Mapping separation power

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Central Problem

- Problem:
  - What is necessary PID quality for PANDA, i.e. what minimal set of PID detectors is needed?
    ... or to be more exact:
  - How much separation power do we need in which phase space region to reach our physics goals?

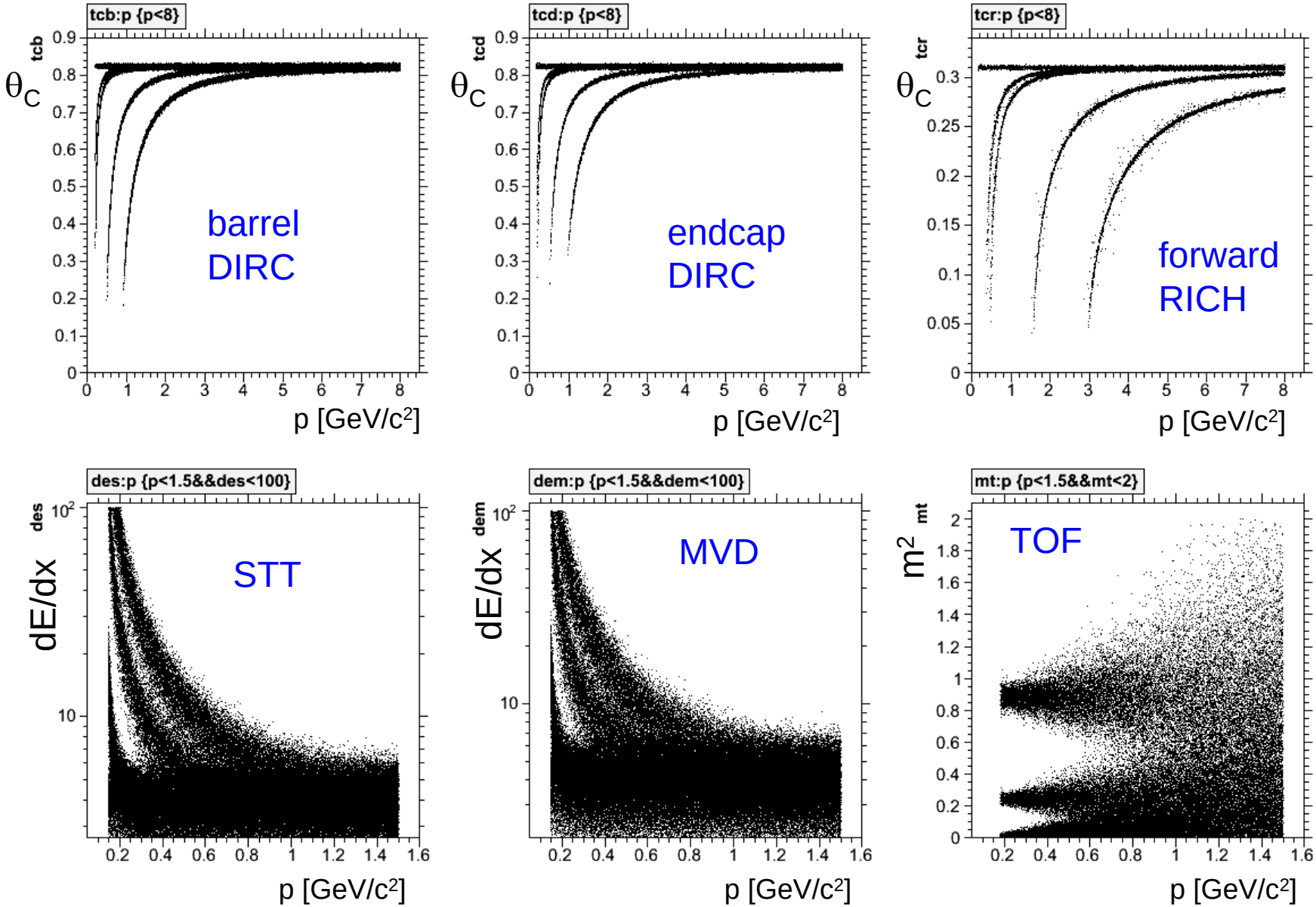
- Answering implies:
  1. How good *is* separation over phase space?
  2. Where is significant kinematic signal/background overlap?

PID information

- **Attempt to answer question No 1.**
- At the moment: almost no reco'd PID info from Full Sim
- Consider parametrized PID info in Fast Sim from det's
  - Barrel DIRC (θ_C) tcb
  - Endcap DIRC (θ_C) tcd
  - Forward RICH (θ_C) tcr
  - Straw Tube Tracker (dE/dx) des
  - Micro Vertex Detector (dE/dx) dem
  - Barrel TOF (m^2) mt
- Dataset: 200k isotropic (θ,p) single track events of every particle type (e, μ, π, K, p)

$$0° < \theta < 180°$$
$$0.15\ \text{GeV/c} < p < 8\ \text{GeV/c}$$

Quality check



Method

- Divide 2-D p, θ region into bins
- for every bin & every 2 PID hypothesis (only ‚neighbours', i.e.: e-μ / μ-π / π-K / K-p)
  - plot the 2 distributions
  - determine mean values μ_i and RMS r_i for both hypothesis (e.g. π and K)
  - separation power (number sigmas) is estimated as

