K→πμμ from NA62

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Outline

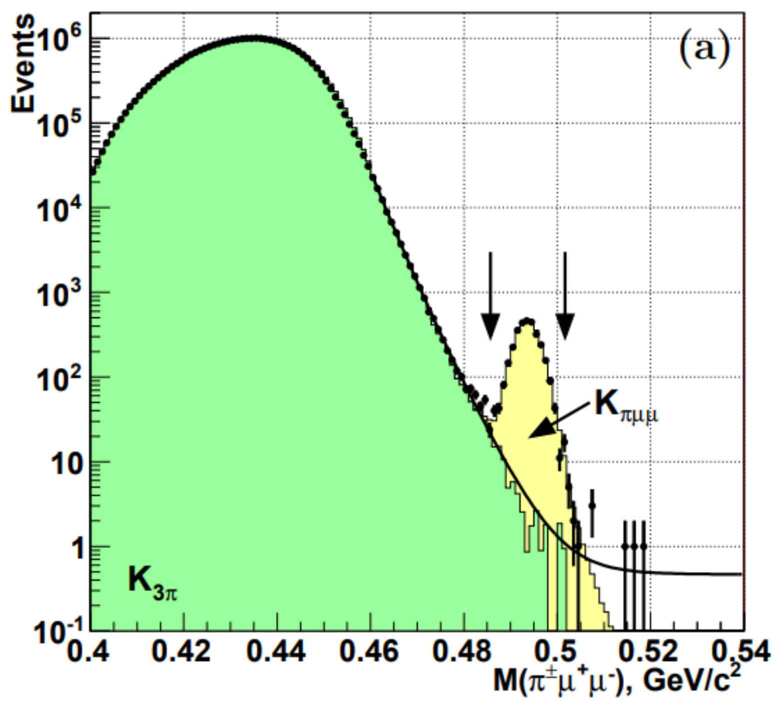
1. Existing measurements of the $K \rightarrow \pi\mu\mu$ form-factor
2. The NA62 experiment (beamline and detectors)
3. The NA62 datasets and trigger setup
4. Event selection and specific backgrounds
5. NA62 trigger conditions and efficiency estimates
6. Outlook and summary

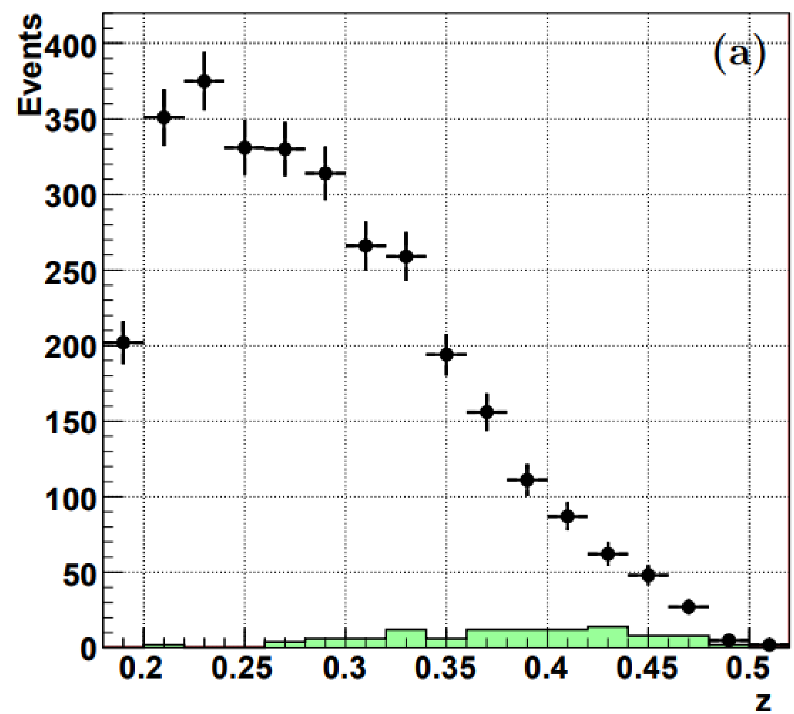
K→πμμ form-factor at NA48/2

- The K→πμμ form-factor **W(z)** was measured at NA48/2 using a sample of 3120 candidates, with 3.3% background

Phys.Lett.B697:107-115,2011

- Worlds largest published sample of K→πμμ: more than 4x larger than all other experiments combined

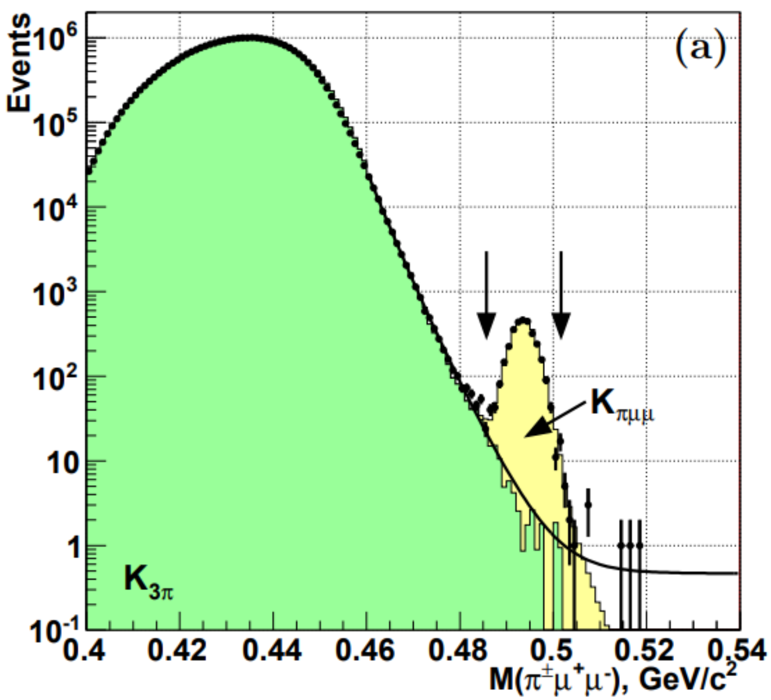


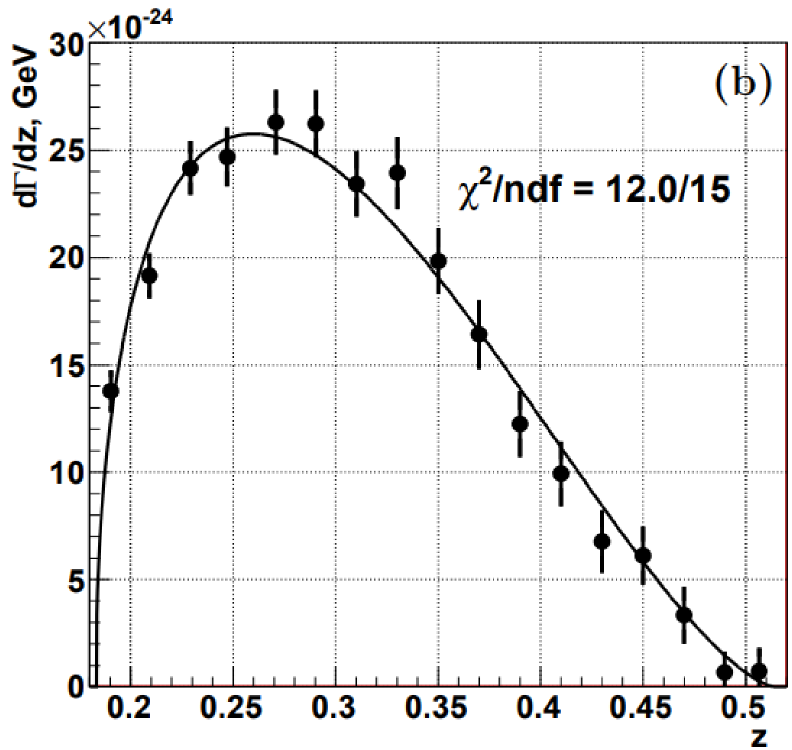


K→πμμ form-factor at NA48/2

- The K→πμμ form-factor **W(z)** was measured at NA48/2 using a sample of 3120 candidates, with 3.3% background

$$\frac{d\Gamma}{dz} = \frac{\alpha^2 M_K}{12\pi(4\pi)^4}\lambda^{3/2}(1, z, r_\pi^2)\sqrt{1-4\frac{r_\mu^2}{z}}\left(1+2\frac{r_\mu^2}{z}\right)|W(z)|^2$$





