RICH based L0 trigger

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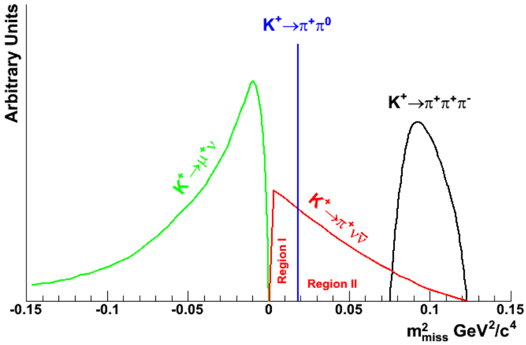
Target background

$K^+ \longrightarrow \pi^+\pi^0$

- most prominent background after L0 selection
- 2 body decay
- easy, peculiar kinematics
- 1+ rings ($\sim 5\%$ fraction of $\gamma \to e^+e^-$ detected)



How to trigger BG rejection...

...using only the RICH detector?

RICH ring

$\downarrow$

$(r, \vec{x}_c)$

$\downarrow$

(β, θ)

$\swarrow \quad \searrow$

geometric corrections   backwards propagation

$\searrow \quad \swarrow$

$(P_\pi, \theta_{K\pi})$

$\downarrow$

check if 2-body decay kinematics fits

or

compare with signal signature

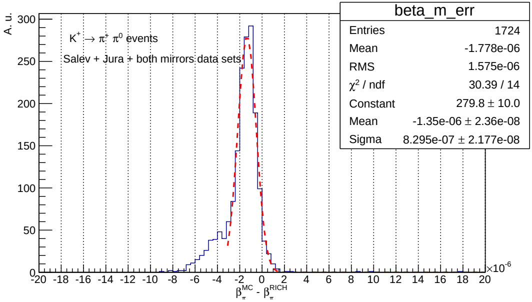
Resolution (old NA62FW rev.)

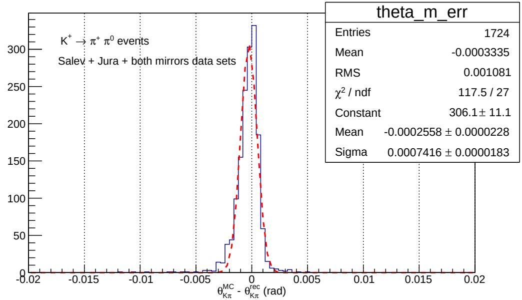
Geometry:

1. correct mirrors tilt (hit by hit)
2. shift X_{center} of the fitted ring according to RICH rotation around the $y-$axis

Propagation:

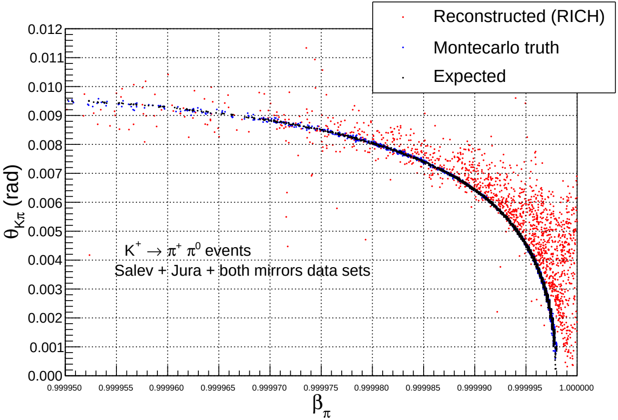
1. Spectrometer magnet: compute P_{kick} assuming particle is a π^+
2. GTK magnet: subtract 12 mrad from $\theta_{K\pi}$





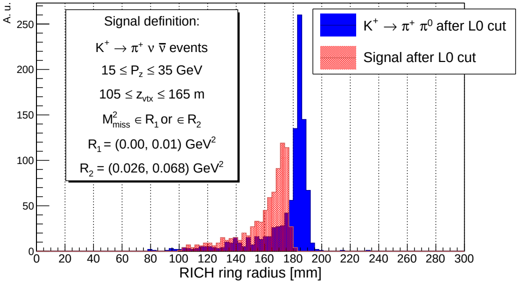
Analysis: limits

- reconstruction asymmetry in β, overestimated
- it reflects in θ through $P(\beta, m_\pi)$ and $P_{\mathrm{kick}}(P)$
- β, $\theta_{K\pi}$ functionally dependent in two-body decay $\longrightarrow$ strong correlation
- errors "explode" when computing $f(\beta, \theta_{K\pi})$, e.g. $M^2_{\mathrm{miss}}(K^+, \pi^+)$



