Recent results from the NA62 experiment at CERN

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(on behalf of the NA62 collaboration)

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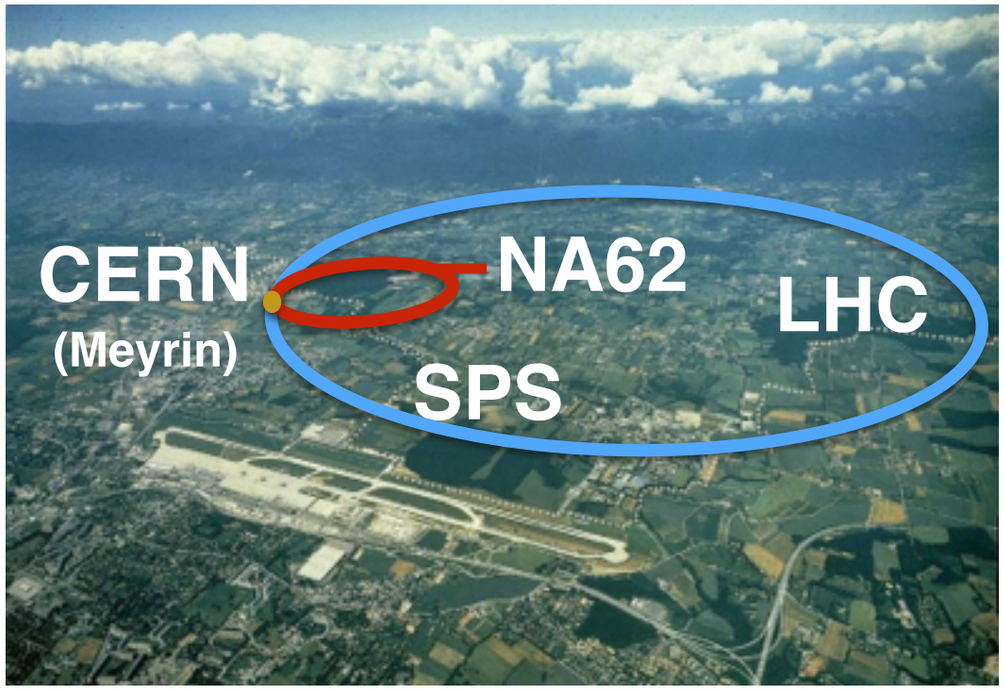
The NA62 Experiment

Fixed Target Experiment

Located at the North Area of CERN

75 GeV/c Secondary Hadron Beam

Carry on the tradition of Kaon experiments at CERN - SPS



NA62 2007 Data Taking

NA48 Apparatus

Beam:

- Simultaneous $K^{\pm}$
- 74 GeV/c

Main Detectors:

- Magnetic Spectrometer

  $\sigma(P)/P = 0.48\% \oplus 0.009\ P(GeV/c)\%$

  $\sigma(P)/P$ @ 20 GeV/c = 0.51%

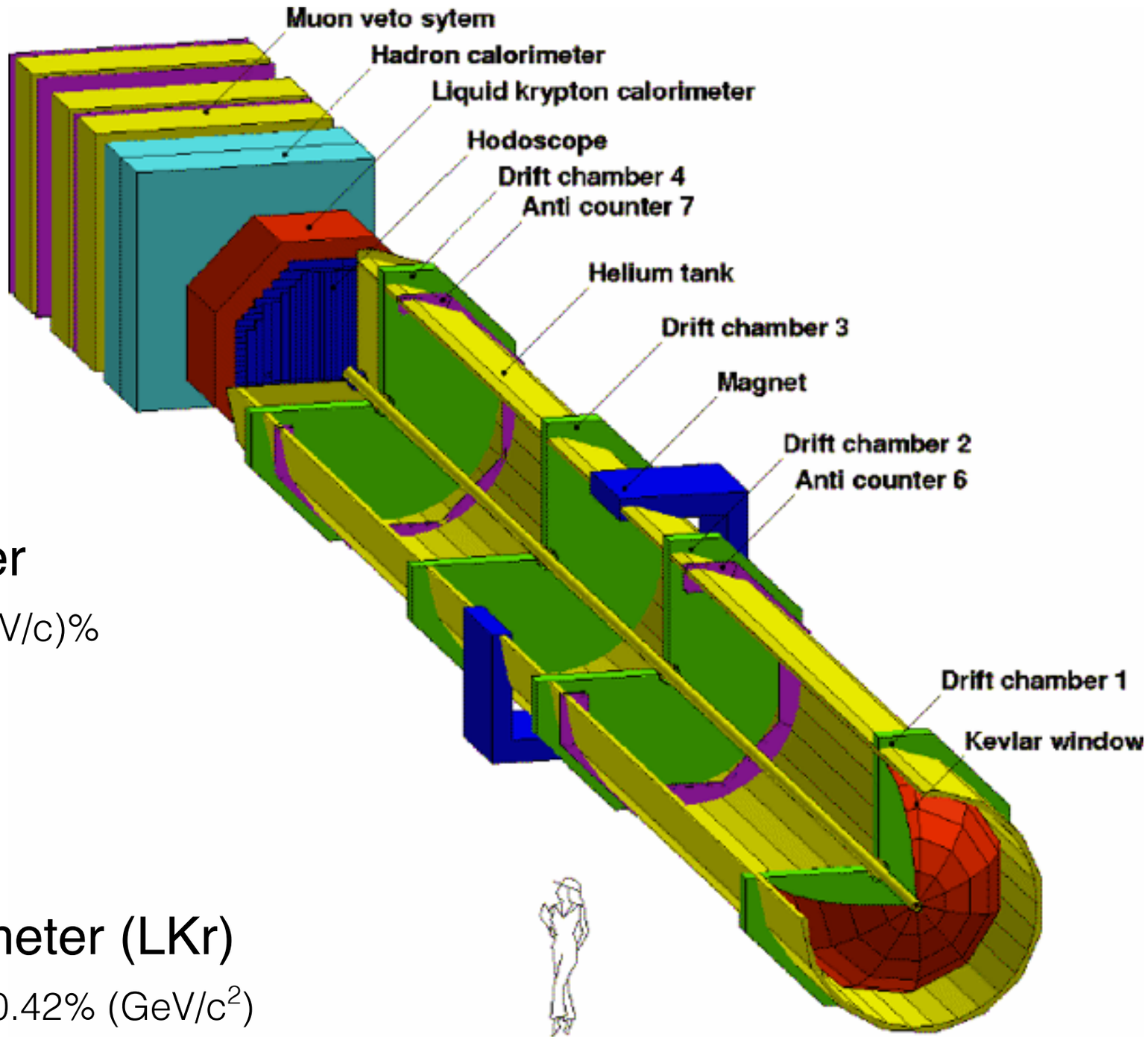
- Hodoscope

  $\sigma(t) \approx 200$ ps

- Liquid Krypton Calorimeter (LKr)

  $\sigma(E)/E = 3.2\%/\sqrt{E} \oplus 9\%/E \oplus 0.42\%$ (GeV/c^2)

  $\sigma(E)/E$ @ 20 GeV/c^2 = 0.94%



Transition Form Factor

$$\pi^o \rightarrow \gamma\gamma^* \rightarrow \gamma e^+ e^-$$

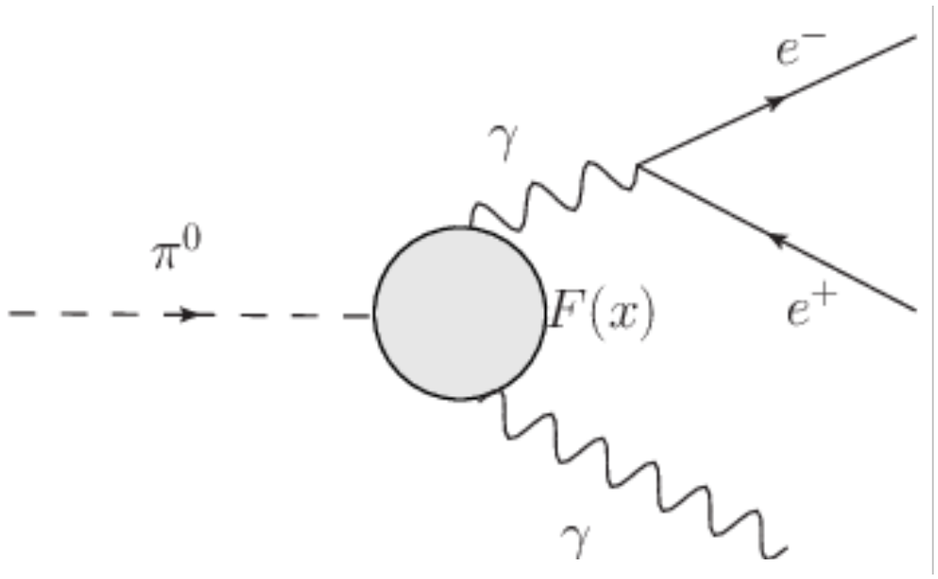
TFF

$$\frac{1}{\Gamma\left(\pi^o_{2\gamma}\right)}\frac{d\Gamma\left(\pi^o_D\right)}{dx} = \frac{2\alpha}{3\pi}\frac{\left(1-x\right)^3}{x}\left(1+\frac{r^2}{2x}\right)\sqrt{1-\frac{r^2}{x}}\left(1+\delta\left(x\right)\right)\left(1+ax\right)^2$$

$$x = \frac{\left(p_{e^-}+p_{e^+}\right)^2}{m^2_{\pi^o}} \qquad r^2 = \left(\frac{2m_e}{m_{\pi^o}}\right)^2$$

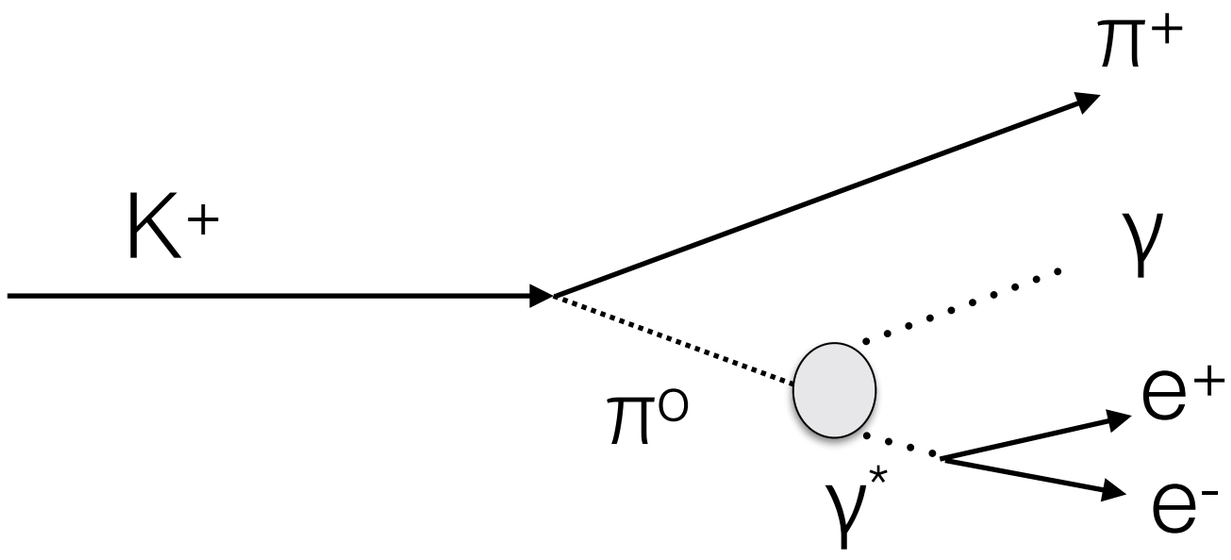
- Transition Form Factor (TFF) to parameterise low energy QCD in π^o
- TFF Theoretical models used in the hadronic light-by-light scattering contribution to $(g-2)_\mu$
- Missing precise direct measurement of the TFF to test theoretical models