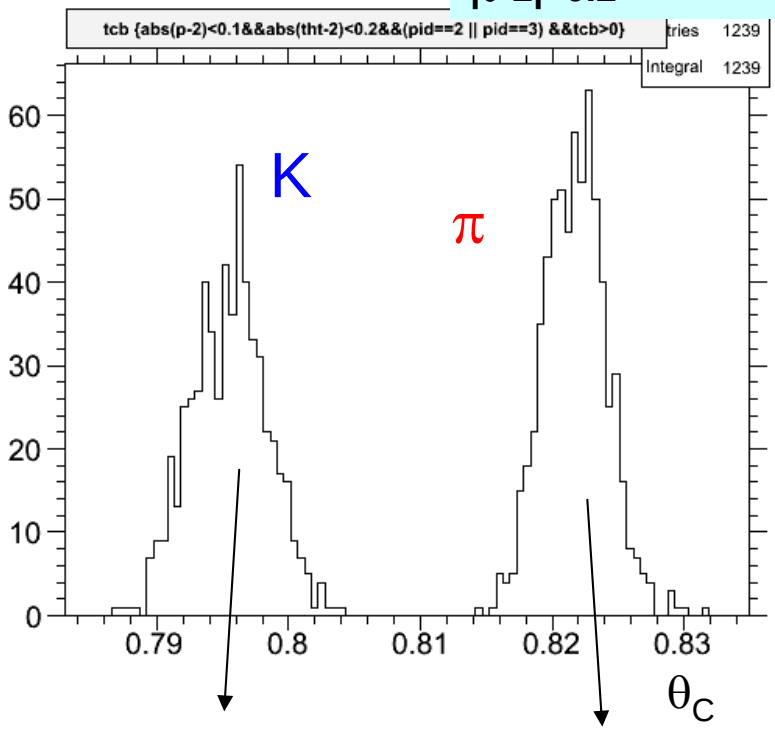
$$n_\sigma = \frac{|\mu_\pi - \mu_K|}{\max(r_\pi, r_K)}$$

  - colorize a 2-D map according to n_σ

Example 1

Barrel DIRC

|p-2.0|<0.1 [GeV]
|θ-2|<0.2



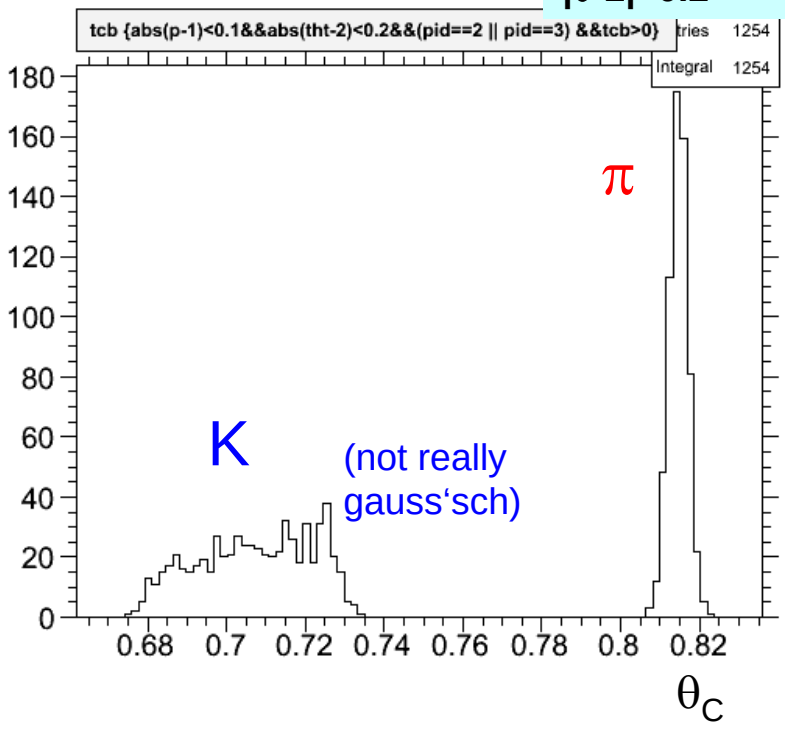
$\mu_K = 0.7955$
$r_K = 0.00288$

$\mu_\pi = 0.8218$
$r_\pi = 0.00239$

$$n_\sigma = \frac{0.8218 - 0.7955}{0.00288} = \frac{0.0263}{0.00288} = 9.13\sigma$$

