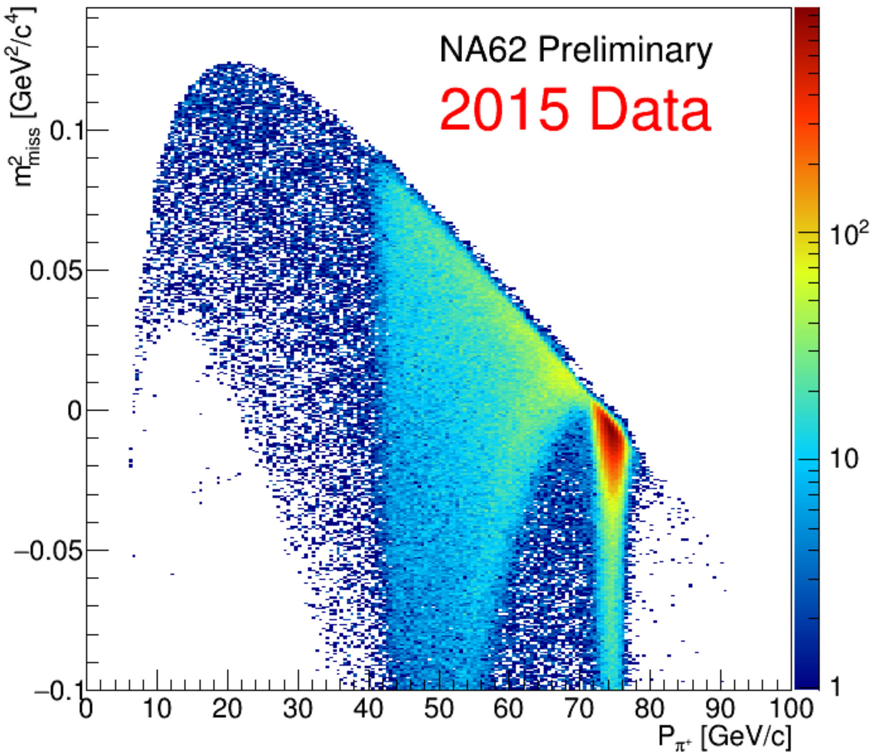
Decay	Events/year
$\boldsymbol{K^+ \to \pi^+ \nu\nu}$	**45**
$K^+ \to \pi^+ \pi^0$	5
$K^+ \to \pi^+ \pi^+ \pi^0$	1
Other three track decays	<1
$K^+ \to \pi^+ \pi^0 \gamma$	<1
$K^+ \to \mu^+ \nu\gamma$	1.5
$K^+ \to \pi^0 e^+ (\mu^+)$, others	0.5
Total BG	**<10**

Kaon ID

One Track Selection and Kaon ID



One Track Selection no Kaon ID



One Track Selection (OTS)