K→πμμ form-factor at NA48/2

- Can parameterise **W(z)** in several ways, e.g. Next-to-leading order χPT,

$$W(z) = G_F M_K^2 (a_+ + b_+ z) + W^{\pi\pi}(z)$$

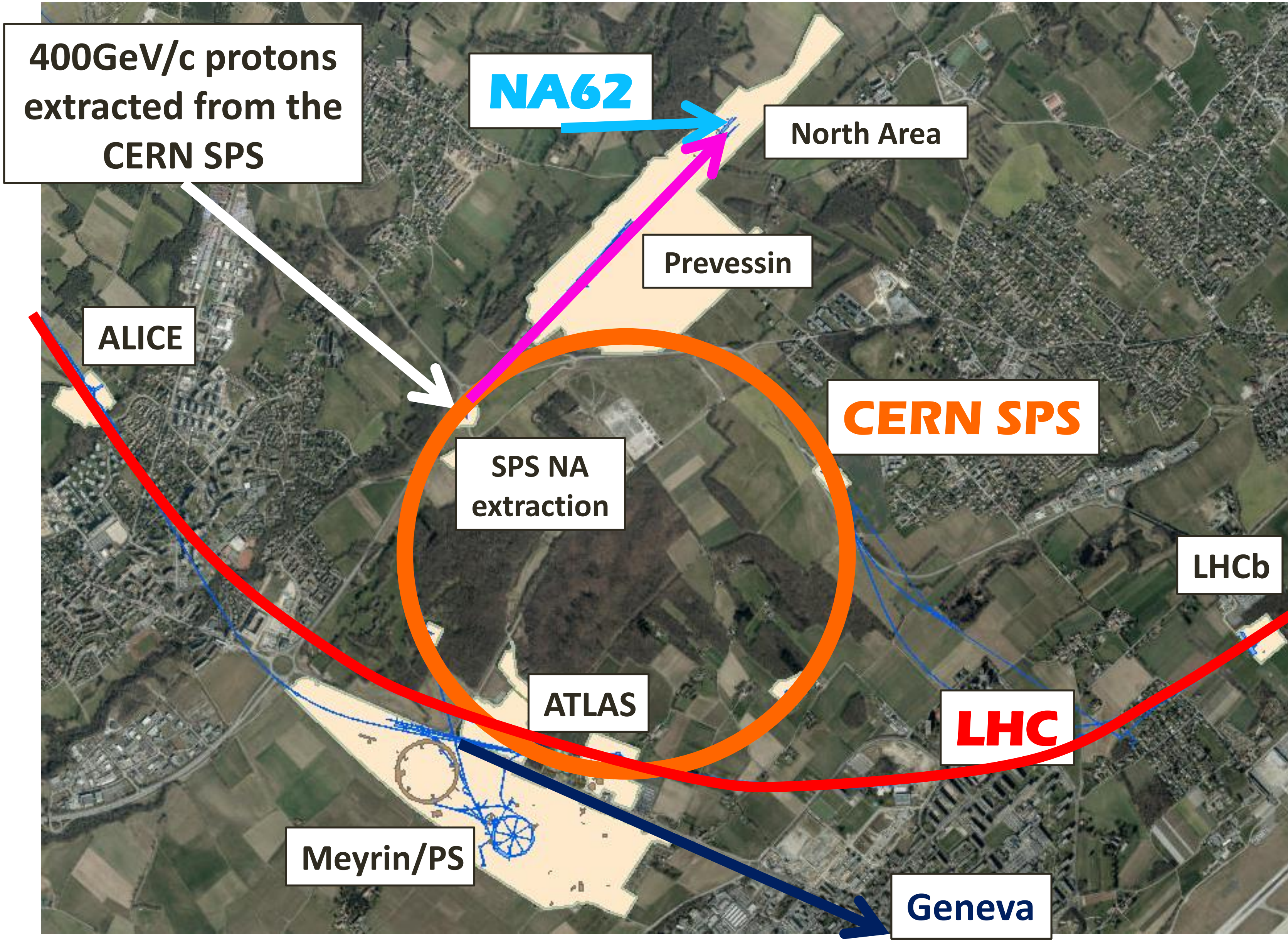
Model (2)			$\rho(a_+, b_+) = -0.976$				$\chi^2/\mathrm{ndf} = 14.8/15$					
a_+	=	-0.575	$\pm$	$0.038_{\mathrm{stat.}}$	$\pm$	$0.006_{\mathrm{syst.}}$	$\pm$	$0.002_{\mathrm{ext.}}$	=	-0.575	$\pm$	0.039
b_+	=	-0.813	$\pm$	$0.142_{\mathrm{stat.}}$	$\pm$	$0.028_{\mathrm{syst.}}$	$\pm$	$0.005_{\mathrm{ext.}}$	=	-0.813	$\pm$	0.145

- Can also compute the model-independent branching fraction

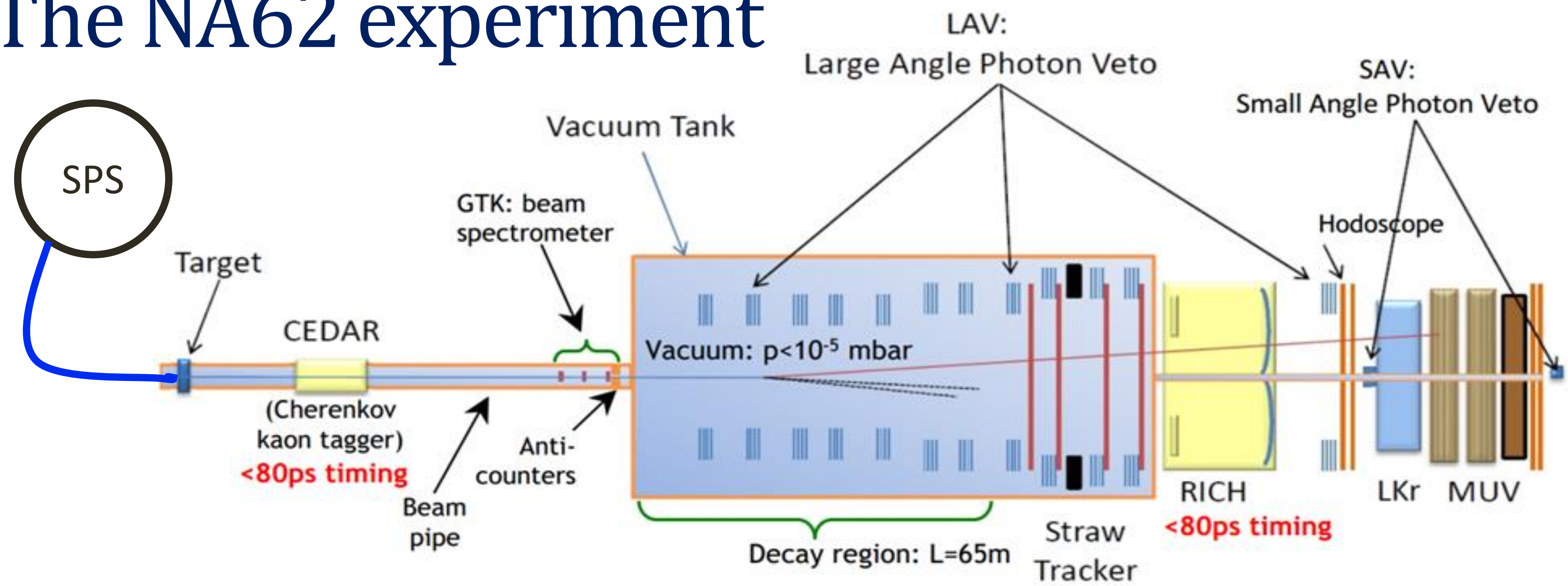
$$(d\Gamma_{\pi\mu\mu}/dz)_i = \frac{N_i - N_i^B}{N_{3\pi}} \cdot \frac{A_{3\pi}(1-\varepsilon_{3\pi})}{A_i(1-\varepsilon_i)} \cdot \frac{1}{\Delta z_i} \cdot \frac{\hbar}{\tau_K} \cdot \mathrm{BR}(K_{3\pi}).$$

$\mathrm{BR} \times 10^8 =$	9.62	$\pm$	$0.21_{\mathrm{stat.}}$	$\pm$	$0.11_{\mathrm{syst.}}$	$\pm$	$0.07_{\mathrm{ext.}}$	=	9.62	$\pm$	0.25