Barrel DIRC

|p-1.0|<0.1 [GeV]
|θ-2|<0.2



$\mu_K = 0.7071$
$r_K = 0.01436$

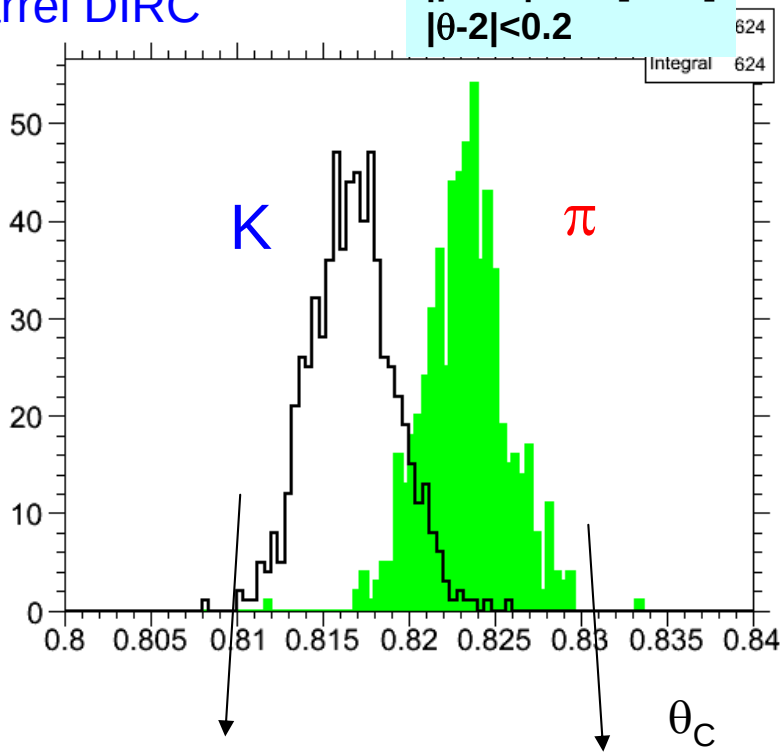
$\mu_\pi = 0.8147$
$r_\pi = 0.00238$

$$n_\sigma = 7.5\sigma$$

Example 2

Barrel DIRC

|p-4.0|<0.1 [GeV]
|θ-2|<0.2



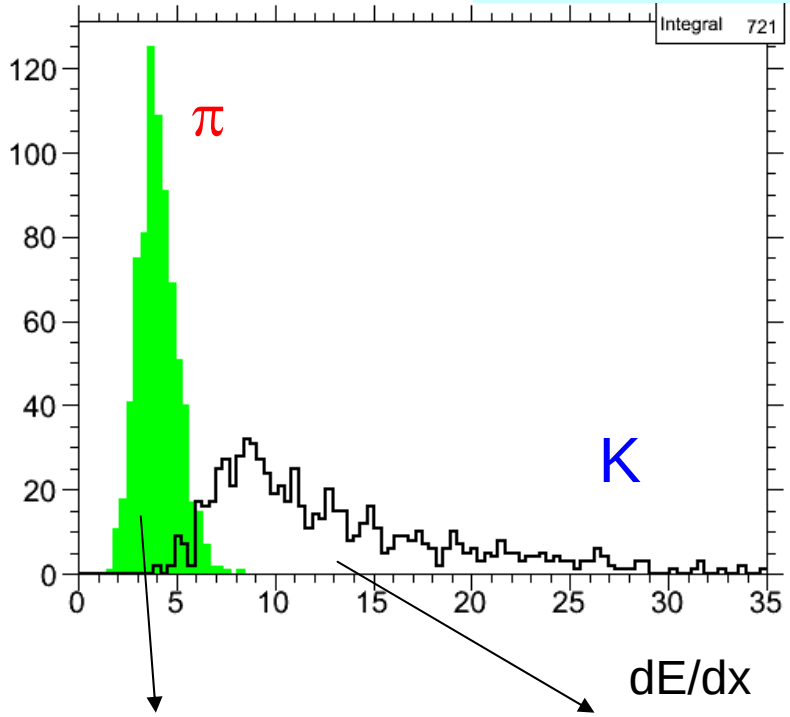
$\mu_K = 0.817$
$r_K = 0.00243$

$\mu_\pi = 0.823$
$r_\pi = 0.00239$

$n_\sigma = 2.6\sigma$

STT

|p-0.3|<0.1 [GeV]
|θ-2|<0.2

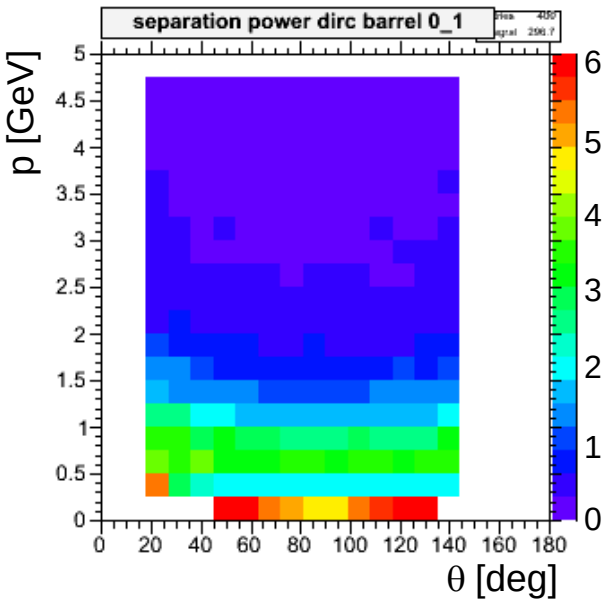


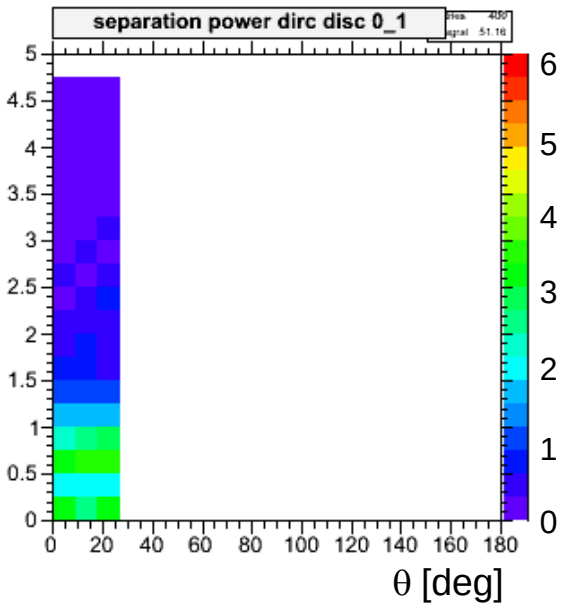