Downstream track matches calo energy

Beam track matches downstream track

Kaon ID

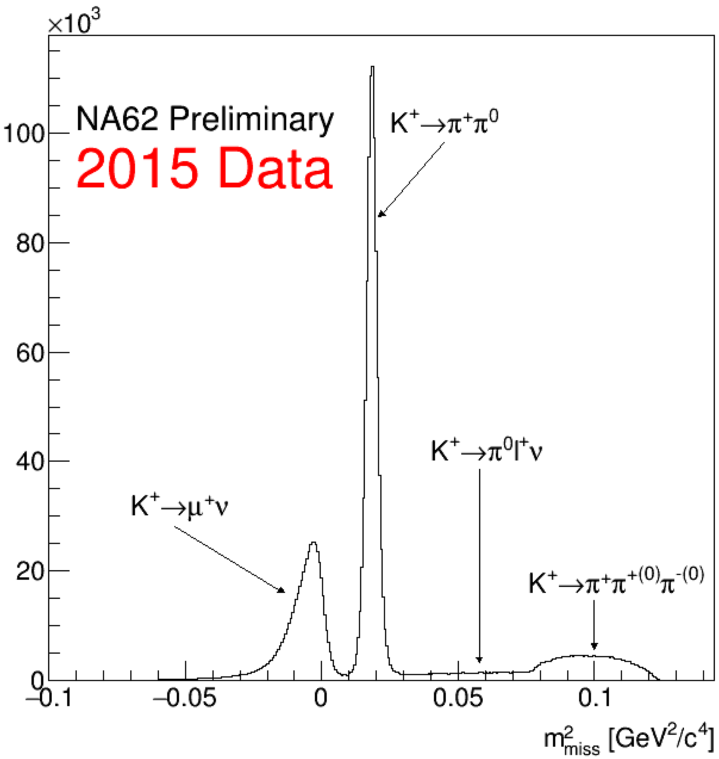
Beam track matches signal in kaon ID

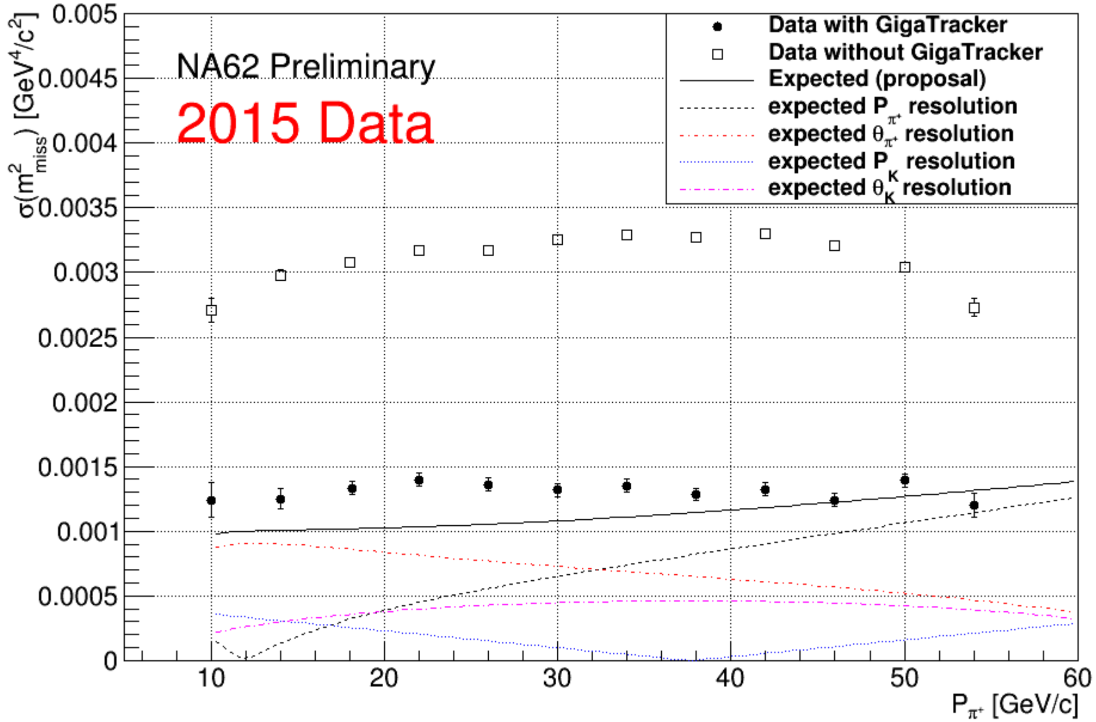
Decay in fiducial region

Timing Resolutions

Kaon ID	<100ps
Beam Track	<100ps
Downstream Track	<200ps
Calorimeters	<1-2ns

Kinematics





Particle Tracking/Momentum Measurement:

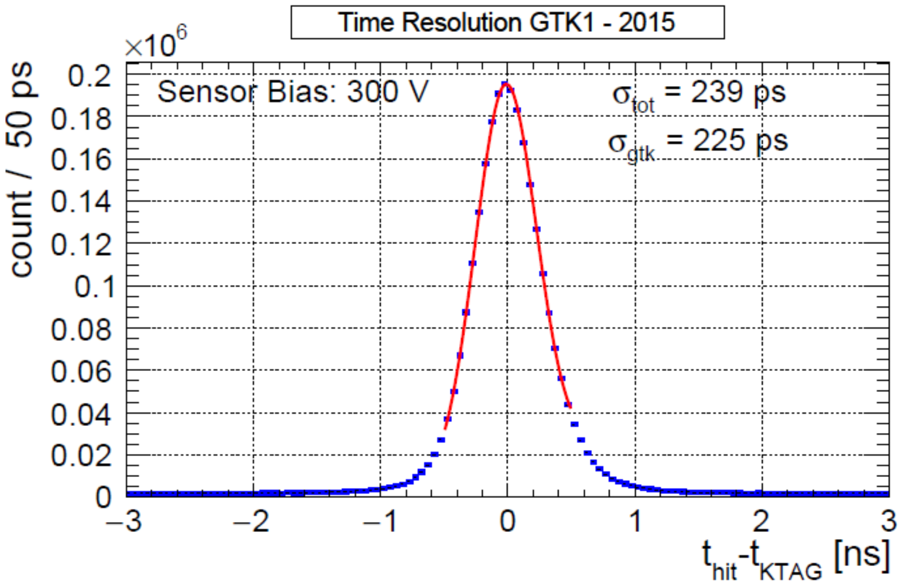
Goal of O(10^4-10^5) suppression from kinematics