The NA62 experiment



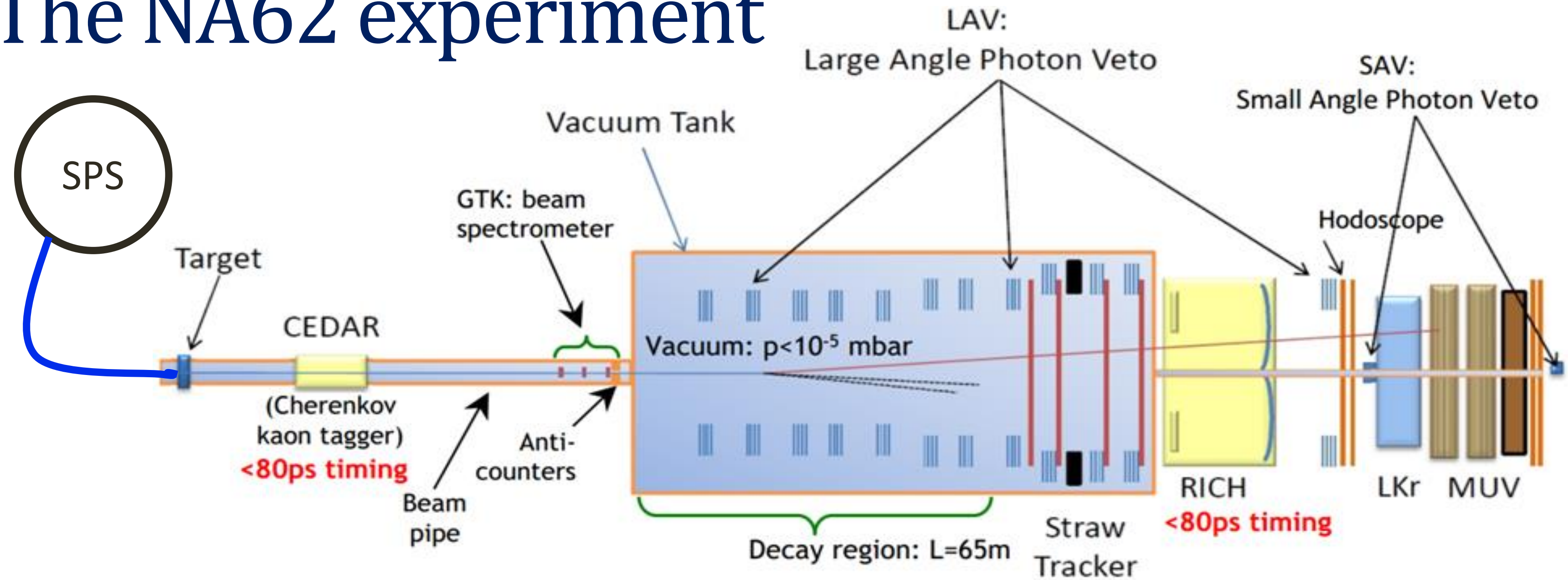
The NA62 experiment



BEAMLINE

- 90x higher Kaon rate
- Only positively-charged Kaons (asymmetric design)
- Higher, more collimated Kaon momentum (75 ± 1 GeV/c)

The NA62 experiment

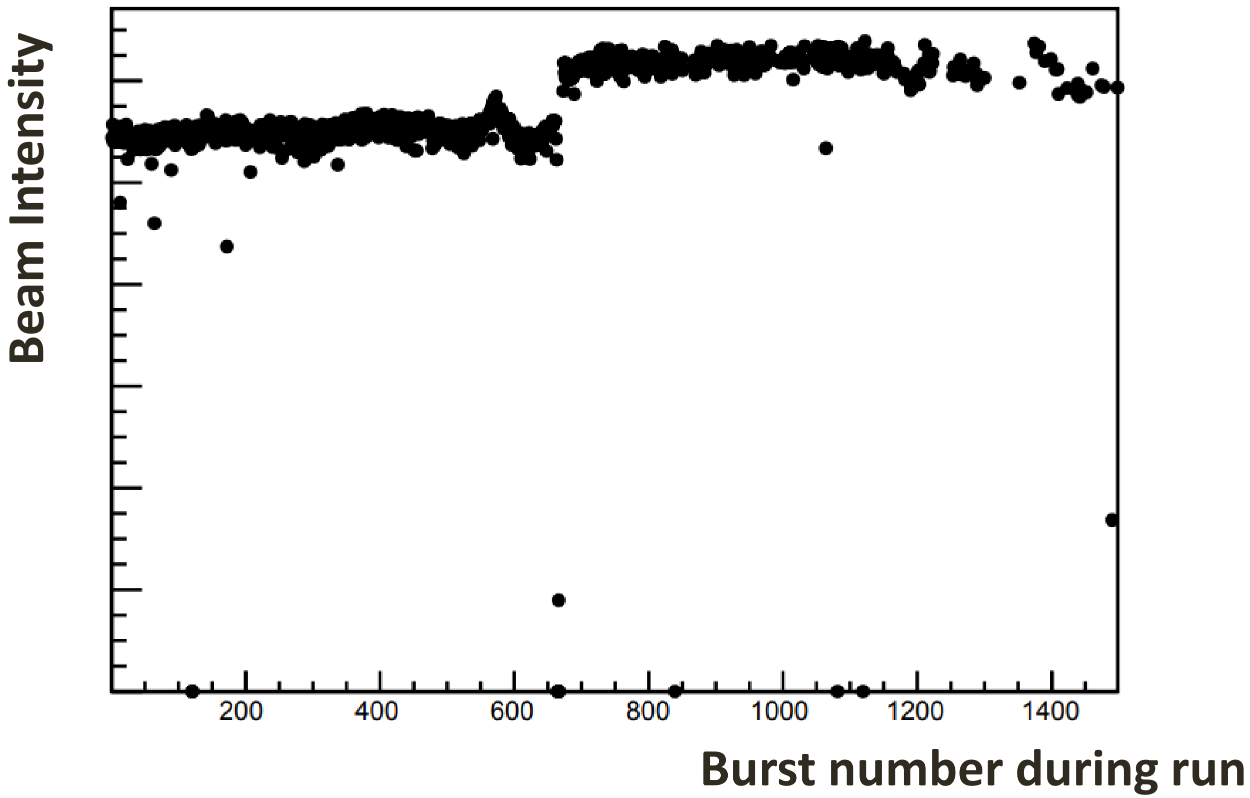


DETECTORS

- STRAW tracker improved, operates in vacuum, stronger magnetic field
- RICH detector for particle identification
- Simpler muon station (MUV3)
- Fiducial volume is reduced from 115 to 65m