$\delta\left(x\right)$ Radiative Corrections



Selection

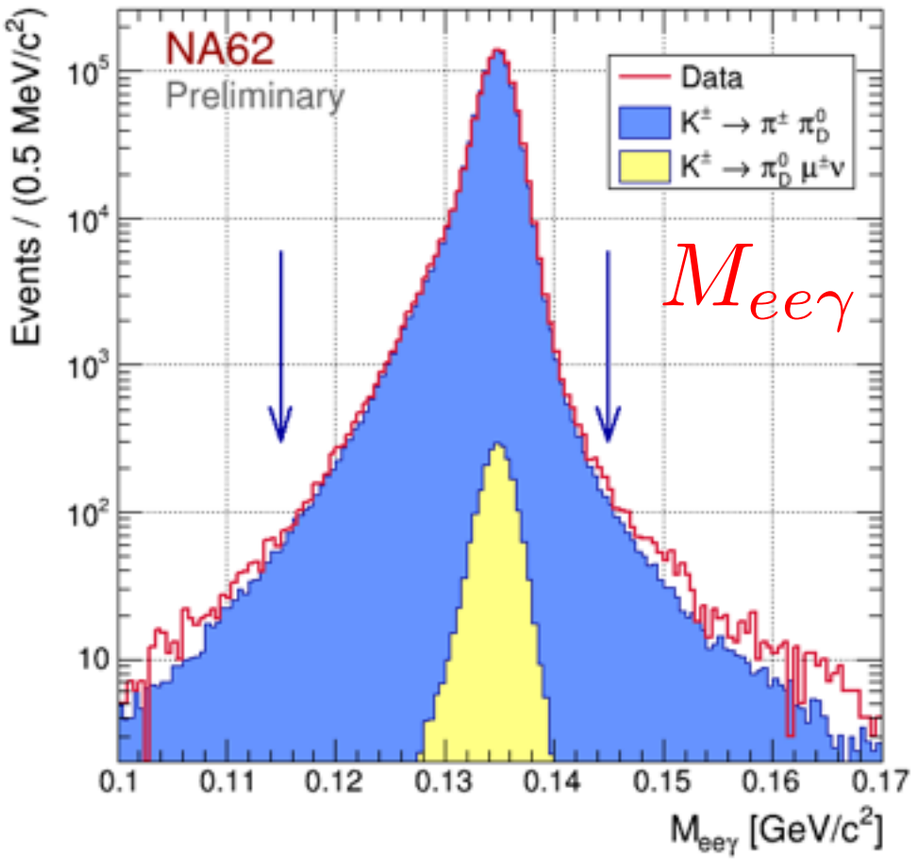
- Full kinematic reconstruction of $K^{\pm} \to \pi^{\pm}\pi^{0}_{D}$ events

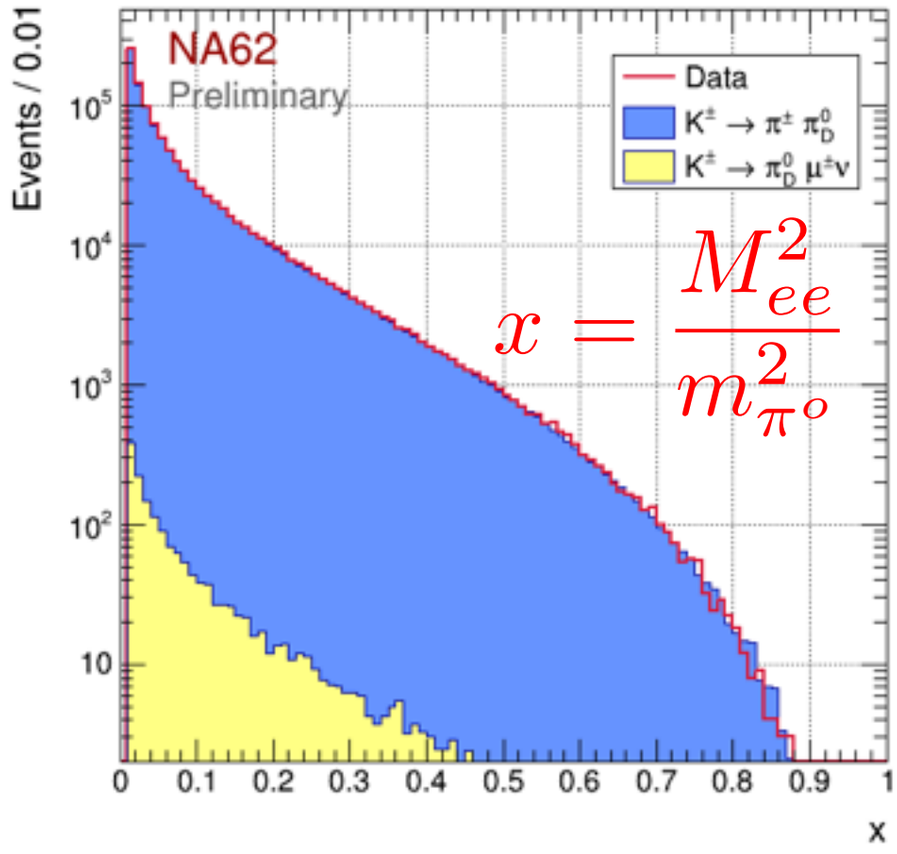


- 3 track topology ($\pi^{\pm}$, e^{+}, e^{-})
- 1 Photon in the LKr Calorimeter
- $x > 0.01$

Selection

- Full kinematic reconstruction of $K^{\pm} \rightarrow \pi^{\pm}\pi^{0}_{D}$ events

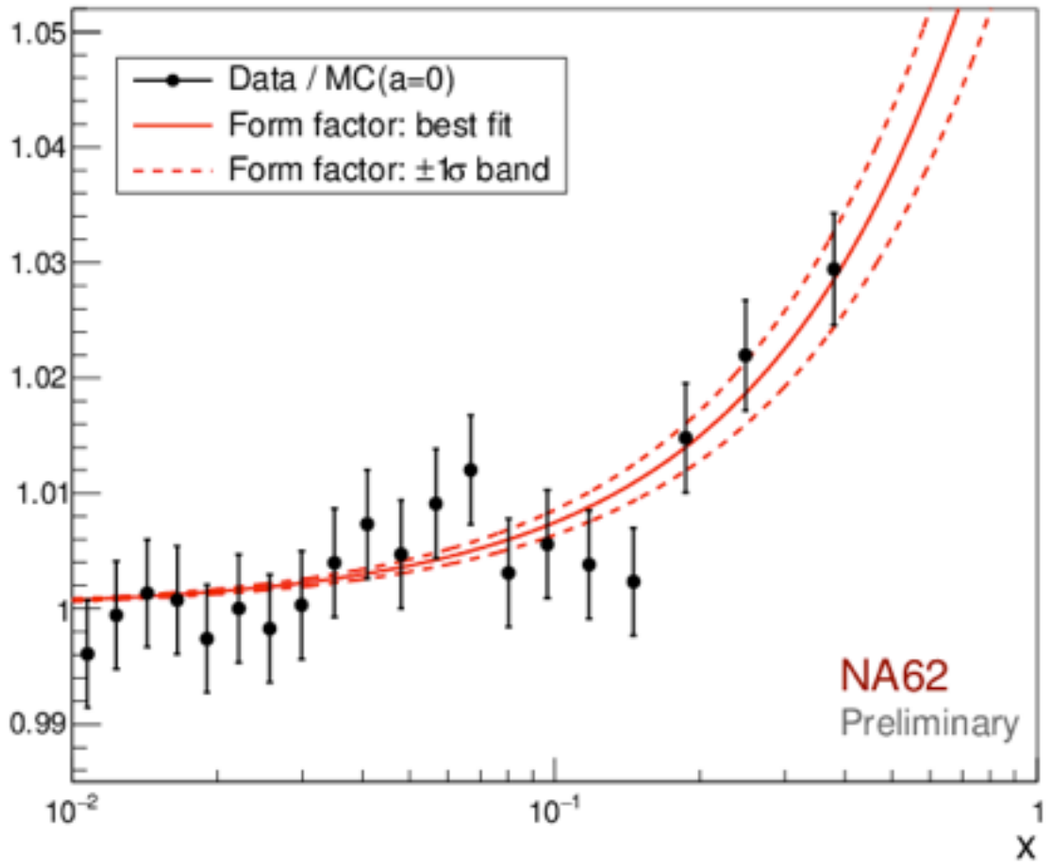


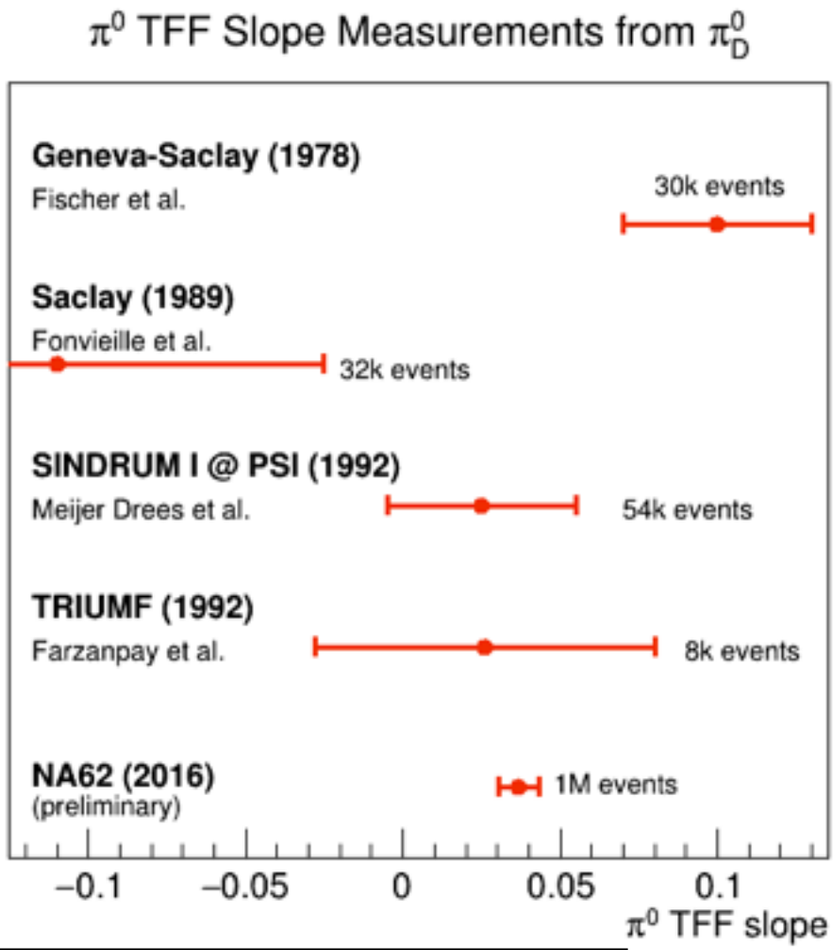


- 1.06 M of $\pi^{o} \rightarrow \gamma\, e^{+}e^{-}$ candidates selected

- TFF obtained by fitting the simulation to the data x spectrum

Preliminary Results





$$a = (3.70 \pm 0.53_{stat} \pm 0.36_{syst}) \times 10^{-2}$$

Theoretical Expectation

- a = (2.90 ± 0.50) x 10^{-2}, χPT, [K. Kampf et al. EPJ C46 (2006), 191]
- a = (3.07 ± 0.06) x 10^{-2}, dispersion theory, [M. Hoferichter et al. EPJ C74 (2014), 3180]
- a = (2.92 ± 0.04) x 10^{-2}, two hadron saturation, [T. Husek et al. EPJ C75 (2015) , 586]