$\mu_\pi = 4.02$
$r_\pi = 0.976$

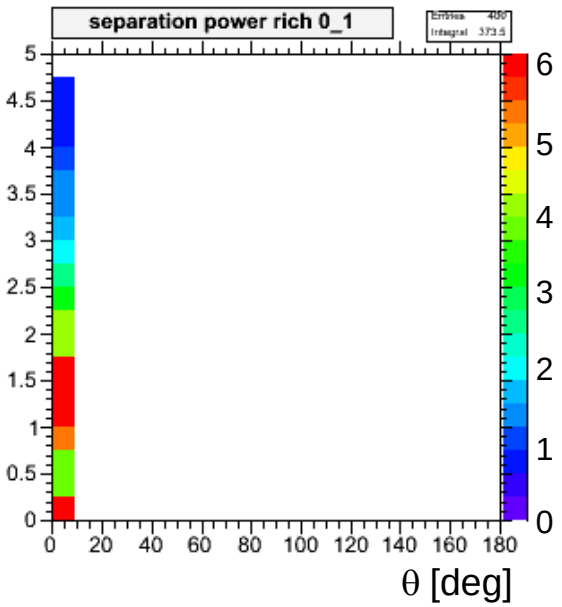
$\mu_K = 12.94$
$r_K = 6.015$

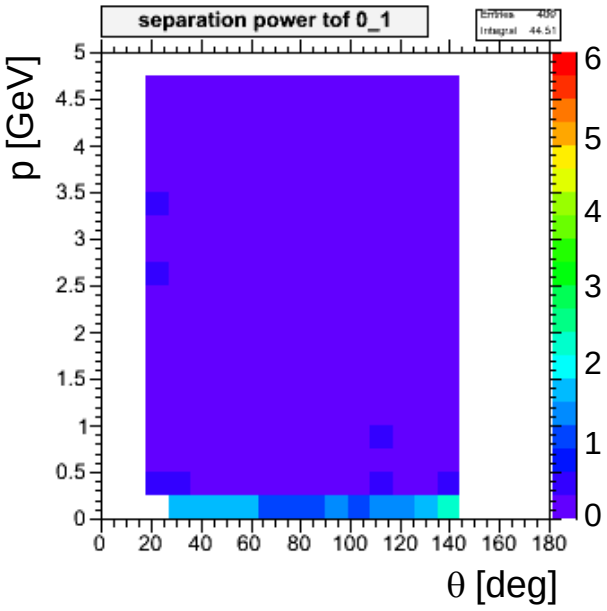
$n_\sigma = 1.5\sigma$

Separation e - mu









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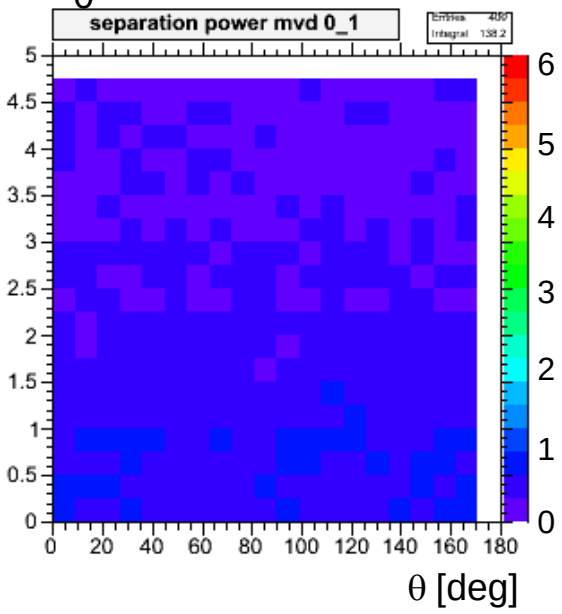
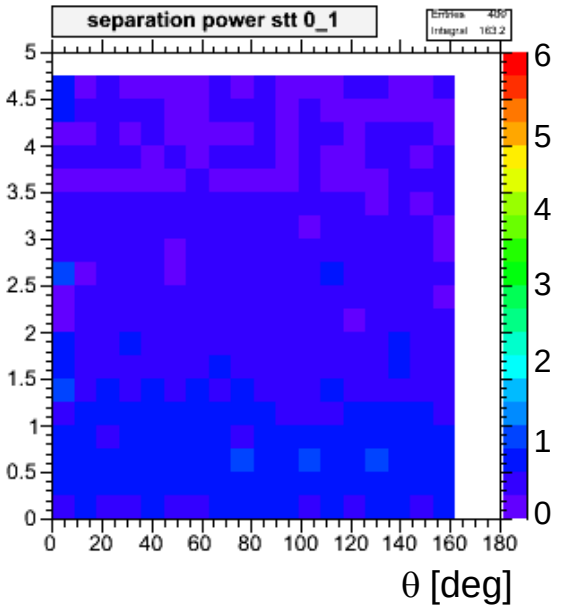
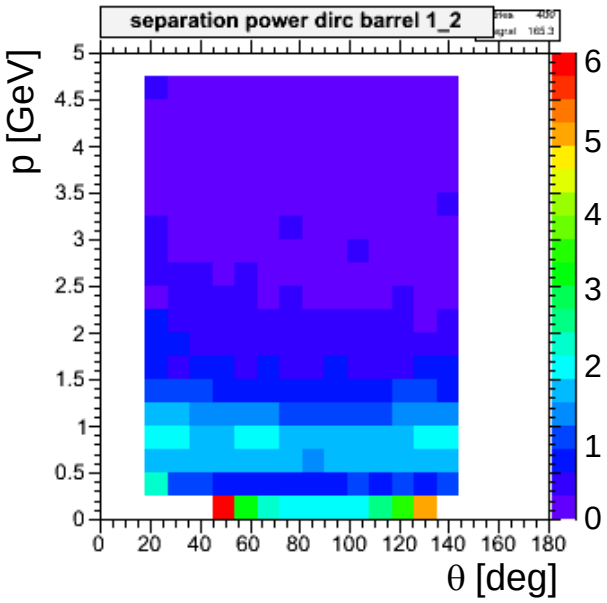
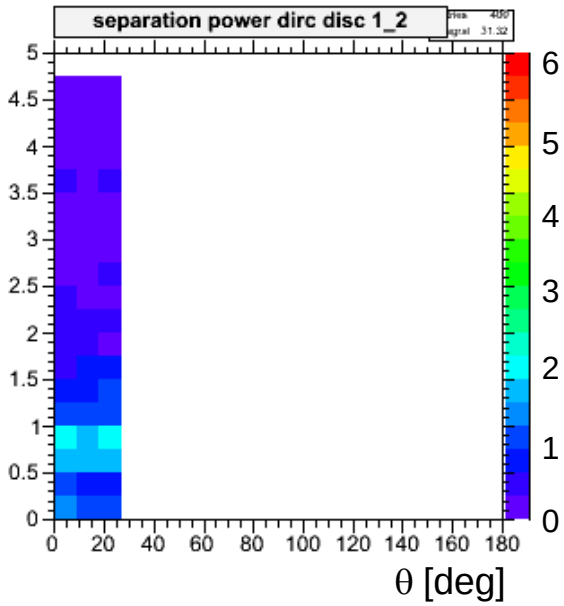
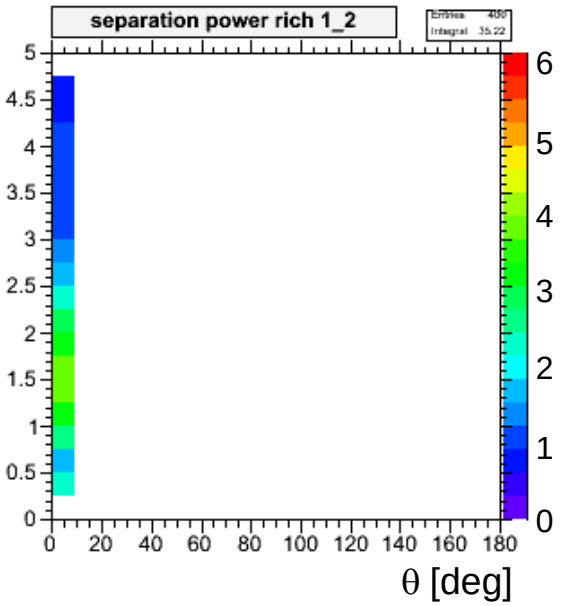