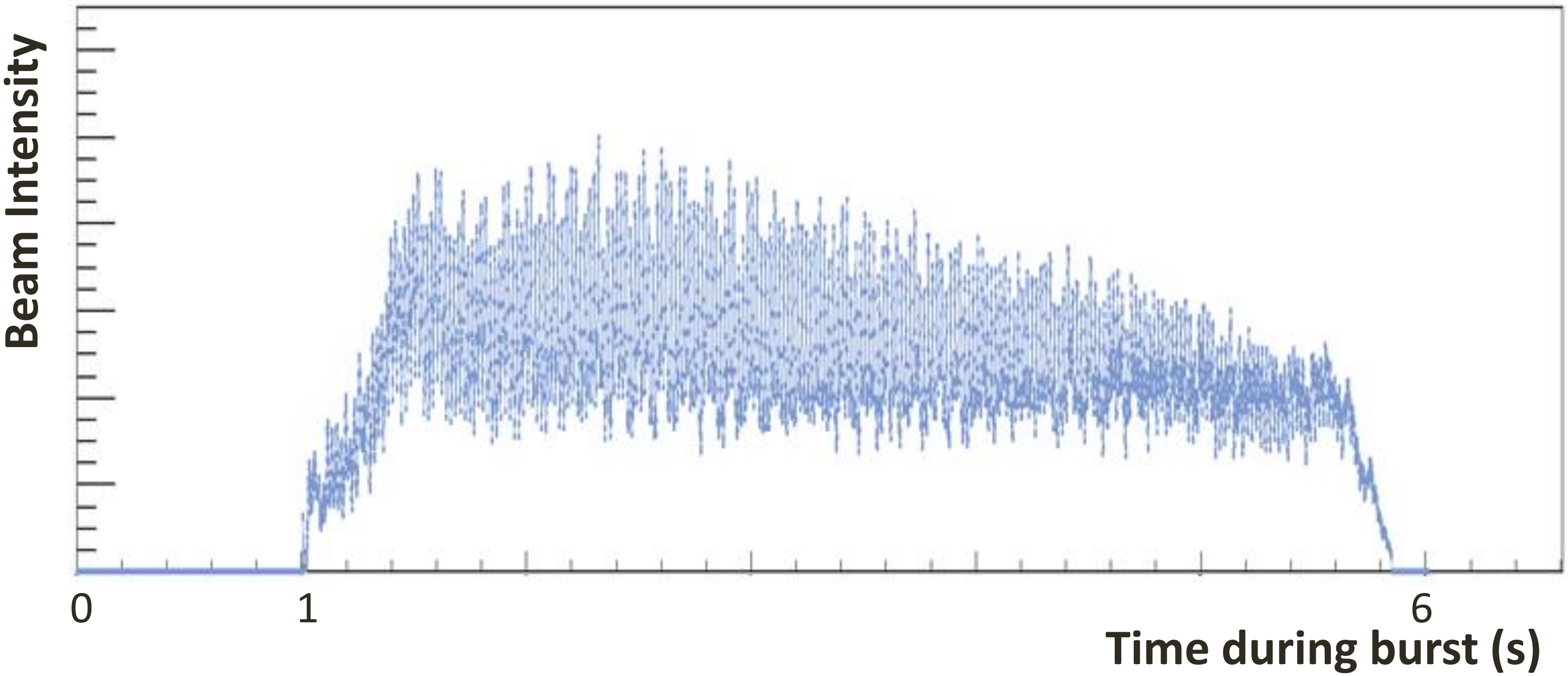
The NA62 beam structure

- Beam arrives to NA62 in "bursts" of about 5s duration
- Beam intensity varies over time (e.g. from burst-to-burst)

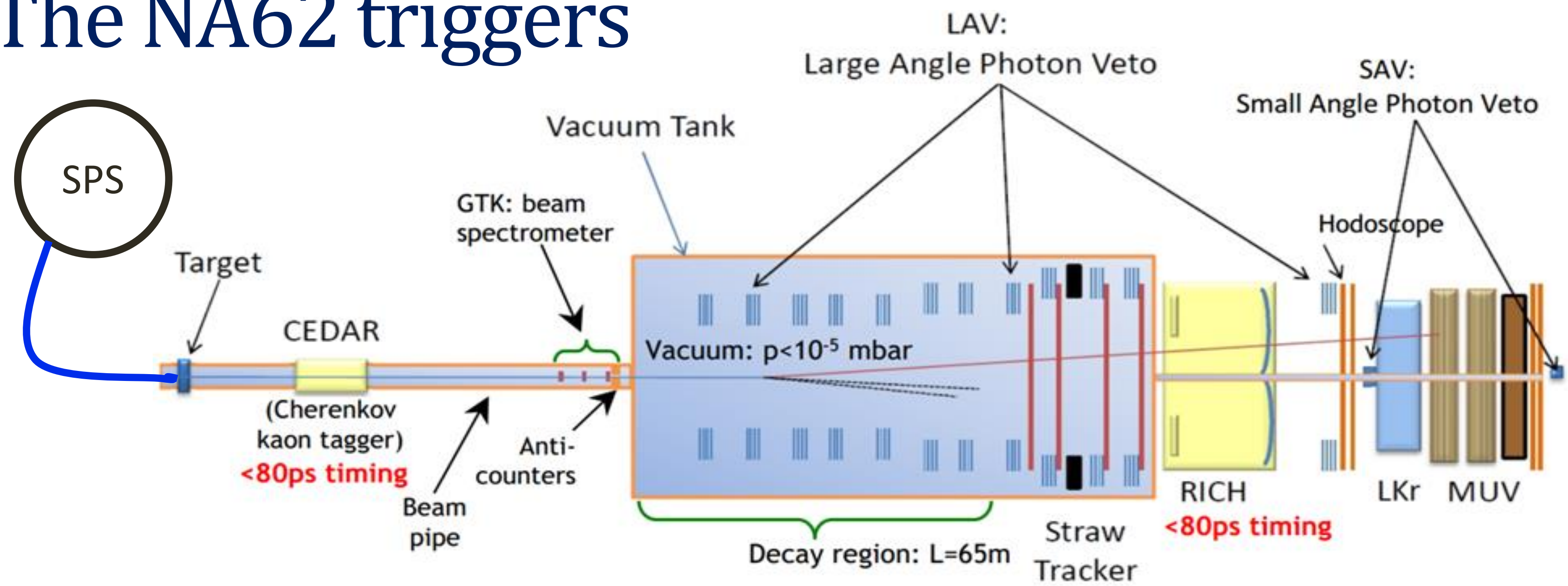


The NA62 beam structure

- Beam arrives to NA62 in “bursts” of about 5s duration
- Beam intensity varies during each burst
- Instantaneous intensity is important for trigger performance



The NA62 triggers



- The high beam intensity means a highly selective trigger system is required, which is implemented in hardware (L0) and software (L1)
- Trigger conditions based on almost all detectors in the experiment

RICH | **CHOD** | **NA48/2 CHOD** | **MUV3** | **LAV12** | **Calorimeters**

KTAG | **STRAW** | **LAV**

NA62 data sets (relevant to this talk)

- **2016A**: **75k** bursts at **40%** nominal beam intensity

πμμ	RICH & QX & MO2	D=1 →	KTAG → LAV → STRAW
K3π	RICH & QX	D=50 →	KTAG → LAV → STRAW

- **2017**: **340k** bursts at **60%** nominal beam intensity
  - **2017A**: **85k** bursts of 2017 dataset

πμμ	RICH & QX & MO2	D=2 →	KTAG → STRAW
K3π	RICH & QX	D=100 →	KTAG → STRAW

- **2018:** expecting another "2017" dataset

Event selection and specific backgrounds

Three-track selection criteria

- **Requirements on reconstructed tracks**

  - Each track in acceptance of relevant detector systems
  - Track momentum between 8 and 48 GeV/c
  - At least one matching (in space only) CHOD candidate
  - Track momentum between 8 and 48 GeV/c

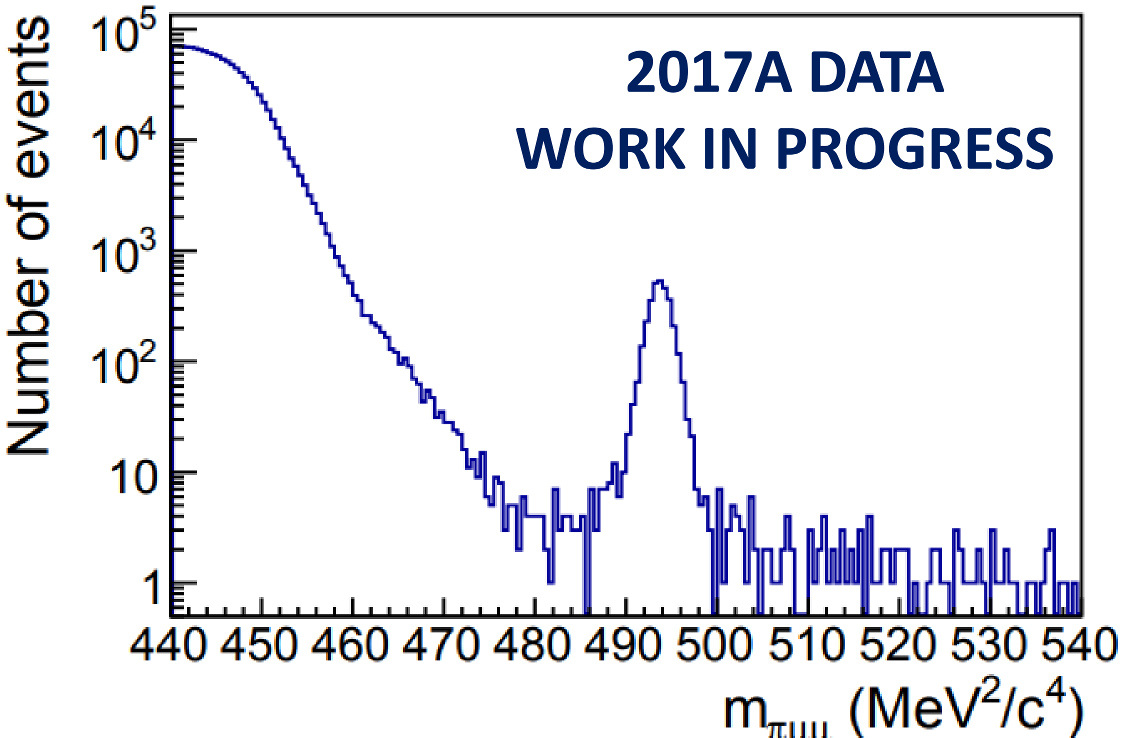
- **Requirements on three-track vertex**