Select events w/ $P_{\pi^+} < 35\ GeV$ to optimize γ suppression

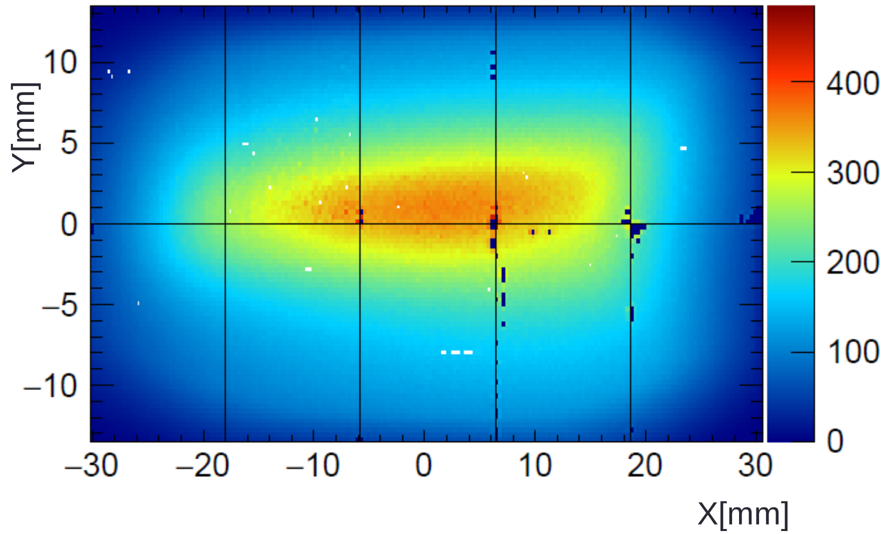
Missing Mass Squared resolution close to design value

O(10^3) kinematic suppression obtained

Beam Tracker (GigaTracker)