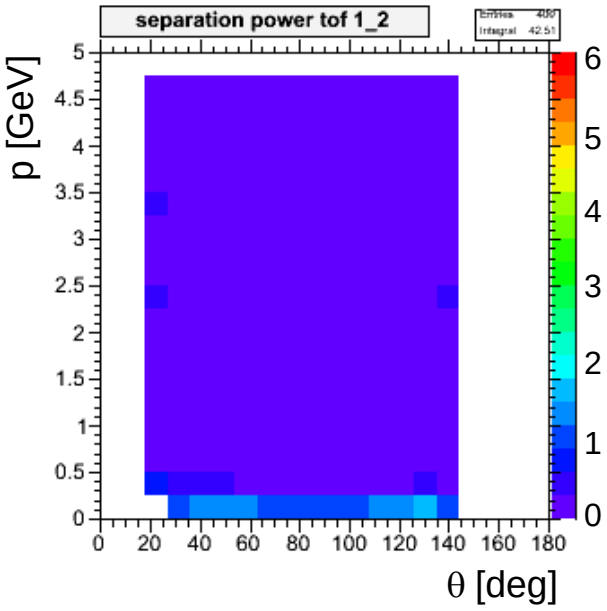


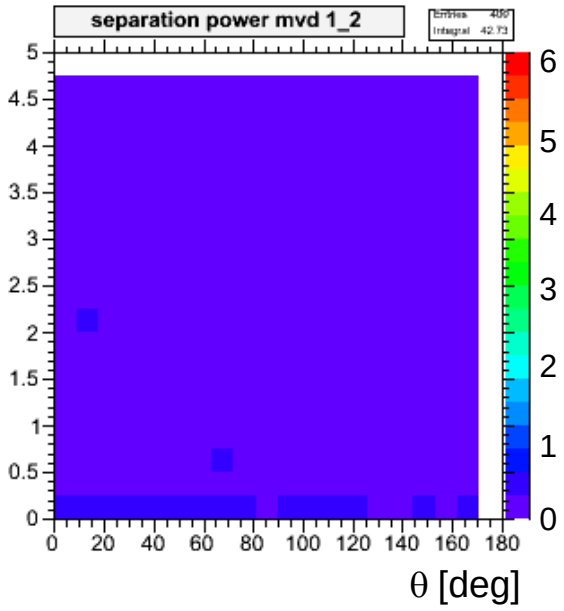
Separation mu - pi

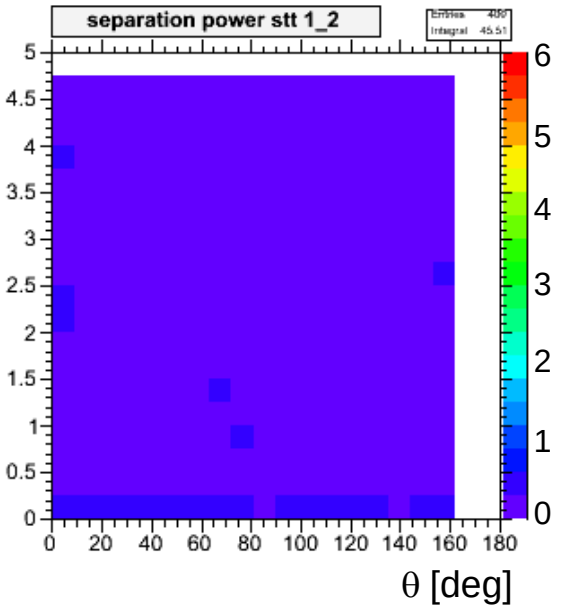




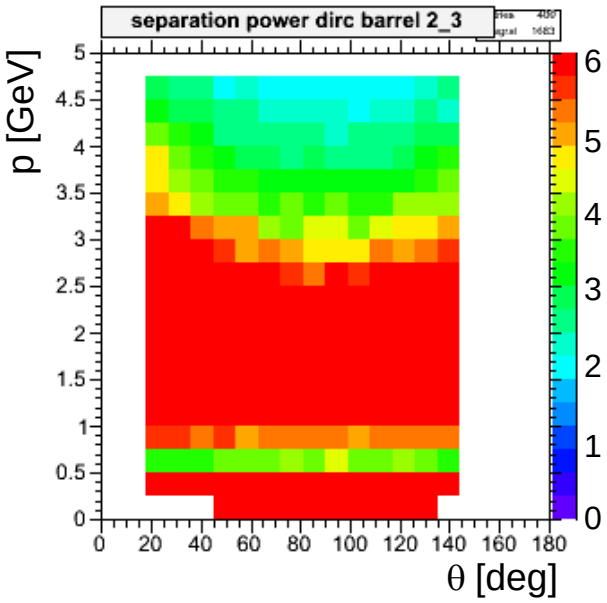


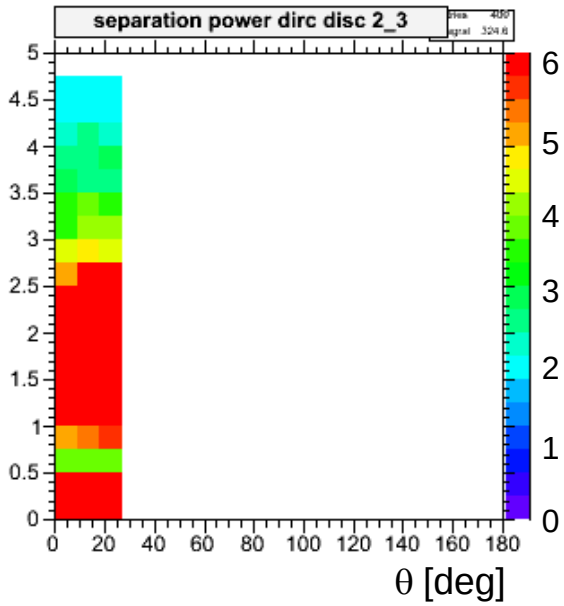


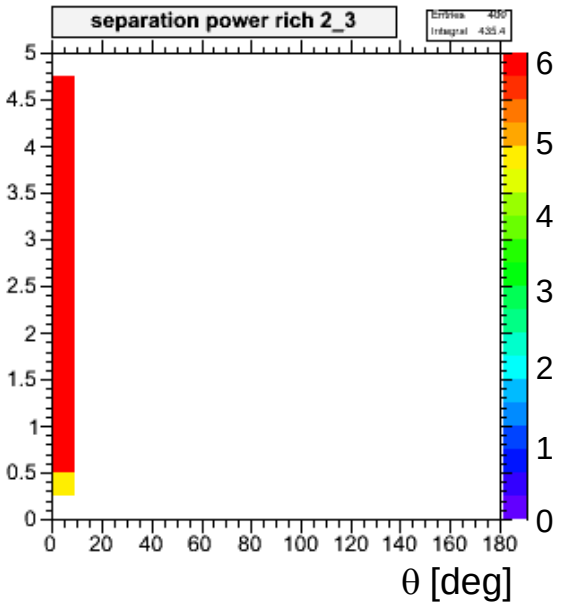


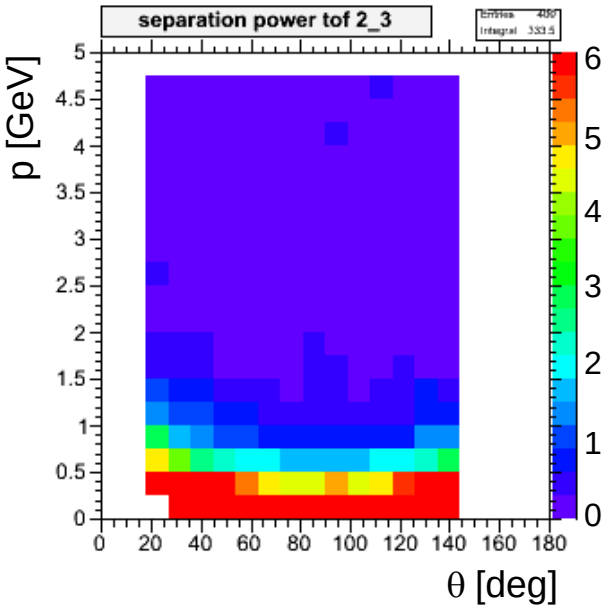


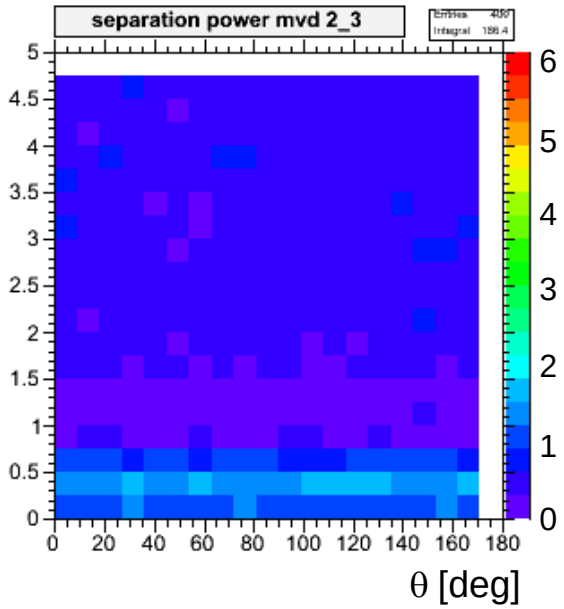
Separation pi - K