The NA62 Experiment

Goal

- Measure BR($K^+ \to \pi^+ \nu\bar{\nu}$) with 10% precision

Requirement

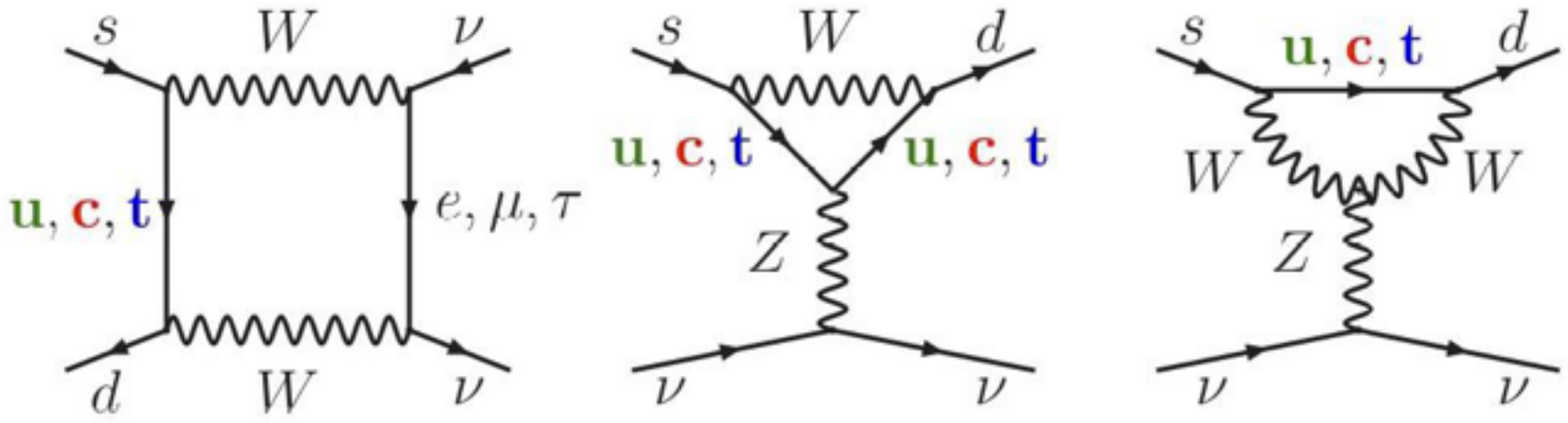
- Collect around **100 events** in the next 2 years (statistics)
  - ➡ **10^{13} K^+ decays** in 2 years with 10% acceptance
- Better than **10% precision** on background measurement (systematics)
  - ➡ **10^{12} background rejection** (<20% background)

Data

- **Runs** in **2014** and **2015**
- **Next Physics run starts end of April**

BR($K^+ \to \pi^+ \nu\bar{\nu}$): Theoretical Motivation

- **FCNC loop** process, highly suppressed, theoretically **very clean**



- **Well calculated** inside the **SM** [A.J. Buras et al., JHEP 1511 (2015) 033]

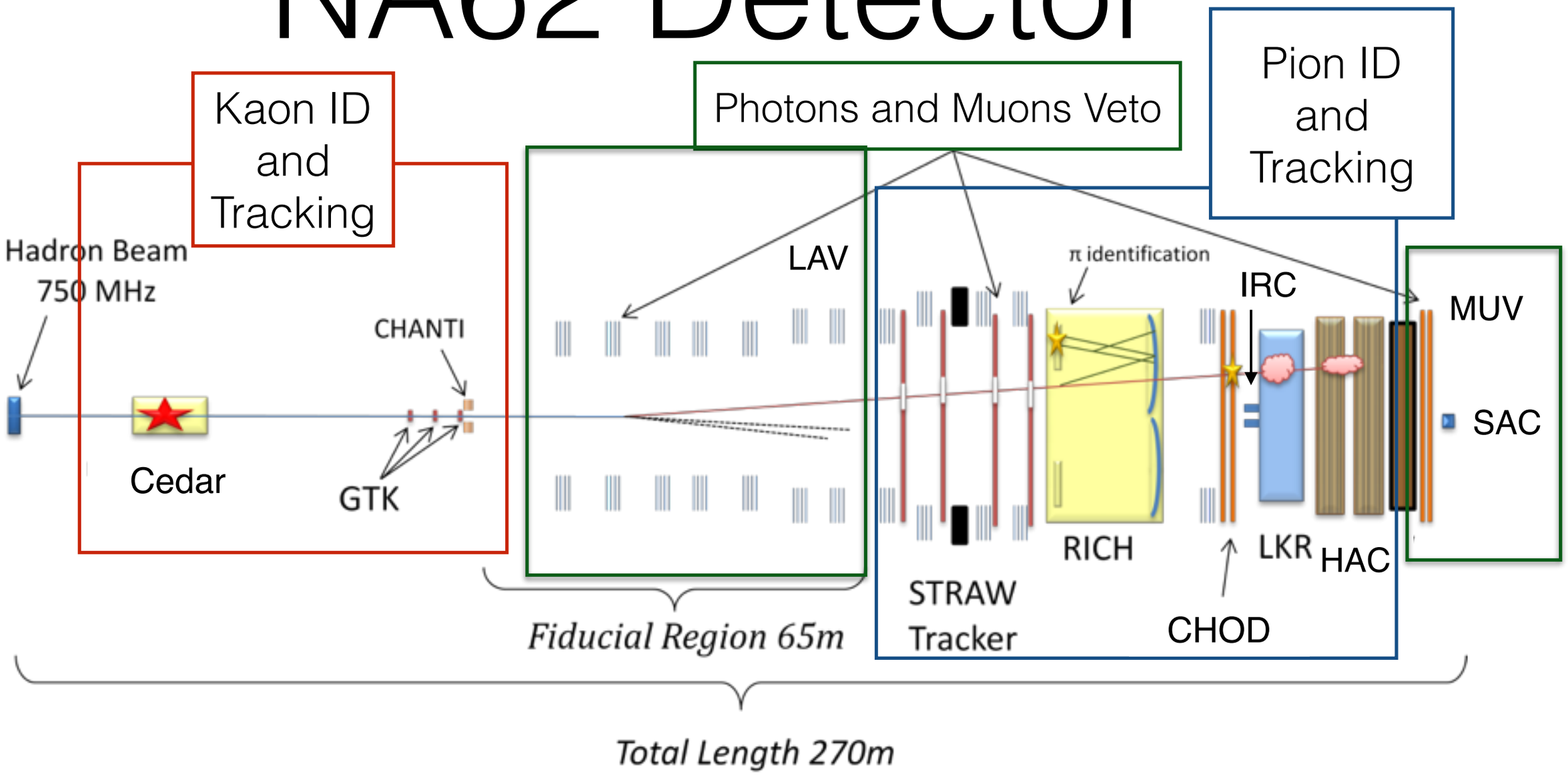
$$BR_{SM}\left(K^+ \to \pi^+ \nu\bar{\nu}\right) = (9.11 \pm 0.72) \times 10^{-11}$$

- Previous **Measurement** (only **7 events**) [BNL E787/E949: PRL101 (2008) 191802]

$$BR_{exp}\left(K^+ \to \pi^+ \nu\bar{\nu}\right) = \left(17.3^{+11.5}_{-10.5}\right) \times 10^{-11}$$

Any deviation from the expected value is a hint of new physics

NA62 Detector



SPS Protons

400 GeV

10^{12} protons/s

3.5 s spill

→ Beryllium Target →

Secondary Beam

75 GeV, $\Delta p/p \sim 1\%$

K (6%), p (23%), π (70%)

750 MHz

→

Kaon Decays

~ 5MHz

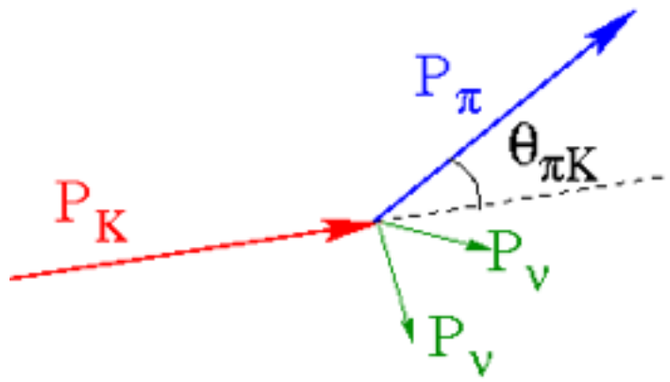
4.5×10^{12} per year

10^{-6} mbar vacuum

Analysis Strategy

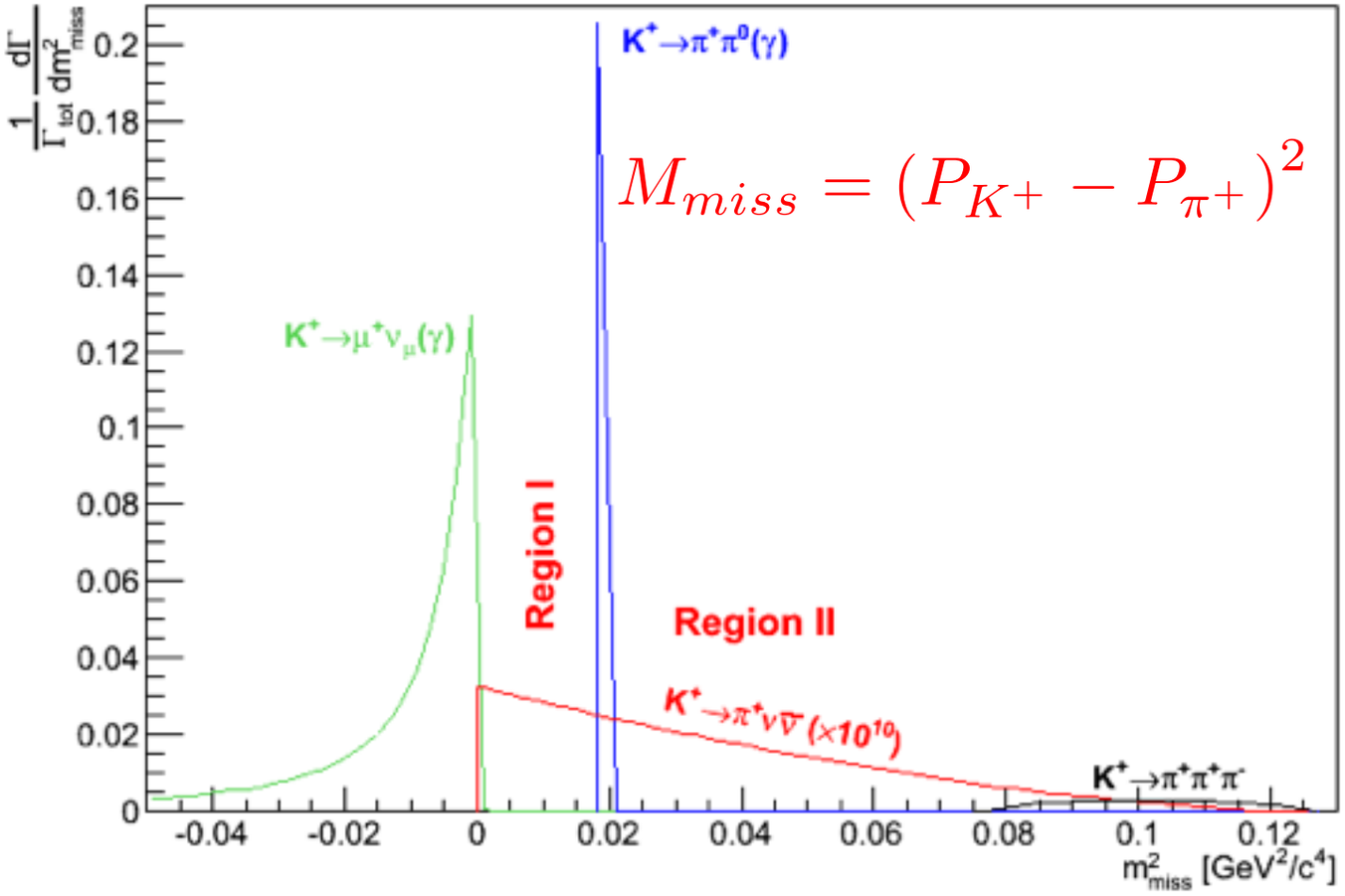
Signal:

- ✓ one beam K^+
- ✓ one π^+
- ✓ **nothing** else



Background:

- x **Beam** activity
- x other K^+ **decays**

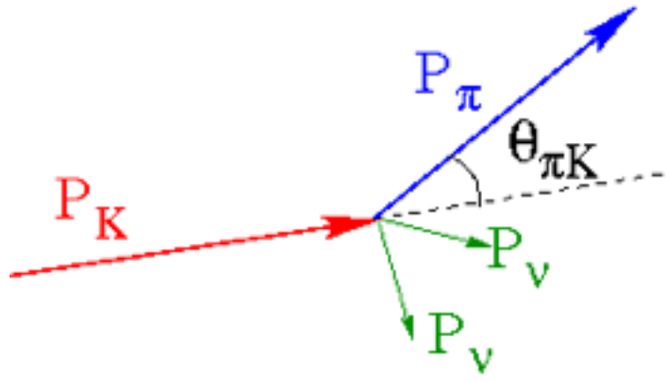


- Precise **kinematic** reconstruction
  - ➡ 2 signal regions
- **PID** for kaons and pions
  - ➡ $15 < P_\pi < 35$ GeV/c
- Hermetic **photon detection**
  - ➡ 65 m long fiducial region