  - Exactly one vertex in the event
  - Vertex χ^2 less than 20
  - Vertex has a charge of +1
  - Vertex p within 2GeV of nominal beam momentum (75GeV)
  - Vertex p_T less than 30MeV/c w.r.t nominal beam
  - Vertex time within 10ns of the trigger time
  - Vertex time within 10ns of a good quality KTAG candidate

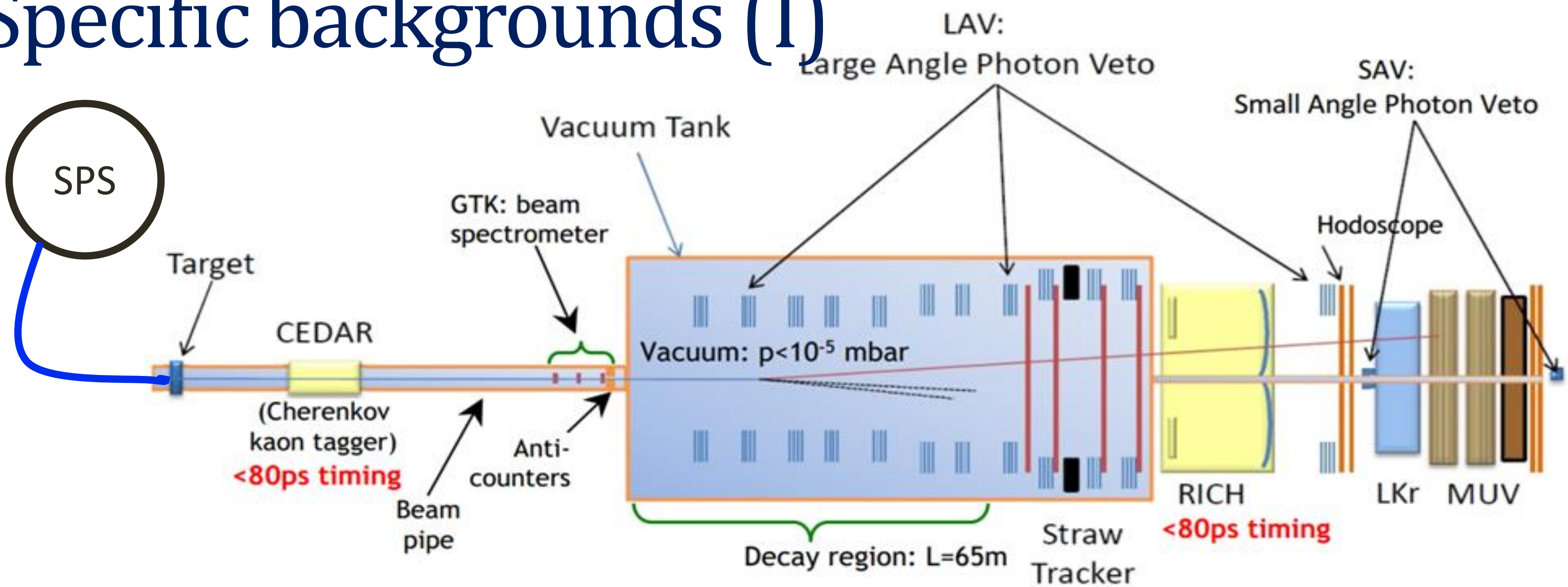
K→πμμ selection criteria

- **Requirements on πμμ tracks**

  - The two 'muon' tracks have matching MUV3 candidates, the 'pion' track has **no** matching MUV3 candidate
  - Opposite charge muon tracks
  - Each track has either: **no** matching LKr cluster; or $E/p < 0.9$



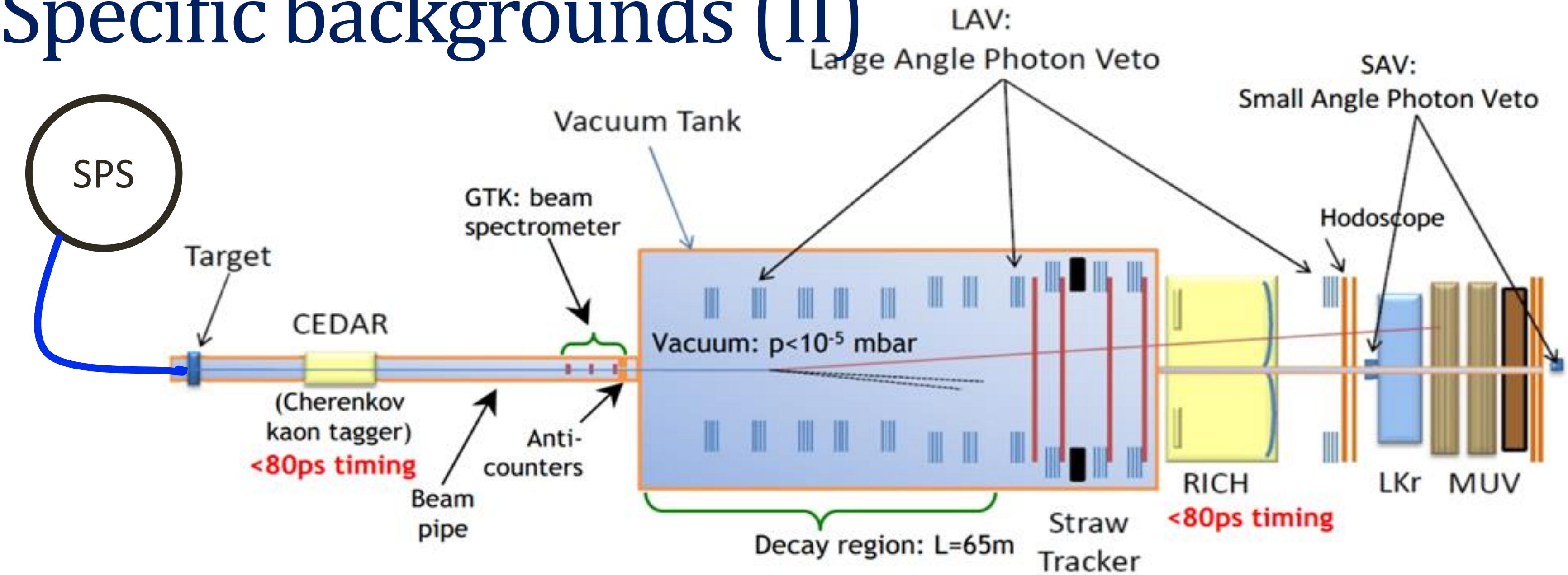
Specific backgrounds (I)



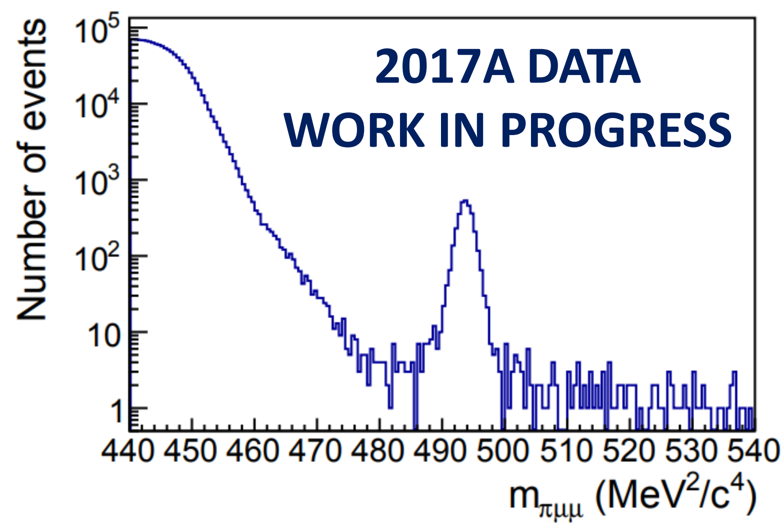
- About 4% of pions (from K3π decays) match to a MUV3 candidate, dominated by π→μ decay-in-flight
- Gives rise to the irreducible background **K3π→2μ**