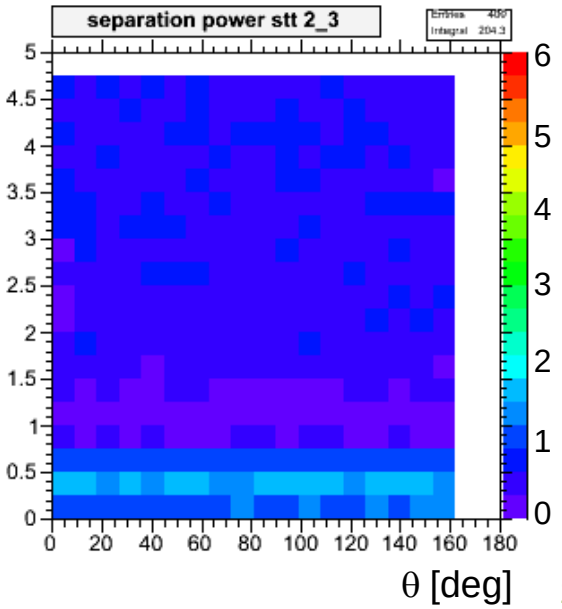




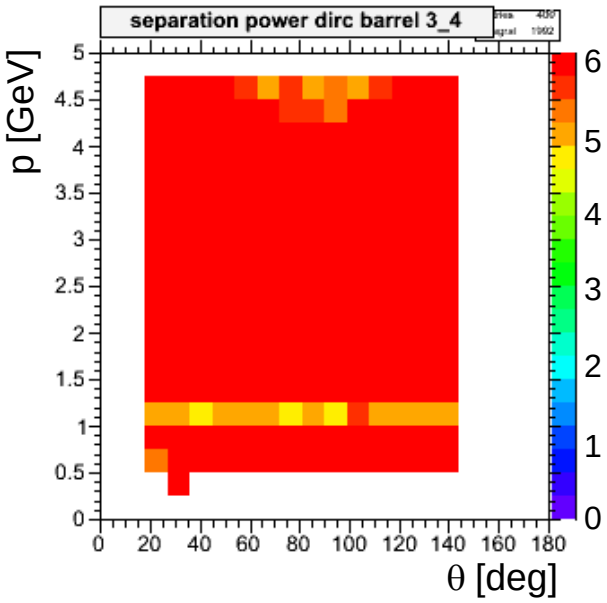


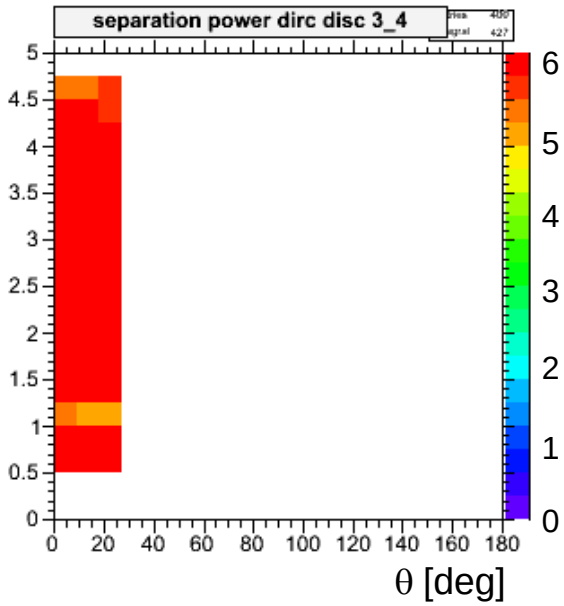


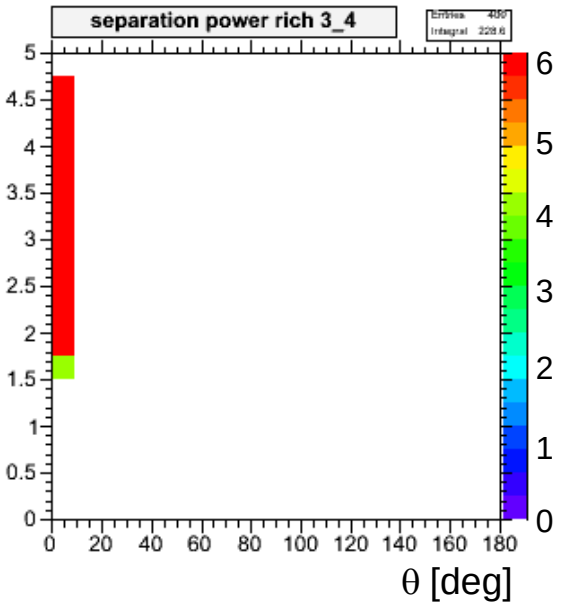


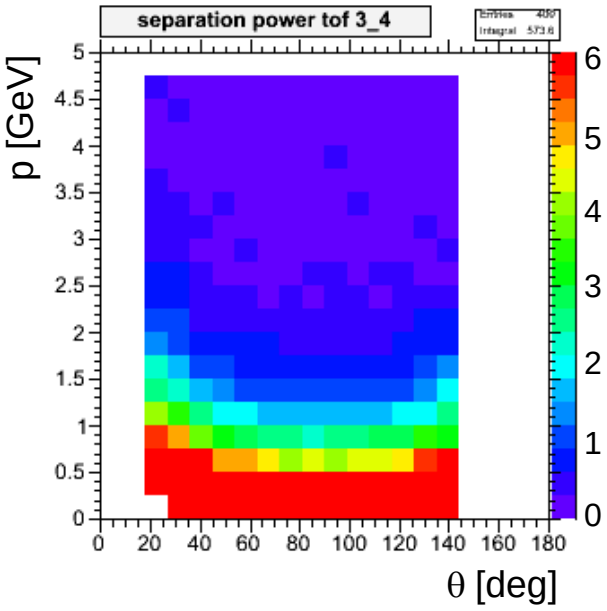


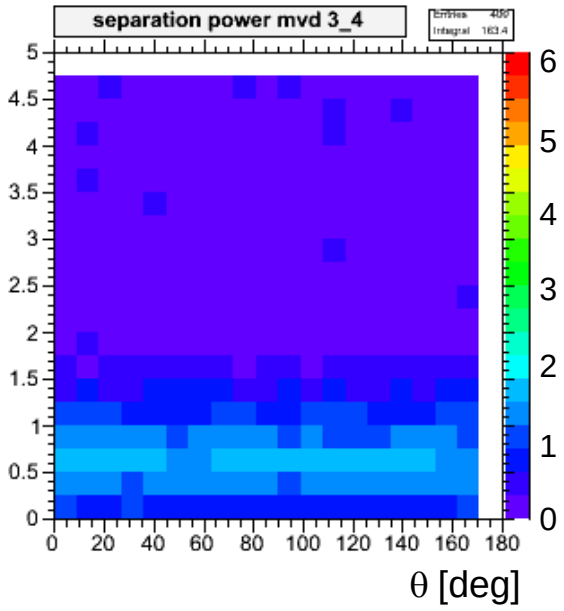
Separation K - p

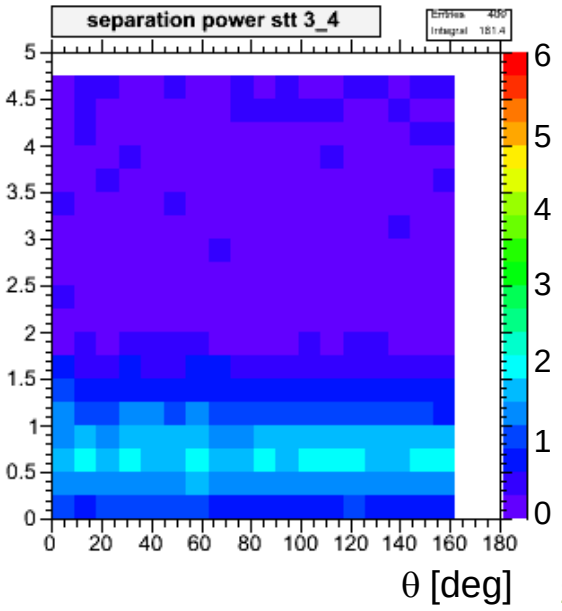










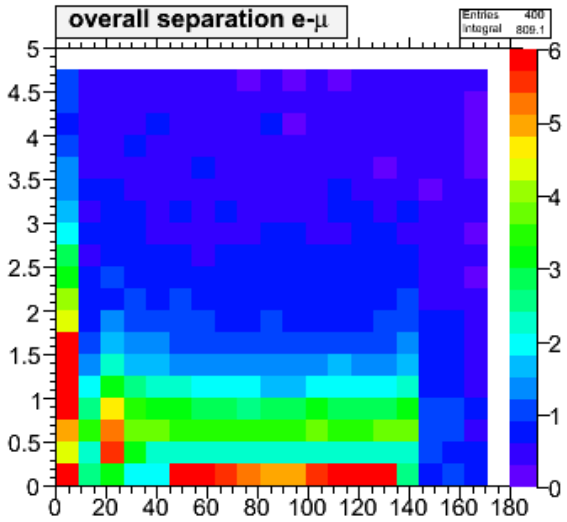