Analysis Strategy

Signal:

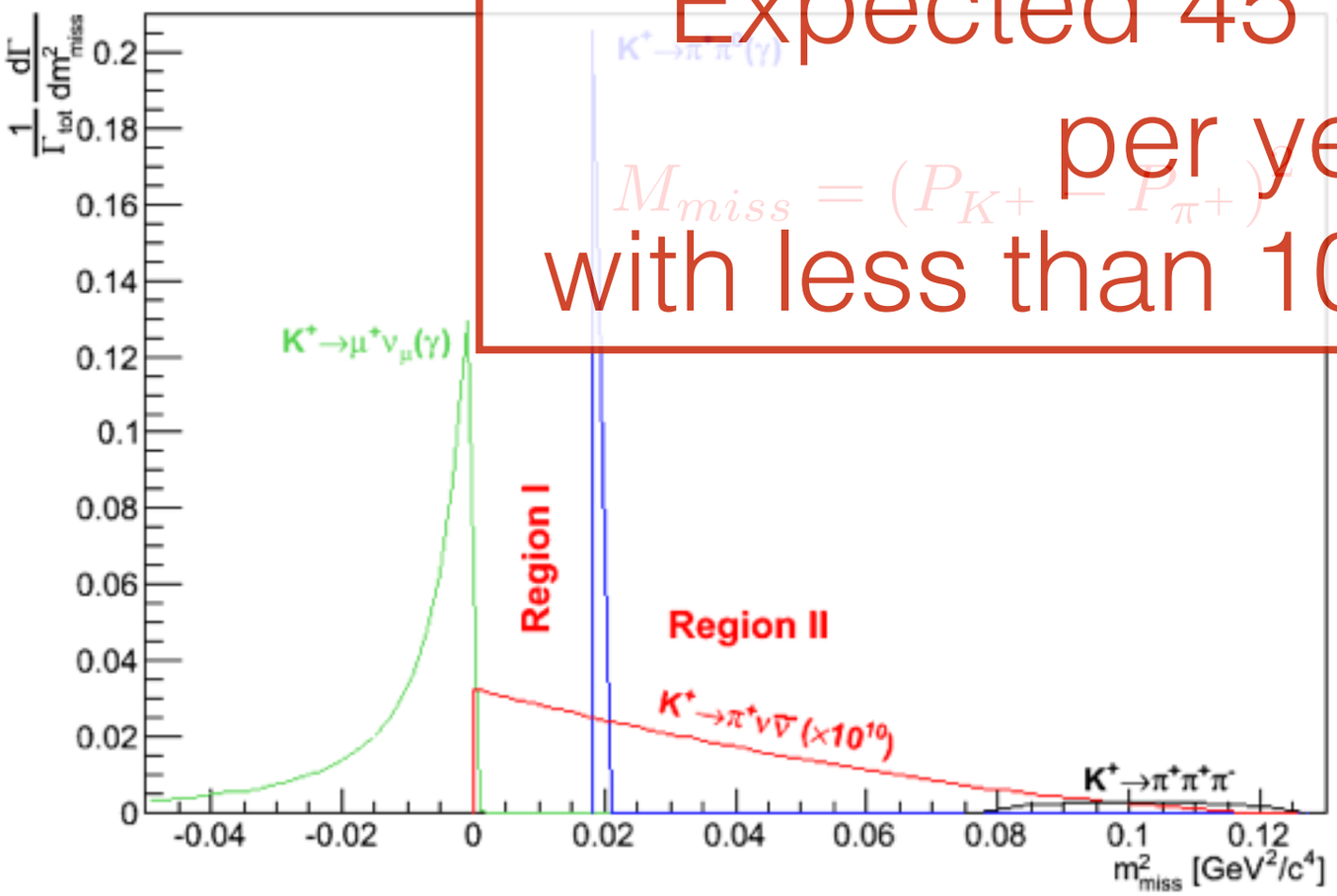
- ✓ one beam K^+
- ✓ one π^+
- ✓ **nothing** else



Background:

- x **Beam** activity
- x other K^+ **decays**

Expected 45 SM events per year with less than 10 background



- Precise **kinematic** reconstruction
  - ➡ 2 signal regions
- **PID** for kaons and pions
  - ➡ $15 < P_\pi < 35$ GeV/c
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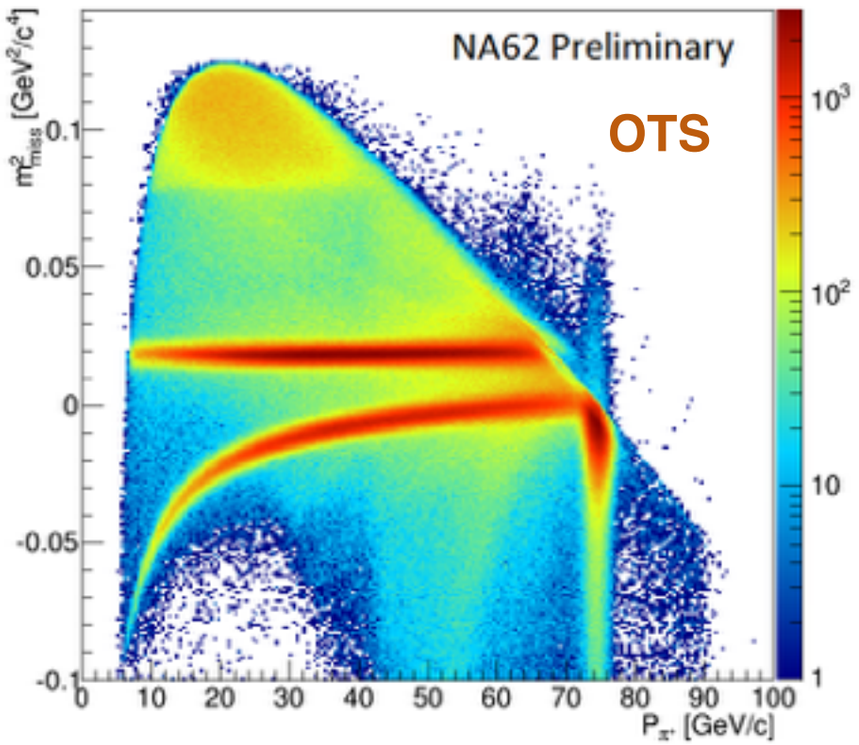
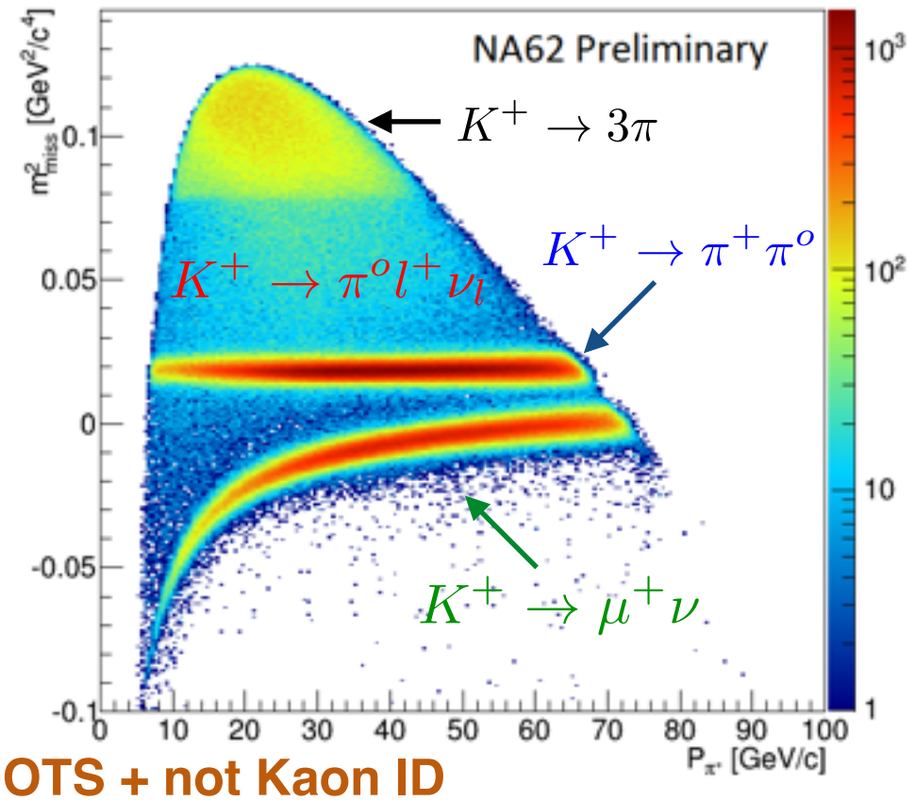
Signal Topology and Kaon ID