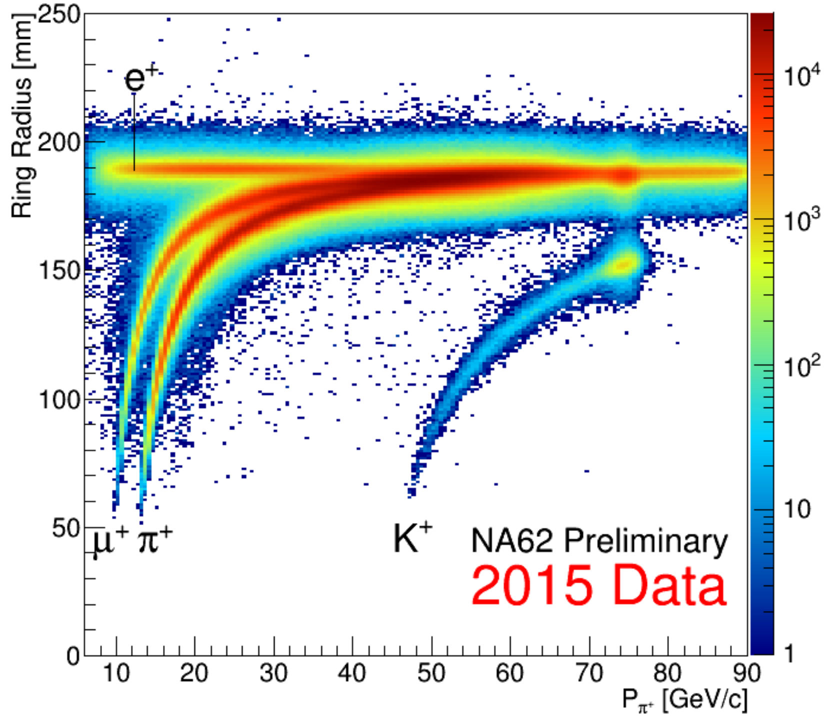
Hit Map of GTK 1

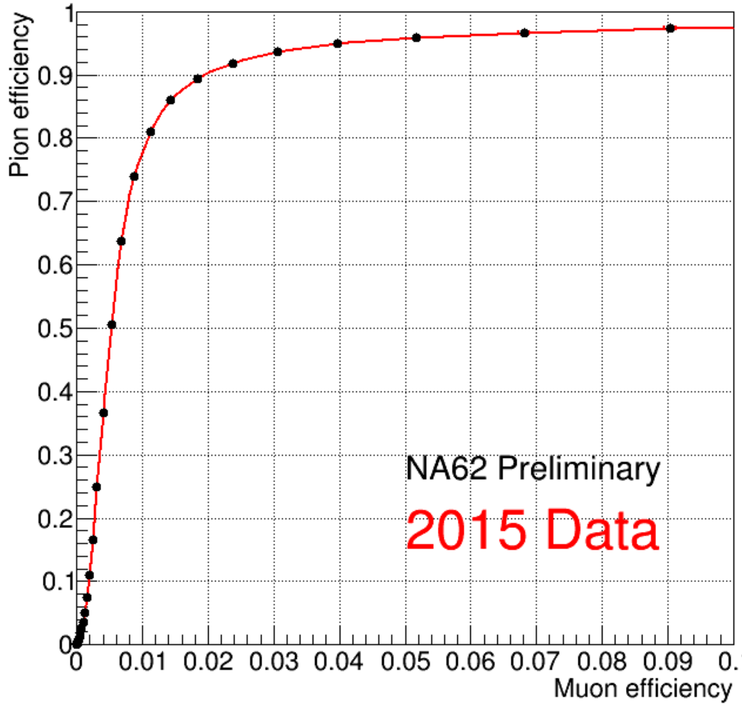


GigaTracker Description

3 Si Pixel Detector Stations
300 x 300 μm pixels, ~54,000 total
On-sensor TDC readout chip
X/X_0<0.5%/station
Measured performance matches design

Downstream Particle Identification





Detectors: RICH & calorimeters

Requirement: O(10^7) π/μ separation

$15 < P_{\pi^+} < 35\ GeV$ selection optimizes RICH separation

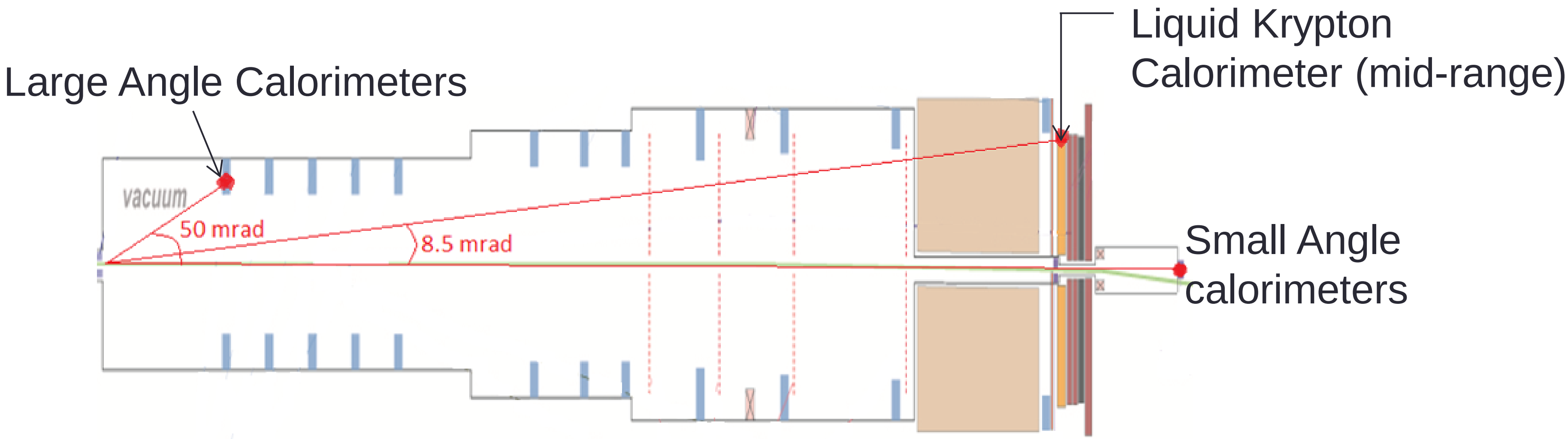
Measured Performance

-Use pure samples of kinematically selected π/μ

-RICH: O(10^2) π/μ separation, 80%(90%) π efficiency in 2015 (2016)

-Calorimeters: $(10^4 - 10^6)$ μ suppression, (90%-40%) π efficiency using cut analysis. Will improve with multi variate analysis.

Photon Suppression



Detectors: EM Calorimeters

Requirement: O(10^8) rejection of π^0

If $P_{\pi^+} < 35\ GeV/c$, then $E_{\pi^0} > 40\ GeV$

Measured Performance

-Use kinematically selected
$K^+ \rightarrow \pi^+\pi^0$ events

-O(10^6) upper limit on pi0 rejection in 2015, limited by statistics and background.

Timeline/Outlook

- Detector fully commissioned in 2014
- Measured missing mass squared resolution/background rejection factors approaching design values
- Beam ran at ~50% nominal intensity in 2016.
- 2016 data currently being analyzed. Hopeful to reach sensitivity of $K^+ \rightarrow \pi^+ \nu\nu$.