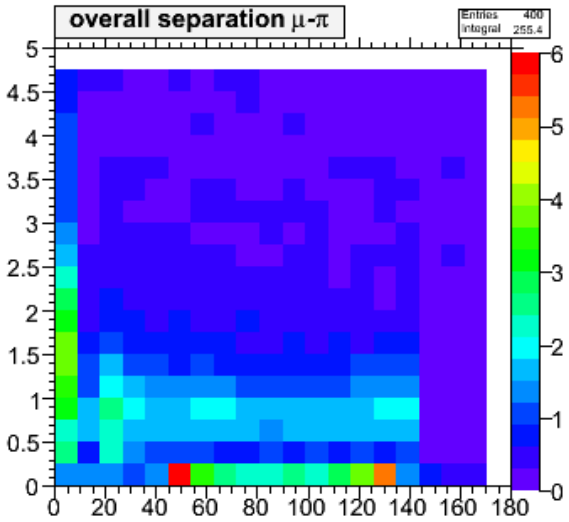
Overall performance

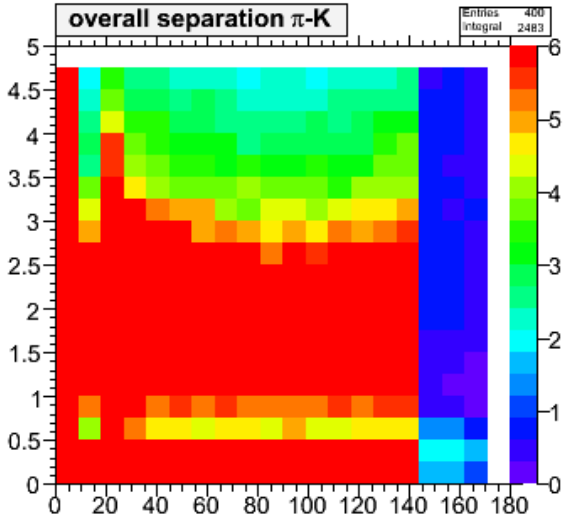
Combined n_σ given by expression

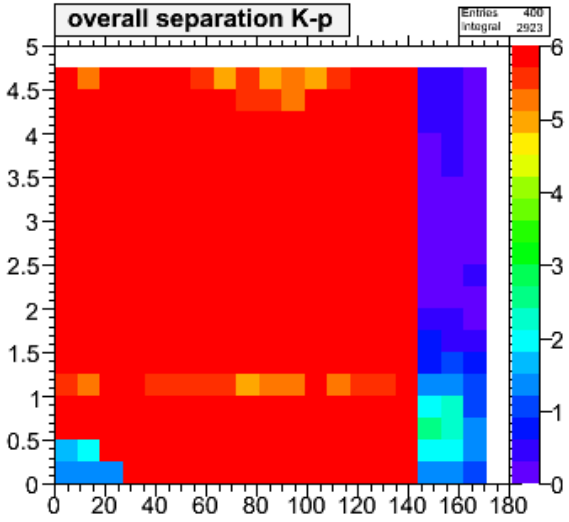
$$n_{\sigma,tot} = \sqrt{\sum_i n_{\sigma,i}^2}$$

Of course, there are still some flaws, but this is the preliminary **separation power map!**









Signal / Background overlap