Analysis: rejection power

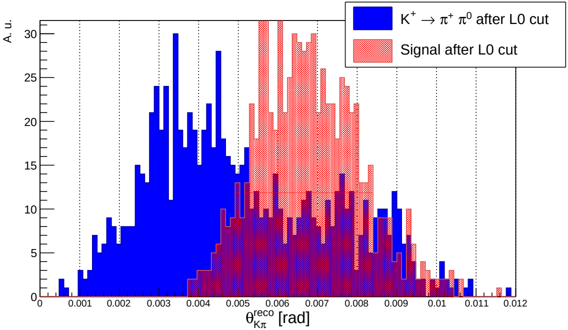
Signal events are selected in momentum $\Longrightarrow$ a maximum radius $R_{\max}$ exists for the rings on the RICH. Even before computing β, set up a cut on $\mathbf{R} \geq \mathbf{R_{th}}$!



$R_{\rm th}$ (mm)	Signal acceptance	L0 rejection	RICH rejection	RICH | LO	L0+RICH
176	0.926	0.767	0.634	**0.701**	0.930
177	0.960	0.767	0.613	**0.683**	0.926
177.5	0.971	0.767	0.598	**0.677**	0.925
178	0.976	0.767	0.585	**0.670**	0.923
178.5	0.983	0.767	0.568	**0.660**	0.921
179	**0.986**	**0.767**	**0.552**	**0.648**	**0.918**
179.5	0.990	0.767	0.533	**0.638**	0.915
180	0.995	0.767	0.513	**0.620**	0.912
181	0.996	0.767	0.470	**0.590**	0.904

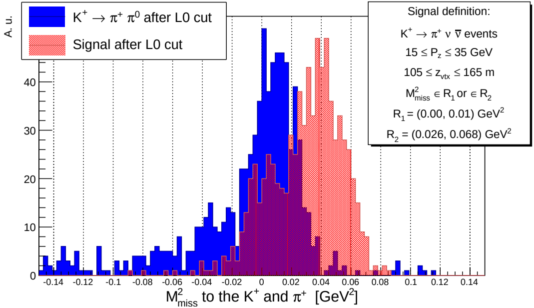
Analysis: rejection power

To do: check if the same can be done with the **reconstructed $\theta_{K\pi}$**, or if these two conditions are totally equivalent.

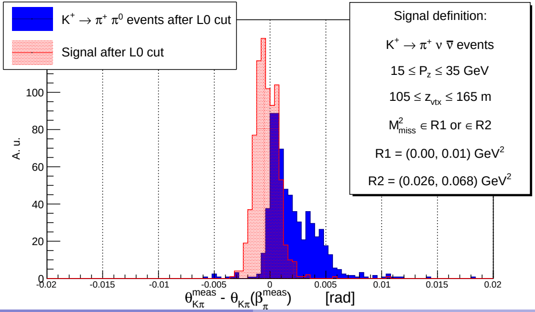


Analysis: more rejection power

Challenge: find the variable that behaves best, i.e. the narrowest possible form in β, $\theta_{K\pi}$, or the one that best separates the signatures from signal and background events.



$\mathbf{M^2_{miss}}$: too complex? Cut $M^2_{\mathrm{miss}}(\text{RICH}) < -0.02\ \text{GeV}^2$?



$\boldsymbol{\theta^{\mathrm{RICH}}_{K\pi} - \theta_{K\pi}(\beta^{\mathrm{RICH}})}$: exploit β asymmetry and cut $\theta_{K\pi} - \theta_{K\pi}(\beta) > \Delta\theta_{\mathrm{th}}$?

Suggestions are welcome!

Analysis: what comes next

All analysis performed with:

- old software (rev. 254-255, from February)
- single ring χ^2 fit

To-do list:

- compile & test new software: rev. 280-281 contains
  - brand new RICH reconstruction
  - multi ring fit
  - new persistency variables (MC truth ring parameters?!)
- try to get some more rejection power using the other variables

RICH momentum **resolution** is probably **not enough** to separate $K^+ \to \pi^+\pi^0$ from $K^+ \to \pi^+\nu\bar{\nu}$ using bi-dimensional cuts.