Expect about 1000 **K3π→2μ** candidates
for each **K→πμμ** candidate

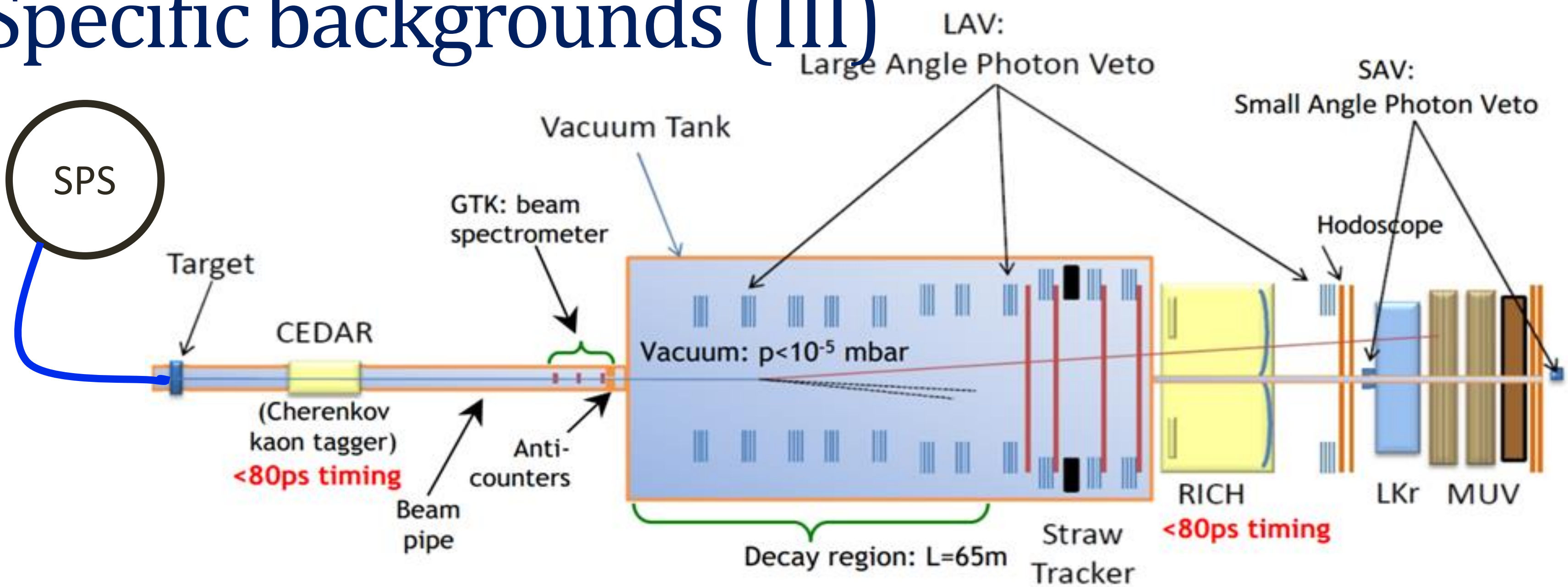
Specific backgrounds (II)



- These candidates are shifted to low **πμμ** invariant masses
- The stronger **STRAW** magnet in NA62 improves the separation of **K→πμμ** and **K3π→2μ** candidates



Specific backgrounds (III)



- **K3π** decays (and therefore **K3π→2μ** decays) can also occur inside the volume of the TRIM5 magnet (40cm long, w.r.t 60m fiducial volume)
- TRIM5 exists due to the asymmetric design of NA62, which was chosen since only positive Kaons are used

About five **K3π→2μ 'TRIM5'** candidates for each **K→πμμ** candidate

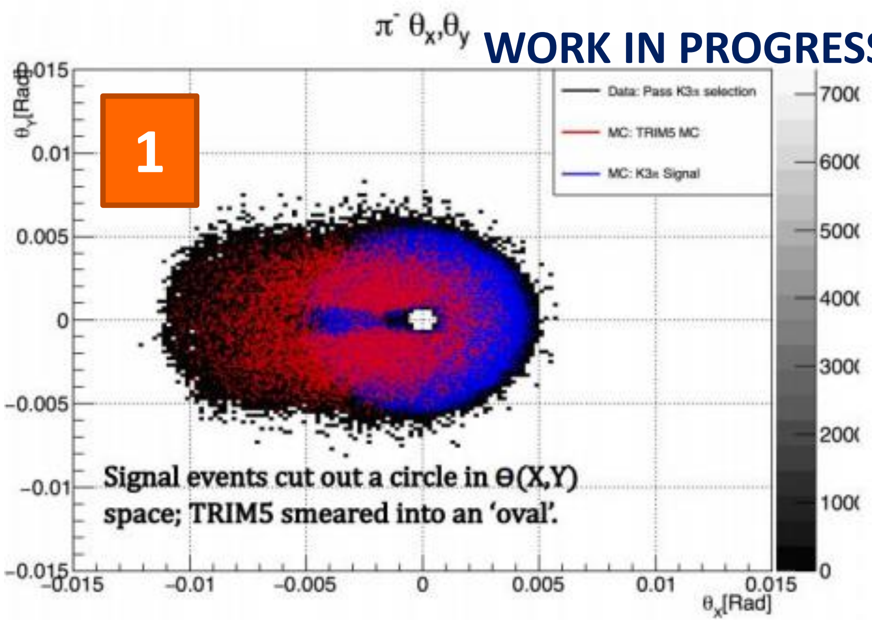
- Due to the bending effect of the TRIM5 magnet, the θ distribution of the particles is affected, smearing the **πμμ** invariant mass

Specific backgrounds (III)

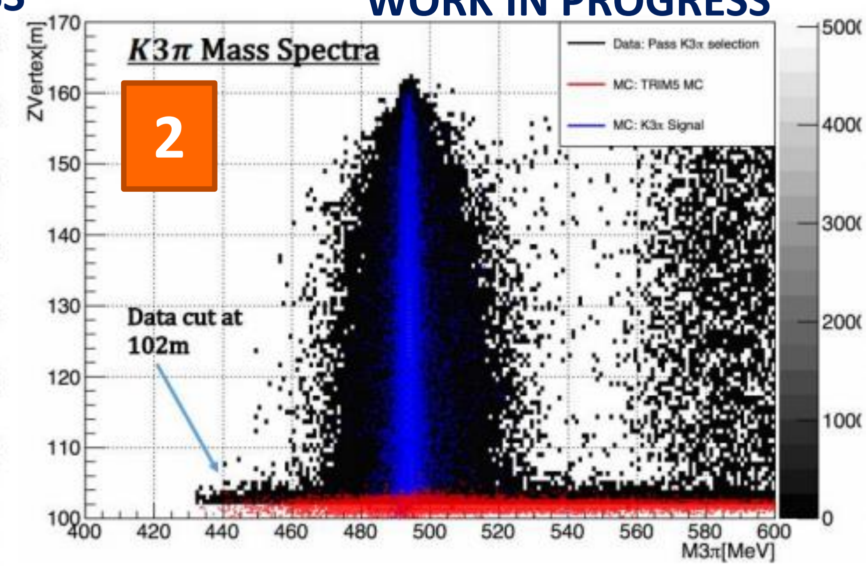
- TRIM5 events can be removed from the data sample by imposing cuts on