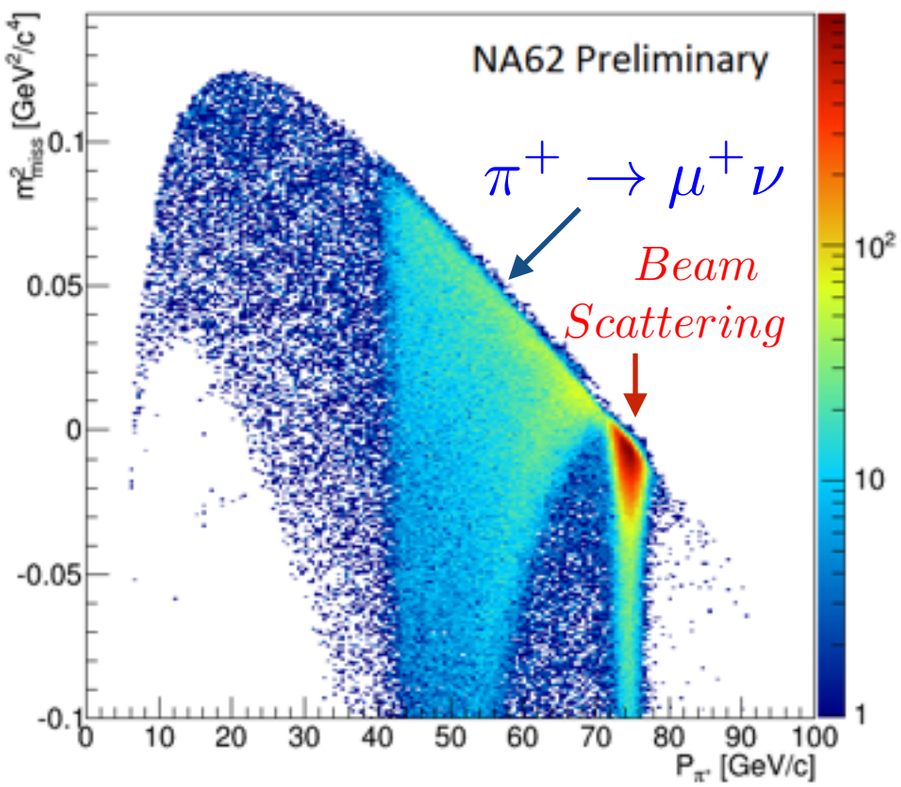
Kaon ID

Not Kaon ID

OTS + Kaon ID + Vertex Cut



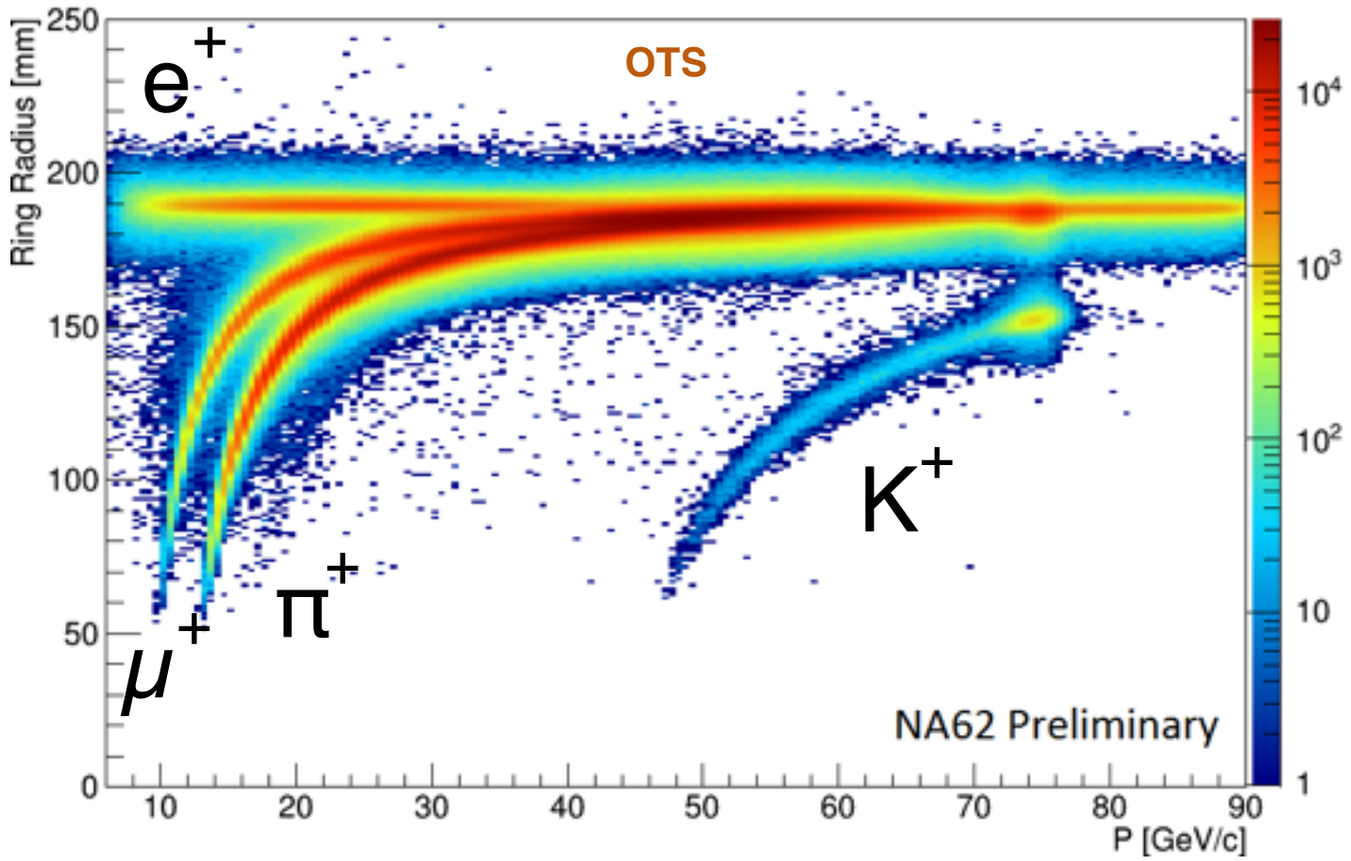
OTS + not Kaon ID

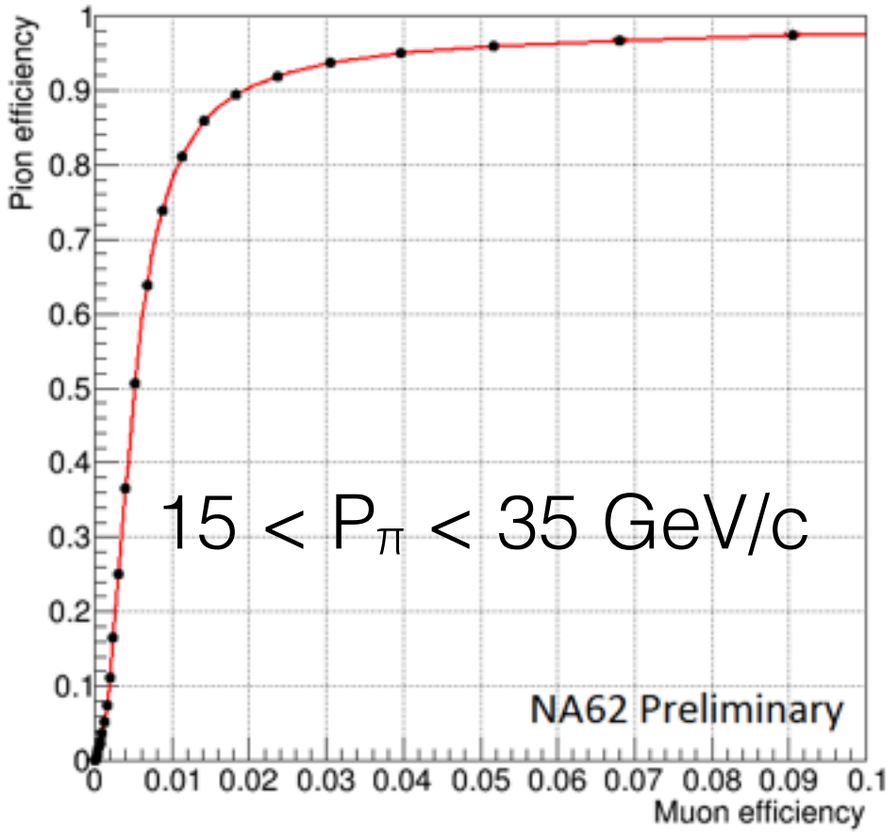


One Track Selection (OTS)

- One downstream track topology
- Beam track matching
- Kaon tag in CEDAR (Kaon ID)
- Energy in the calorimeters

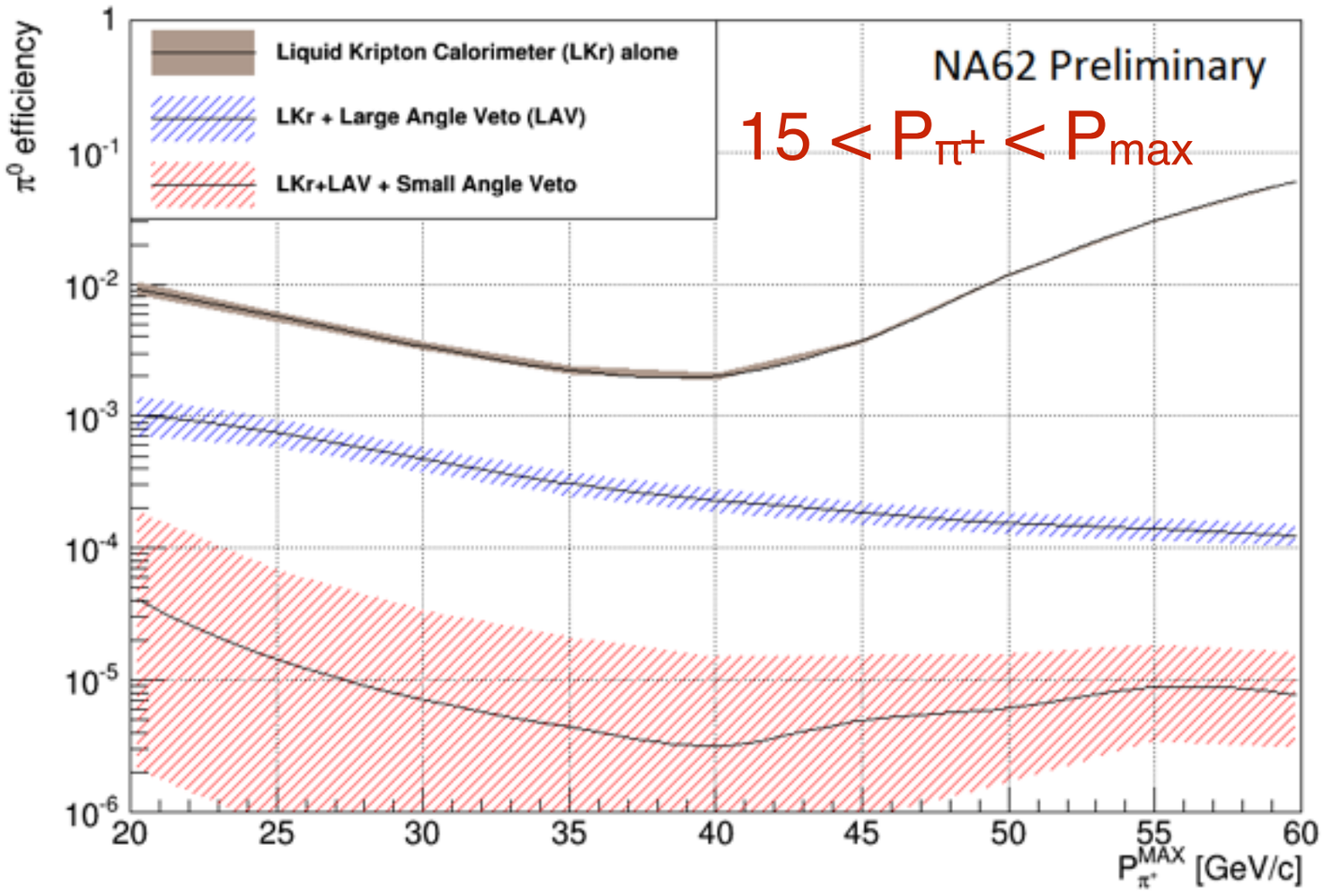
2015 Data Quality: PID





- ✓ Information from **RICH and Calorimeters**
- ✓ **Need O(10^7)** μ suppression, mainly **for $K^+ \rightarrow \mu^+\nu$**
- ✓ **80% pion efficiency in RICH with O(10^2) π/μ separation**
- ✓ Simple cut analysis **on calorimeters** provide **($10^4 \div 10^6$) μ suppression**, with (90%÷40%) π efficiency
  - ➡ **Room for improvement**

2015 Data Quality: Photon Veto



- ✓ Exploiting **correlation between photons from** the same **π^0**
- ✓ **Need O(10^8)** rejection of π^0, mainly **for $K^+ \rightarrow \pi^+\pi^0$** suppression
- ✓ **2015 Measurement statistically limited**