The GPU algorithm

What it needs to be:

- **seedless**: it will be fed with RICH raw data
- **fast**: run parallel to the L0 trigger (maximum latency 1ms)
- **accurate**: we don't want any responsibility for signal loss!
- **multi-ring friendly**: to account for $\pi^+\pi^-\pi^+$ and π^0 Dalitz decays

– Idea: two steps algorithm –

Pattern recognition: find out how many rings are there and feed them to a single ring fitting algorithm

$\longrightarrow$
$\longrightarrow$
$\longrightarrow$
$\longrightarrow$
$\longrightarrow$

Single ring fitting: find the best performing algorithm

Single ring algorithm

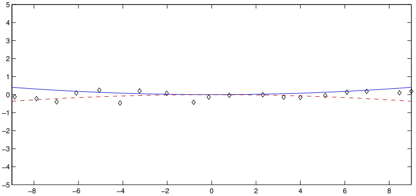
Geometric circle parametrisation:

$$(x - \mathrm{a})^2 + (y - \mathrm{b})^2 - \mathrm{R}^2 = 0$$
$$\mathrm{R} > 0$$

Algebraic circle parametrisation:

$$\mathrm{A}(x^2 + y^2) + \mathrm{B}x + \mathrm{C}y + \mathrm{D} = 0$$
$$\mathrm{A} > 0$$
$$\mathrm{B}^2 + \mathrm{C}^2 - 4\mathrm{AD} = 1$$

The latter is **more robust** with respect to the parameter R, especially when the data points lie on a short arc (*N. Chernov, "Circular and linear regression: Fitting circles and lines by least squares"*).



Single ring: tested algorithms

math

The simplest fitting procedure. It minimizes the sum of algebraic distances of data points to the circle:

$$f_i \equiv (x_i - a)^2 + (y_i - b)^2 - R^2$$
$$\mathcal{F}_1 = \sum_i f_i^2$$

Taubin

The distances f_i defined above can be written as:

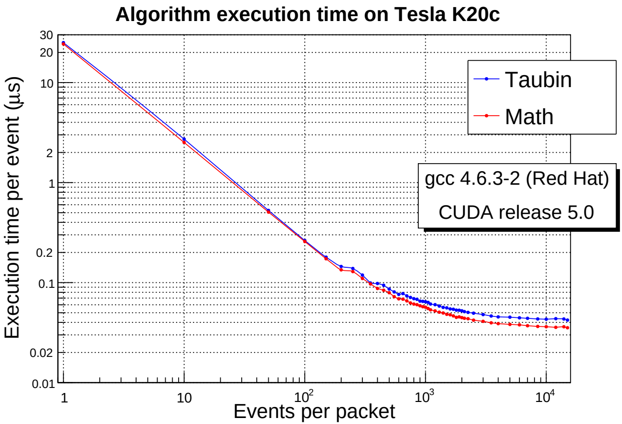
$$f_i = (r_i - R)(r_i + R) \qquad r_i \equiv \sqrt{(x_i - a)^2 + (y_i - b)^2}$$

$\Rightarrow$ **math** biased towards small circles. Taubin's algorithm minimizes the data points distances to the *nearest* point of the circle:

$$\mathcal{F}_1 = \sum_i (r_i - R)^2$$

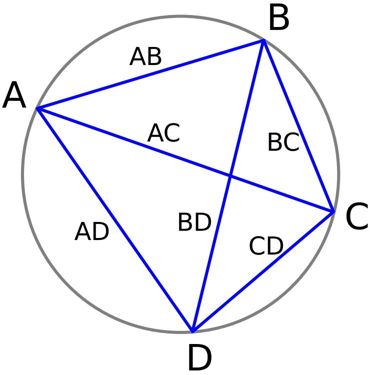
Single ring: tested algorithms

Any algorithm needs to be fast. I measured **math**'s and **Taubin**'s execution time by means of Gianluca's framework (this is not the final algorithm, but only a comparison between the two most convenient single ring fitters):



Pattern recognition step

Open question: **math** and **Taubin** where chosen from the pool of the best *seedless* single ring circle fitting algorithms. A step of pattern recognition will input a seed to the fitting step: are those still the best choice, or may a faster solution exist?



Ptolemy's theorem

If a quadrilateral is inscribable in a circle, then the product of the measures of its diagonals is equal to the sum of the products of the measures of the pairs of opposite sides.

- choose 3 data points **(in an appropriate way)**
- check if any other data point stands to Ptolemy's condition; if it does, it belongs to the same ring
- apply the same algorithm to the data points left out, and so on...

Pattern recognition step: choosing the initial triplets

Non avevo voglia di fare il disegno con inkscape.