1. The lab-frame angle between the particle and the kaon
2. The vertex position: at least 110m from the target

WORK IN PROGRESS

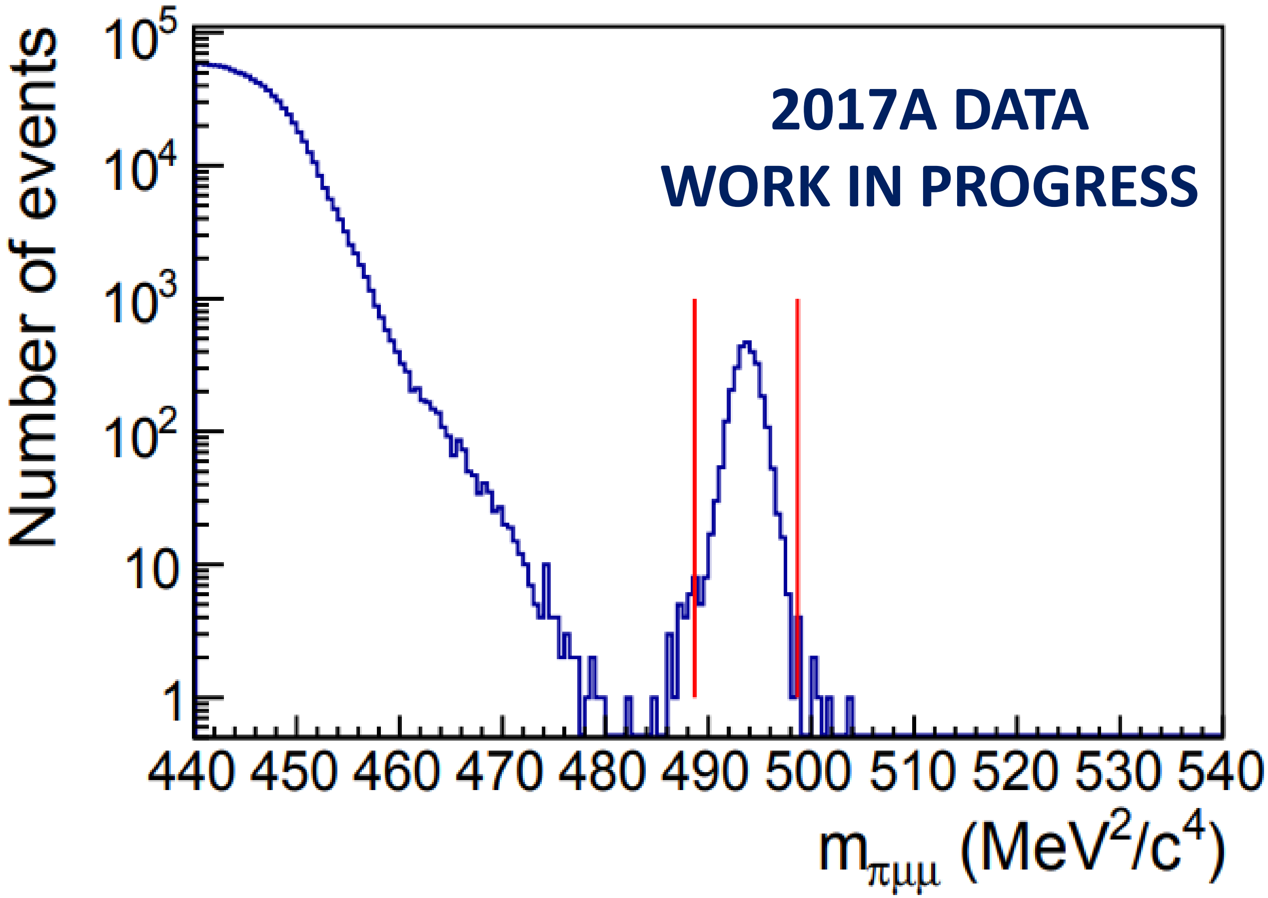


WORK IN PROGRESS



K→πμμ event sample

- Sample of **K→πμμ** events clearly separated from the specific background **K3π→2μ**
- There are **2780** candidates in ±5 MeV/c around the **K⁺** mass



Extrapolated K→πμμ event sample

- With 2750 candidates in 2017A, we expect:
  - **2017** to contain **11000** candidates
  - **2018** to contain a further **11000** candidates

- A total of **22k** candidates
- More than **7x** current largest sample

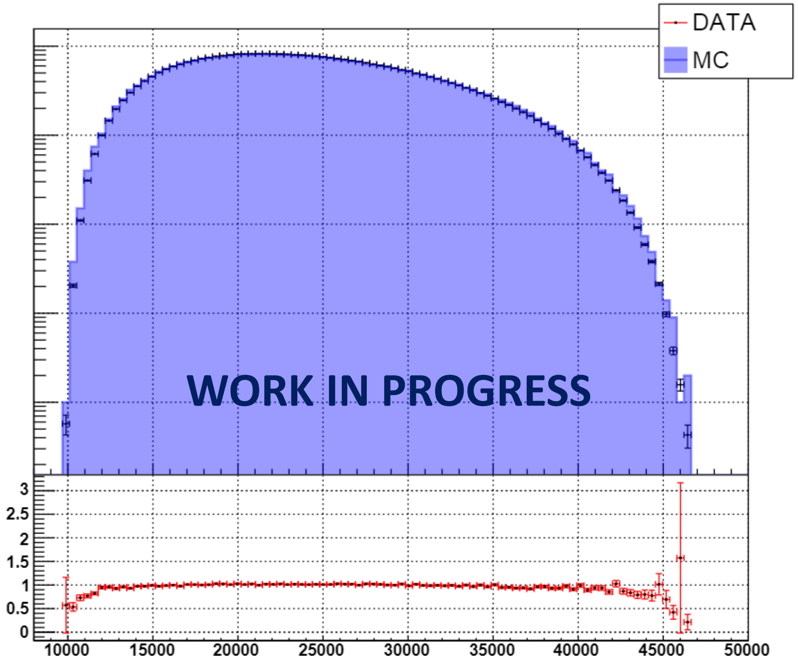
- Background from **K3π** reduced to a very low level
  - Larger momentum kick of the magnet sweeps K3π away from the signal region
  - Mass resolution: $\boldsymbol{\sigma_m \approx 1.1\ \mathrm{MeV}^2/c^4}$ **(NA62)**
    $\boldsymbol{\sigma_m \approx 2.5\ \mathrm{MeV}^2/c^4}$ **(NA48/2)**

Estimating the event acceptance

- **K3π** and **πμμ** acceptances are estimated using MC events

- **K3π** acceptance: **NA62**: **15.2%**
  NA48/2: **22.2%**

- **NA62** MC events reproduce data very well in key quantities

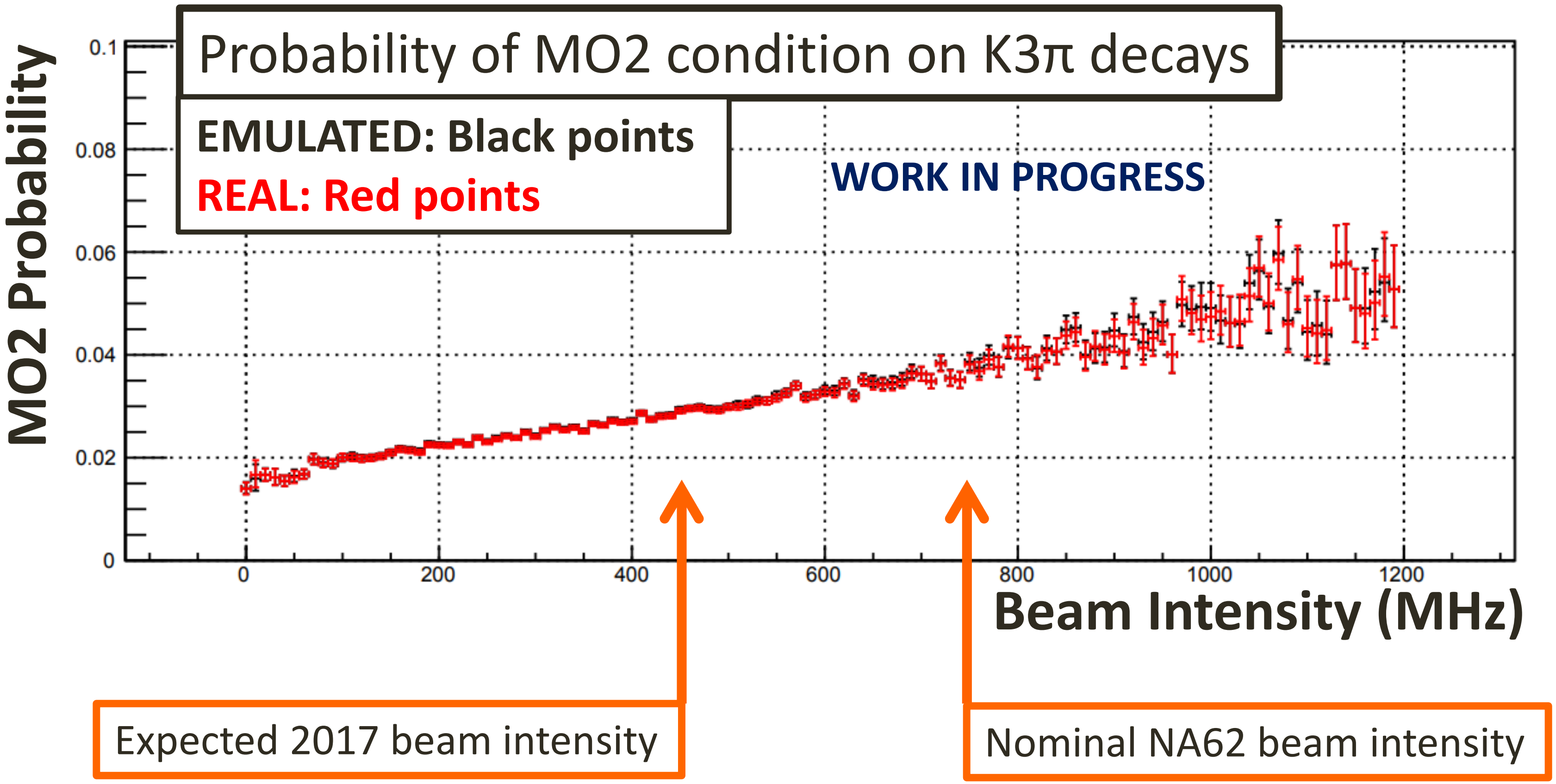


π⁺ momentum (Mev/c)