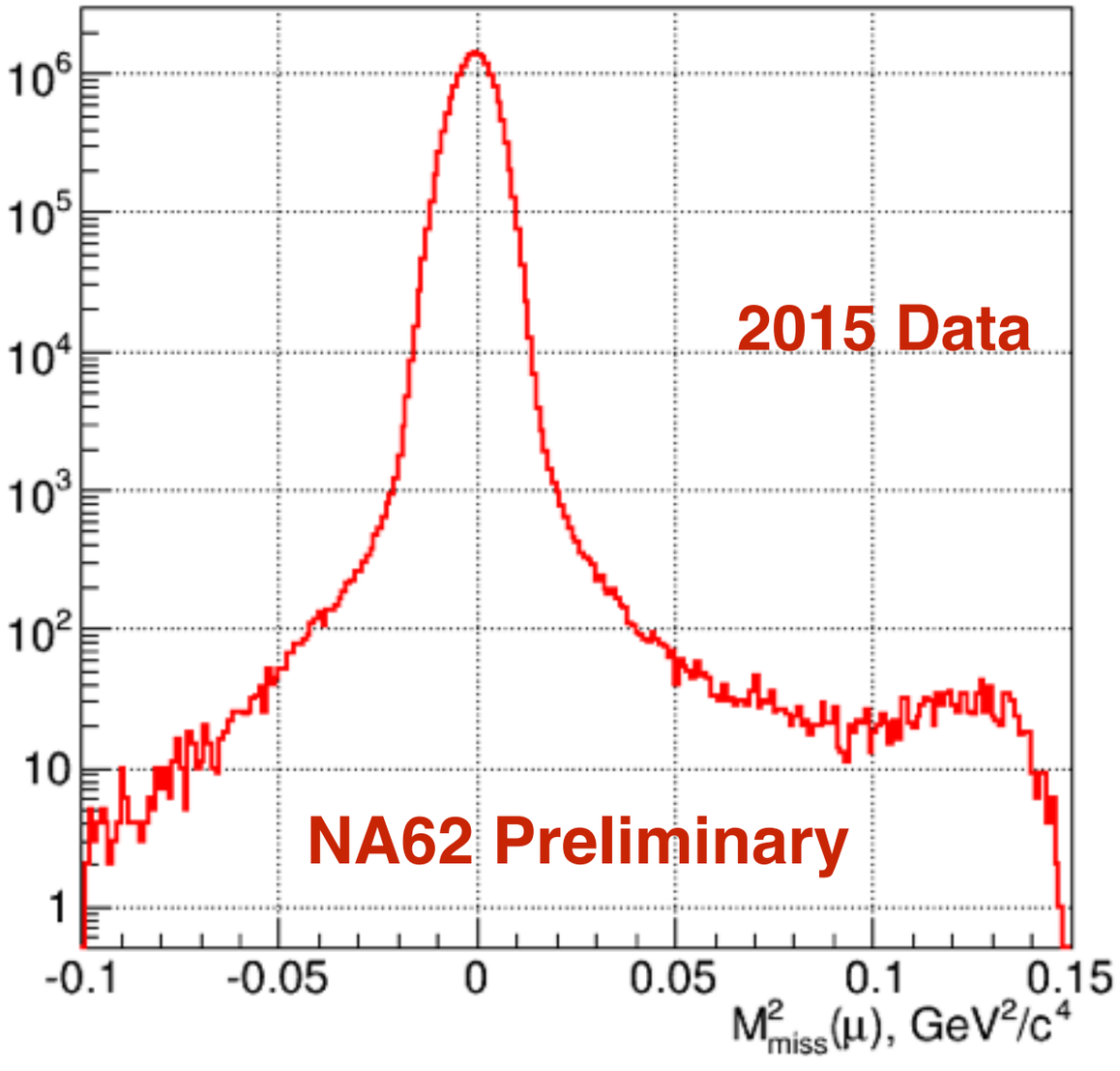
Other Physics Program

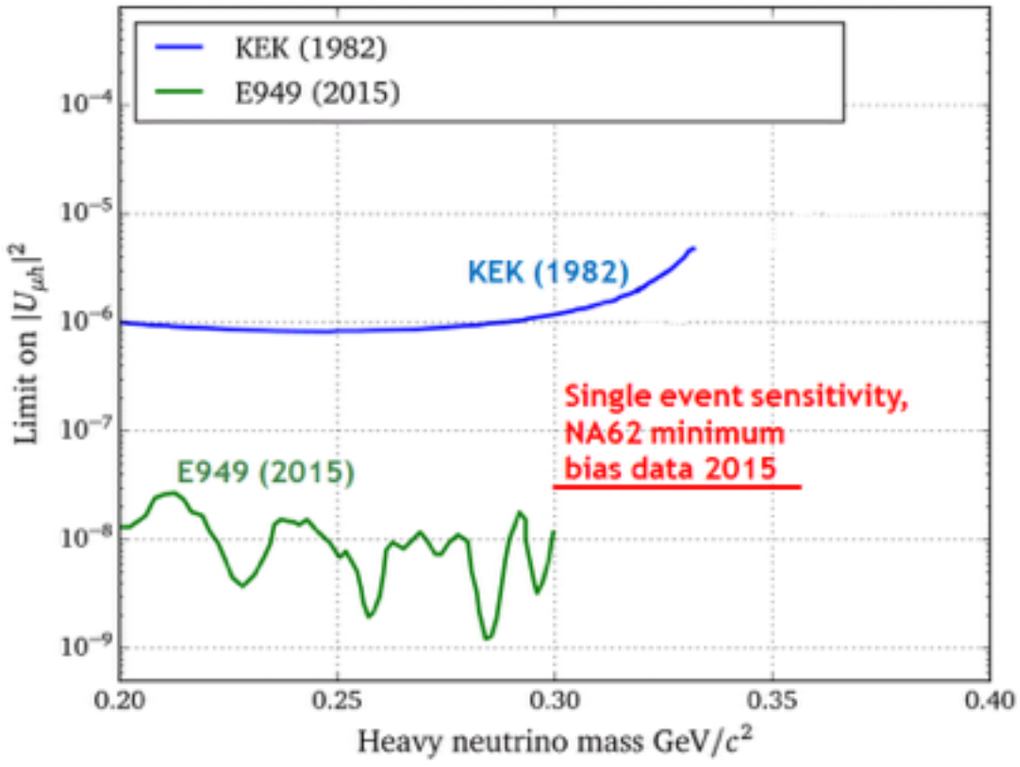
- Compelling Physics program at NA62

Decay	Physics	Present limit (90% C.L.) / Result	NA62
$\pi^+\mu^+e^-$	LFV	1.3×10^{-11}	0.7×10^{-12}
$\pi^+\mu^-e^+$	LFV	5.2×10^{-10}	0.7×10^{-12}
$\pi^-\mu^+e^+$	LNV	5.0×10^{-10}	0.7×10^{-12}
$\pi^-e^+e^+$	LNV	6.4×10^{-10}	2×10^{-12}
$\pi^-\mu^+\mu^+$	LNV	1.1×10^{-9}	0.4×10^{-12}
$\mu^-\nu e^+e^+$	LNV/LFV	2.0×10^{-8}	4×10^{-12}
$e^-\nu\mu^+\mu^+$	LNV	No data	10^{-12}
π^+X^0	New Particle	$5.9 \times 10^{-11}\ m_{X^0} = 0$	10^{-12}
$\pi^+\chi\chi$	New Particle	–	10^{-12}
$\pi^+\pi^+e^-\nu$	$\Delta S \neq \Delta Q$	1.2×10^{-8}	10^{-11}
$\pi^+\pi^+\mu^-\nu$	$\Delta S \neq \Delta Q$	3.0×10^{-6}	10^{-11}
$\pi^+\gamma$	Angular Mom.	2.3×10^{-9}	10^{-12}
$\mu^+\nu_h, \nu_h \to \nu\gamma$	Heavy neutrino	Limits up to $m_{\nu_h} = 350\ MeV$	
R_K	LU	$(2.488 \pm 0.010) \times 10^{-5}$	>×2 better
$\pi^+\gamma\gamma$	χPT	< 500 events	10^5 events
$\pi^0\pi^0e^+\nu$	χPT	66000 events	$O(10^6)$
$\pi^0\pi^0\mu^+\nu$	χPT	-	$O(10^5)$

Other Physics Program

- Compelling Physics program at NA62
- Search for heavy neutrinos in $K^+ \rightarrow e^+ \nu_h$ and $K^+ \rightarrow \mu^+ \nu_h$ decays





- Sensitive for mass region 100 - 380 MeV/c^2
- Background in the mass search region ~5 order of magnitude below the $K^+ \rightarrow l^+ \nu_{SM}$ peak

Conclusion

- Preliminary **world best measurement of π^0** Transition Form Factor (**TFF**) **slope** performed using NA62 2007 data

$$a = (3.70 \pm 0.53_{stat} \pm 0.36_{syst}) \times 10^{-2}$$

- **Commissioning** of the NA62 experiment for $K^+ \to \pi^+ \nu\bar{\nu}$ **is over**
- Preliminary study of the data at low intensity:
  - **Physics sensitivity** for the $K^+ \to \pi^+ \nu\bar{\nu}$ measurement is **close to the design**
  - Analysis of higher intensity data is on going
  - A further interesting physics program is going to be addressed
- Data taking will resume on the April 25th with around 200 days of run in 2016

Backup Slides

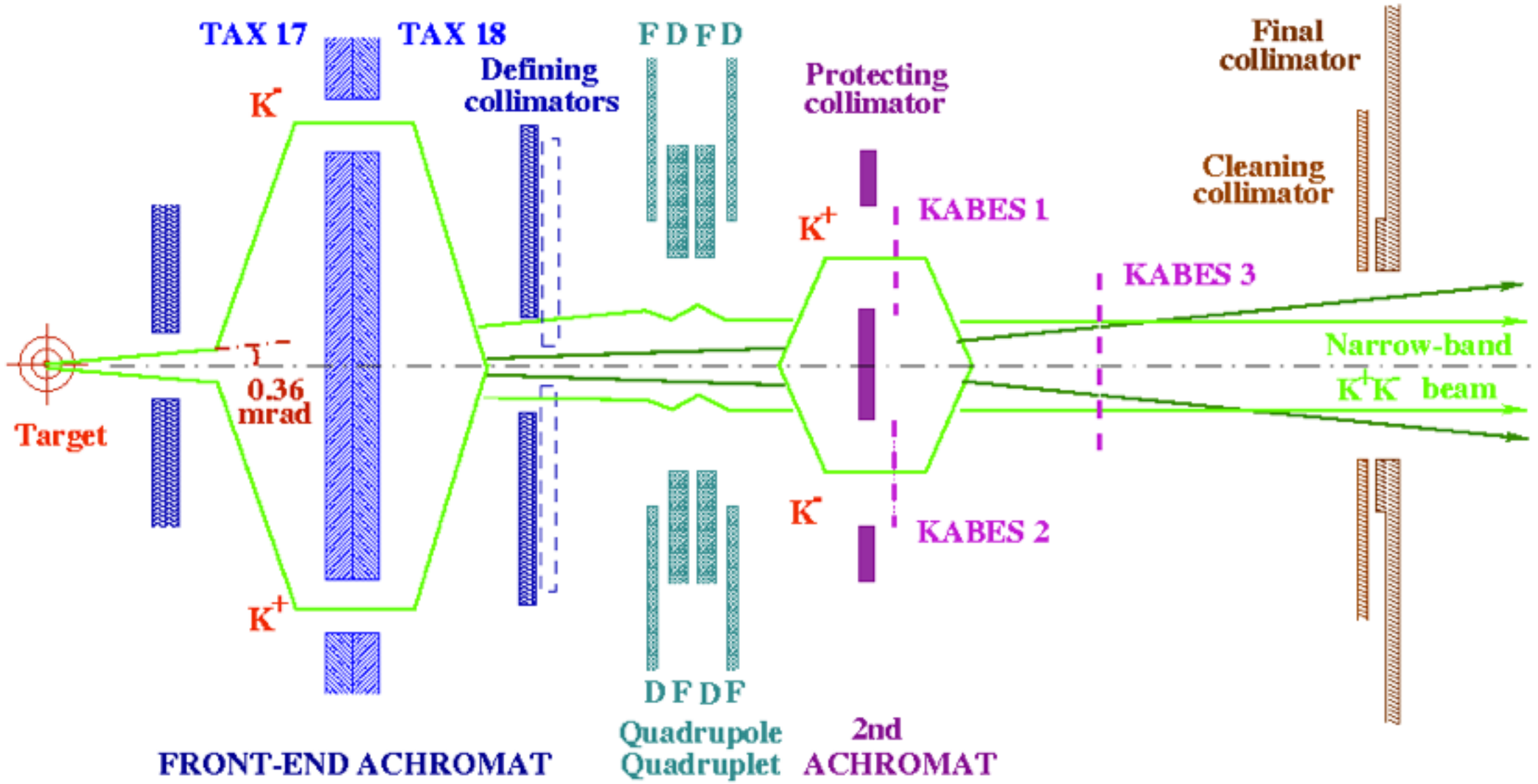
Kaon @ CERN - SPS

’86 - ‘89	**NA31**	**Hint** of direct **CP violation** in Neutral Kaon decays
’97 - ‘01	**NA48**	ε’/ε: **Proof** of direct CP violation
‘02	**NA48/1**	K_s rare decays
’03 - ‘04	**NA48/2**	CP violation in **Charge Kaons** decays
’07 - ‘08	**NA62 (NA48/3)**	Lepton Universality (R_k)
’14 - ‘18	**NA62**	$K^+ \rightarrow \pi^+ \nu\bar{\nu}$ decay

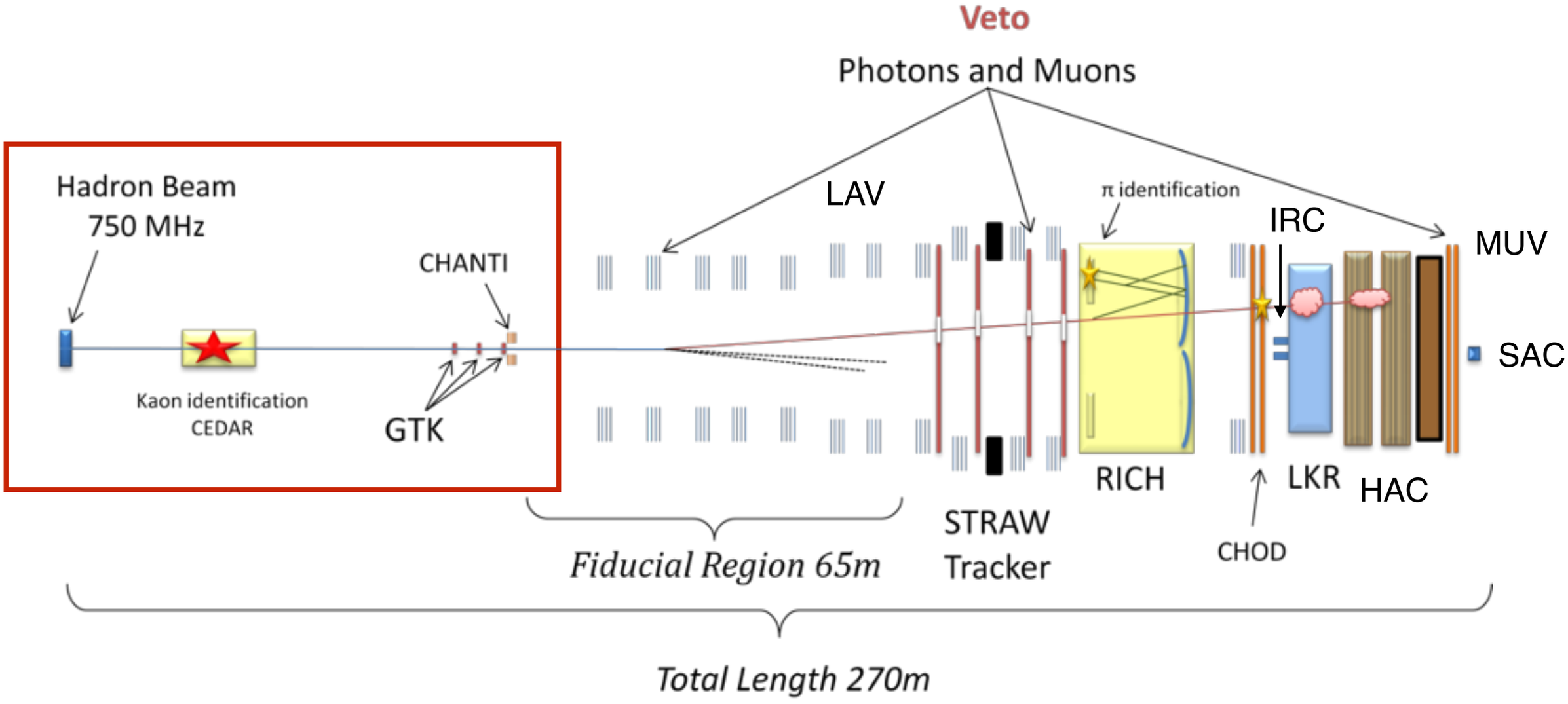
NA62 2007 Data Taking

Simultaneous $K^{\pm}$ beams

74 ± 2 GeV/c



NA62 Detector



Kaon Tagging - CEDAR

45 MHz rate

time: 100 ps

Kaon Tracking - GTK

time: ≈200ps

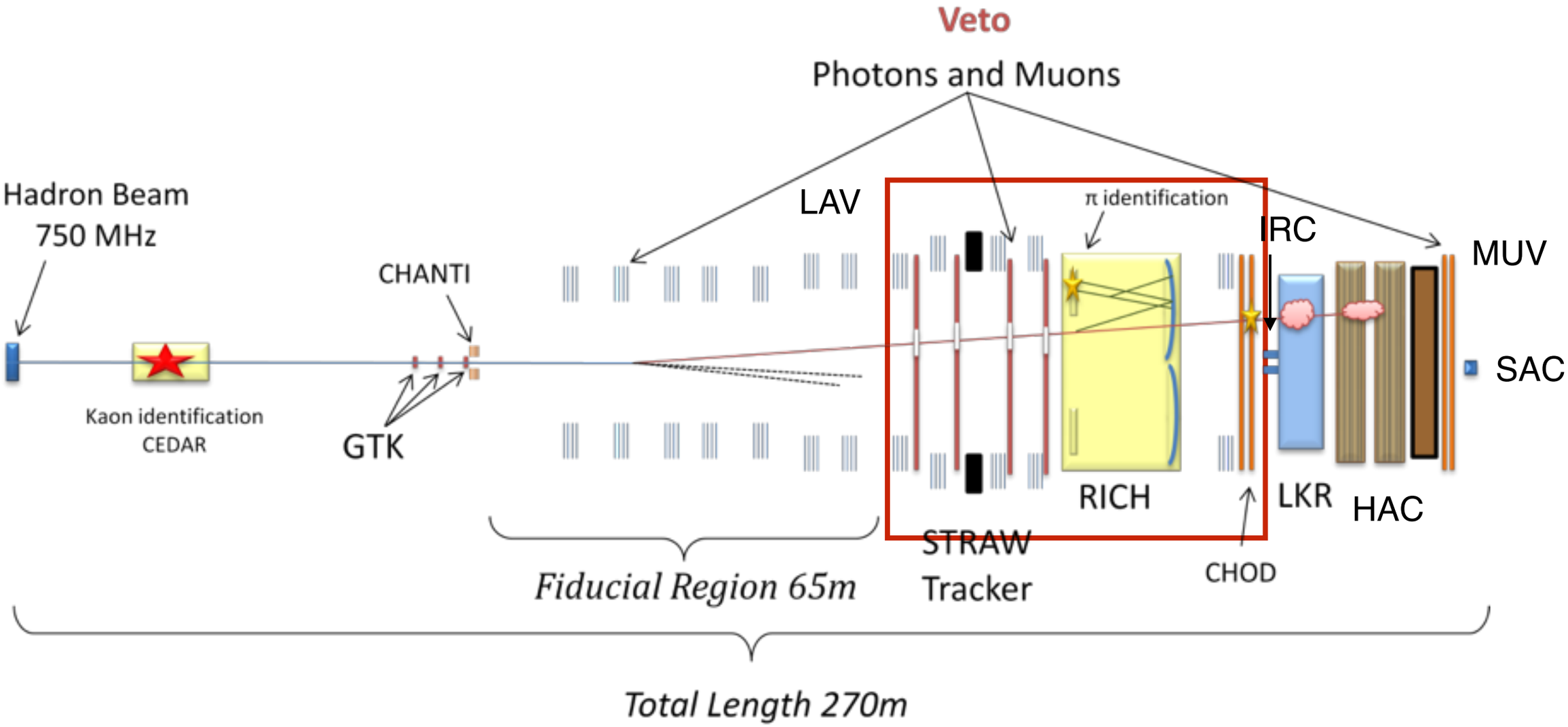
momentum: dp/p < 0.4%

direction : ≈0.016 mrad

Guard Ring - CHANTI

To detect beam interaction within the last GTK station

NA62 Detector



Pion Tracking - STRAW

momentum: dp/p < 0.33%

direction : ≈10 mrad

extracted vertex: ≈1mm

Pion ID - RICH

time: <100 ps

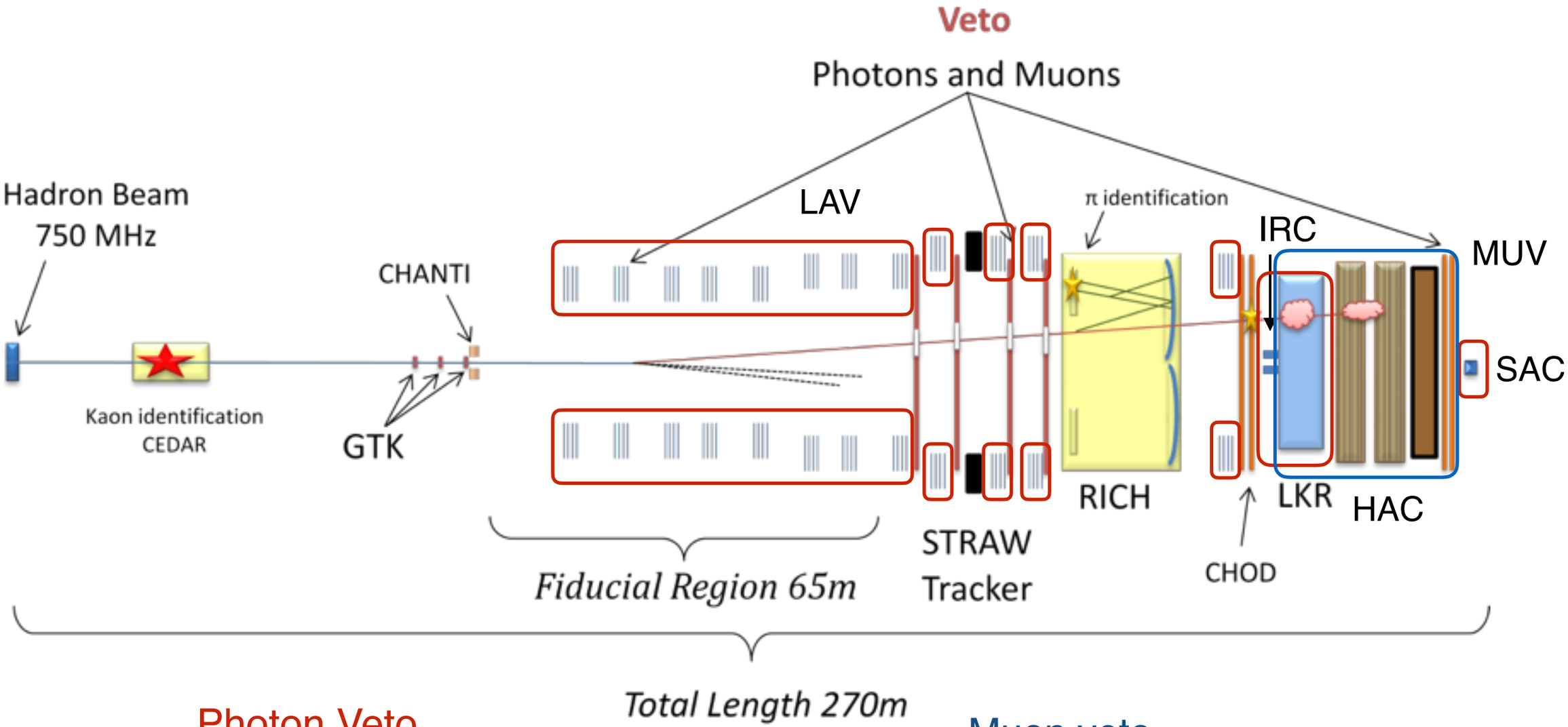
π/μ separation: 10^2

Pion Timing - CHOD

time: <300ps

Charged Trigger

NA62 Detector



Photon Veto

Hermetic coverage

Large Angle: **LAV**

Intermediate Angle: **LKr**

Small Angle: **IRC**, **SAC**

Muon veto

Muon rejection 10^5

Calorimeters: **LKr**, **HAC**

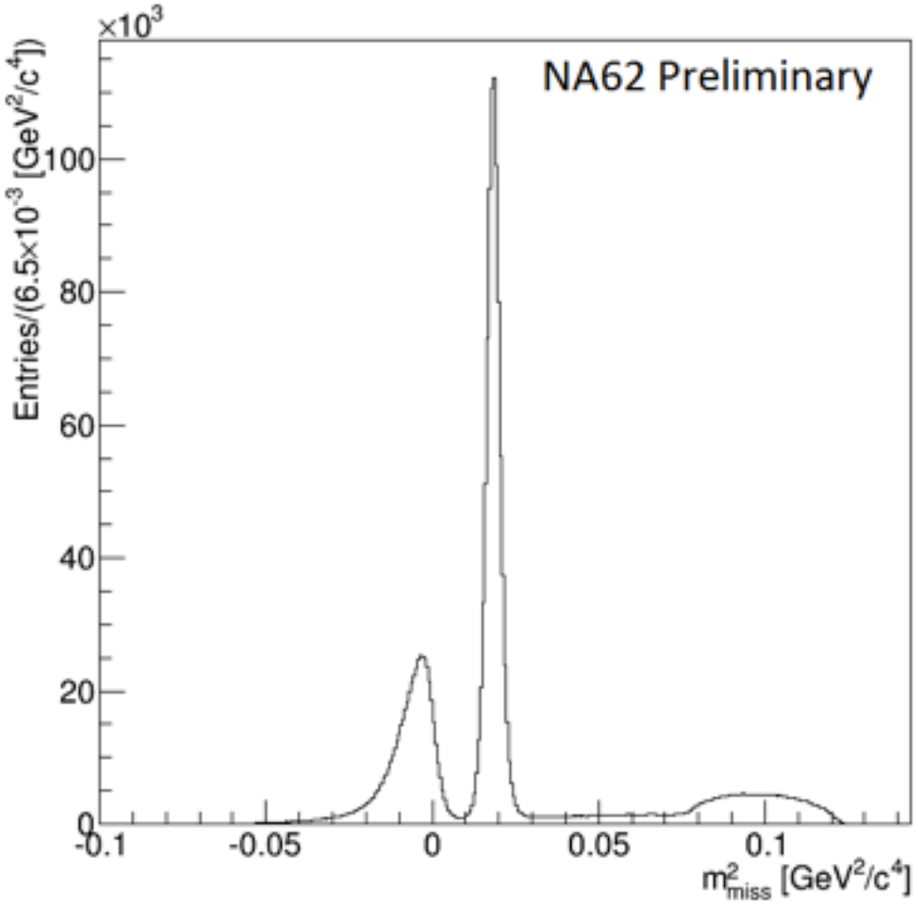
Trigger for hadronic showers

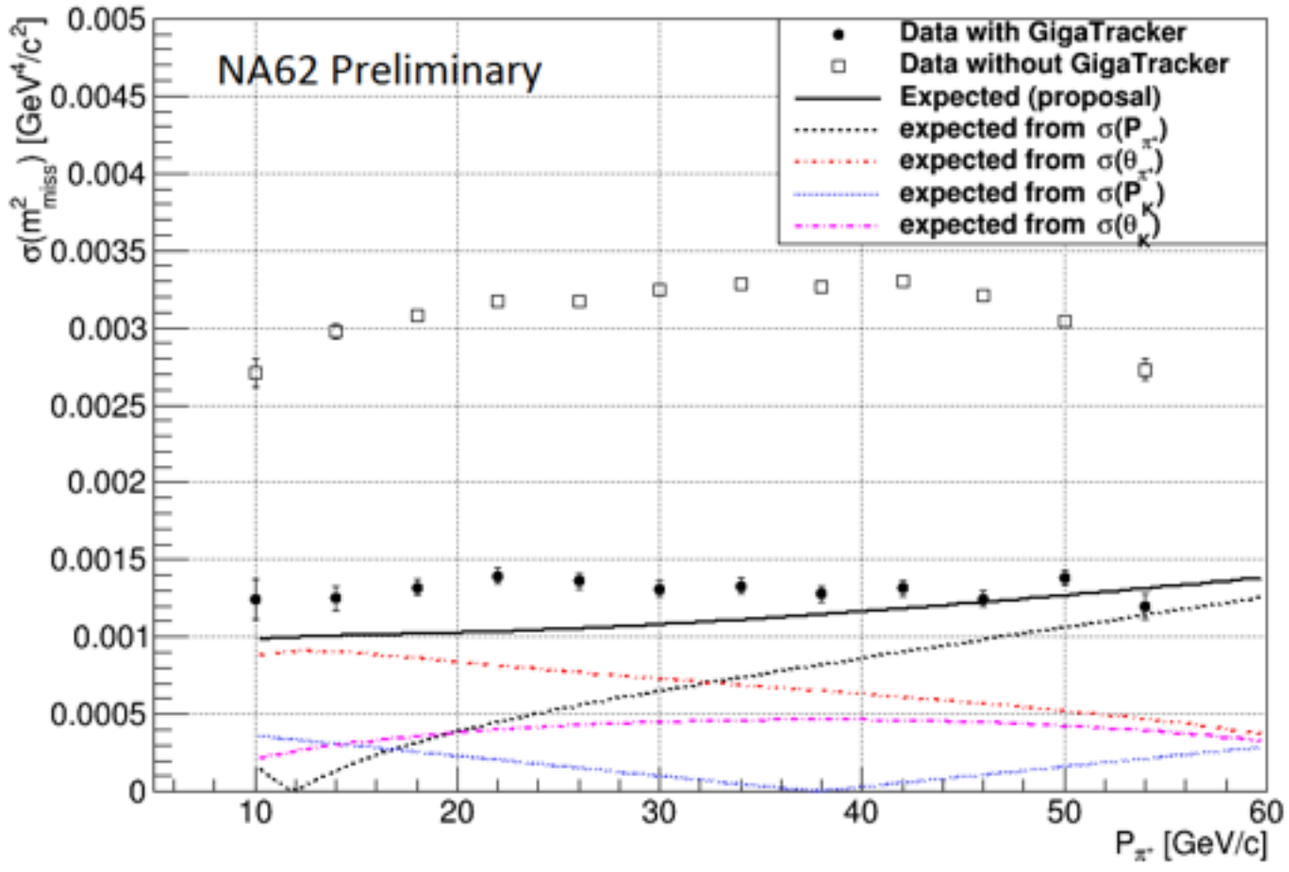
Fast Veto: **MUV**

Status of the Experiment

- **Commissioning** runs in **2014** and **2015**
- **Beam commissioned** up to nominal intensity
- Beam Detectors:
  - **Cedar** (K ID) and **CHANTI** (guard ring) fully **commissioned**
  - **GTK** (tracker) **partially** commissioned (full detector in 2016)