π⁻ momentum (Mev/c)

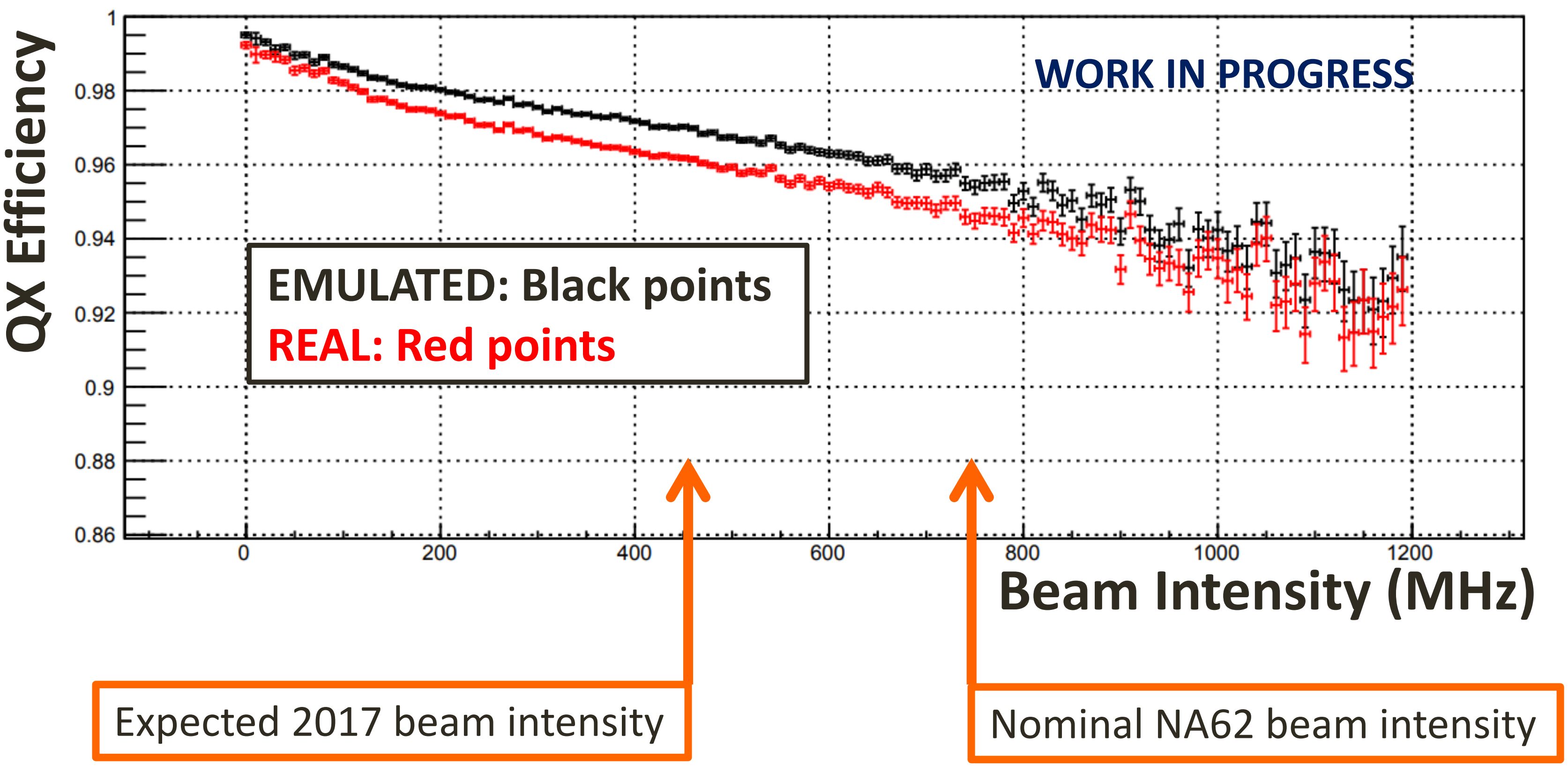
L0 Trigger conditions

- The **MO2** trigger condition (from MUV3) is only required for **K→πμμ** events. No cancellation between **K→πμμ** and **K3π**!
- The **MO2** efficiency can be estimated: using **K3π→2μ** decays in data; or by emulating the firmware

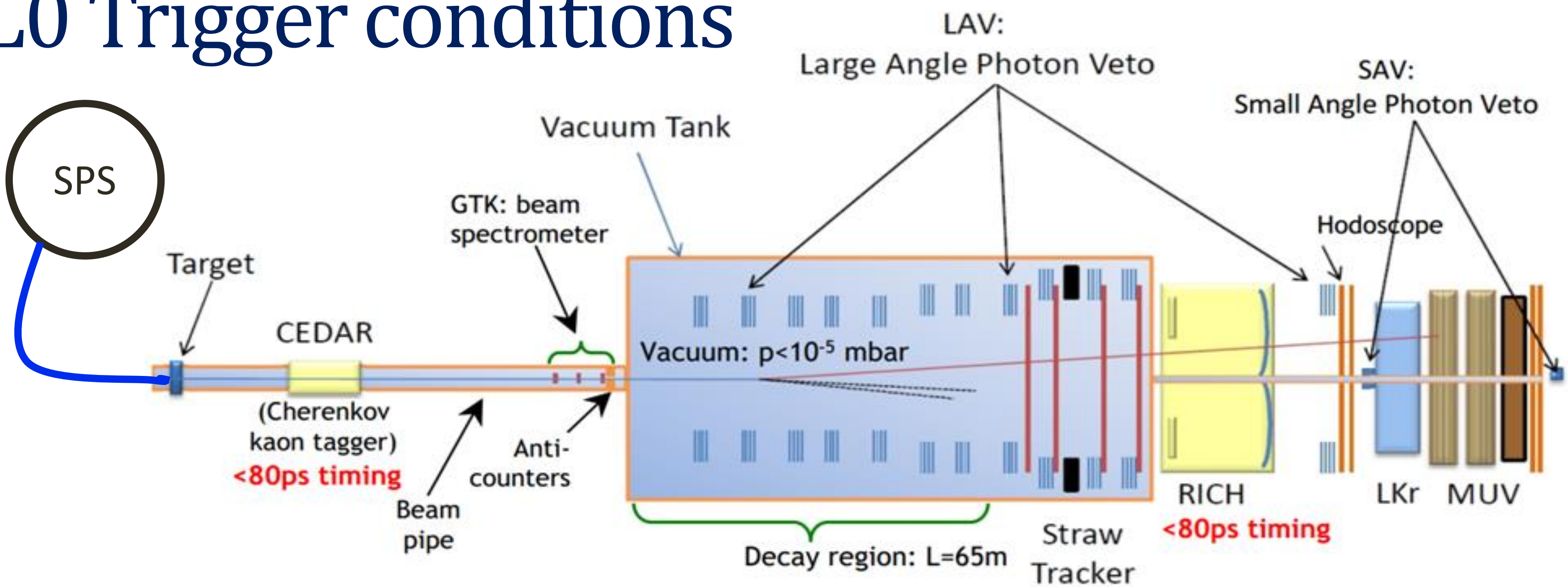


L0 Trigger conditions

- QX efficiency (as a function of instantaneous beam intensity) agrees to within 1% “out of the box”
- Much worse agreement than observed with the **MO2** condition – even though it’s the same algorithm



L0 Trigger conditions



- The CHOD detector (giving the QX trigger condition) is directly **behind the RICH**: particles **pass through RICH gas/mirror/endcap**
- About 4% probability for a hadronic interaction of **$\pi^{\pm}$** in RICH material
- These interactions cause large events in the CHOD, causing reduced trigger efficiency.
- Size of the inefficiency different for **K→πμμ** and **K3π** events

Outlook and Conclusions

- The NA62 experiment is a currently running at CERNs North Area designed to study the **K→πνν** decay
- NA62 expects to collect about **22k K→πμμ** decays by the end of 2018, more than **7x** the current largest dataset
- The experimental environment is very challenging – lots of work needed to reduce systematic uncertainties related to e.g. the trigger