- **Downstream** detectors:
  - **Fully commissioned**
- **Trigger**:
  - **L0** fully **commissioned**
  - **L1, L2 partially** commissioned
- **Analysis**:
  - **Low intensity** data taken with minimum bias trigger **for detector performance** studies
  - **Up to full intensity** data taken with calorimetric trigger, work **on going**

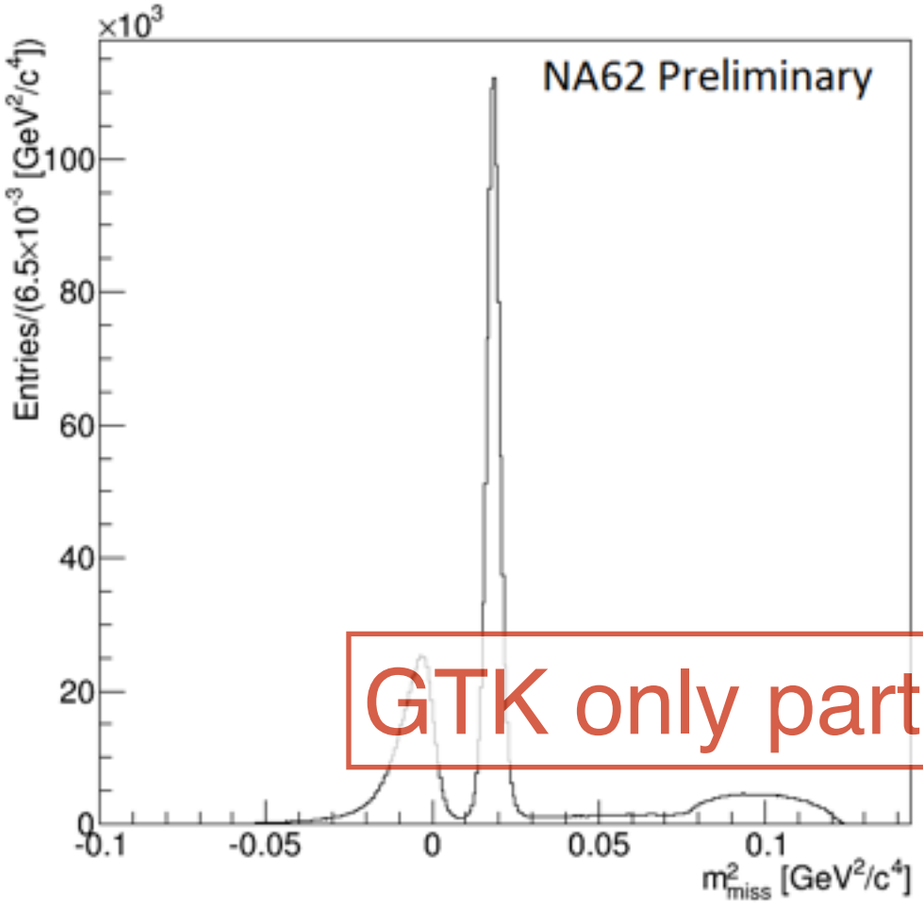
2015 Data Quality: Kinematics

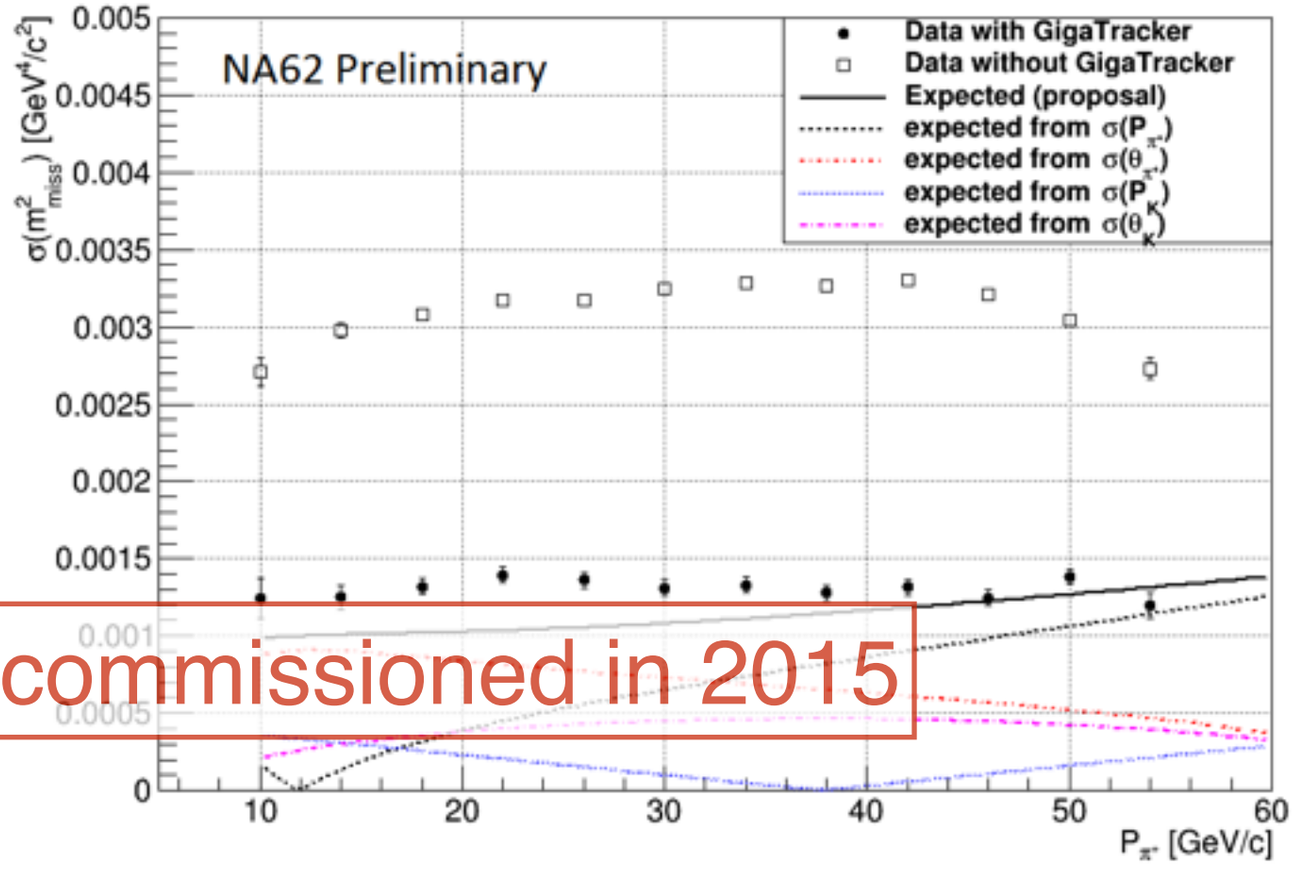




- ✓ Combine information from **GTK and STRAW** trackers
- ✓ **Need O(10^4÷10^5)** suppression for main kaon decay modes
- ✓ Kinematics **studied with $K^+ \to \pi^+\pi^0$** sample selected using the **LKr** calorimeter
- ✓ **Resolutions** close to design
- ✓ **O(10^3)** kinematic suppression factor **in 2015**

2015 Data Quality: Kinematics





GTK only partially commissioned in 2015

- ✓ Combine information from **GTK and STRAW** trackers
- ✓ **Need O(10^4÷10^5)** suppression for main kaon decay modes
- ✓ Kinematics **studied with $K^+ \to \pi^+\pi^0$** sample selected using the **LKr** calorimeter
- ✓ **Resolutions** close to design
- ✓ **Best $K^+ \to \mu^+\nu$ suppression for $P_\pi < 35$ GeV/c**
- ✓ **O(10^3)** kinematic suppression factor **in 2015**