- How does this now apply to our physics cases?
- Compare the following:

- EvtGen: Kaon p-θ distributions of benchmark channel, e.g.

$$\bar{p}p \rightarrow \phi\phi \rightarrow K^+K^-K^+K^-$$

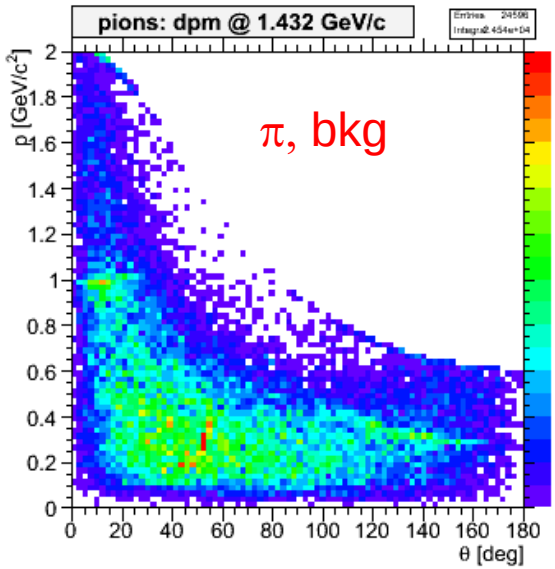
  at different pbar momenta (1.432, 5.0, 10.0, 15.0 GeV/c)

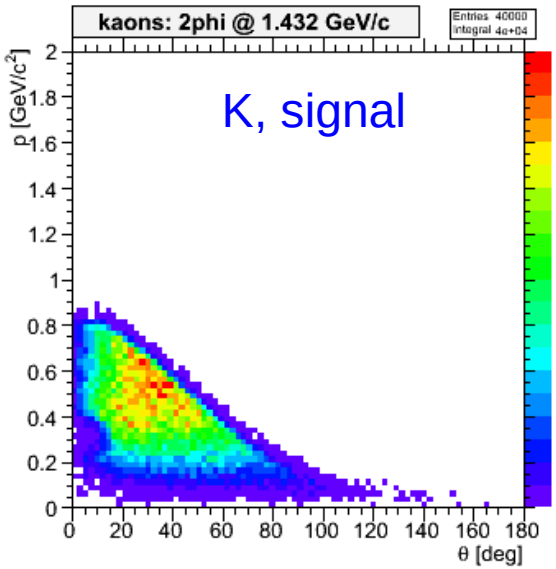
- DPM Gen: Pion p-θ distribution at same energies

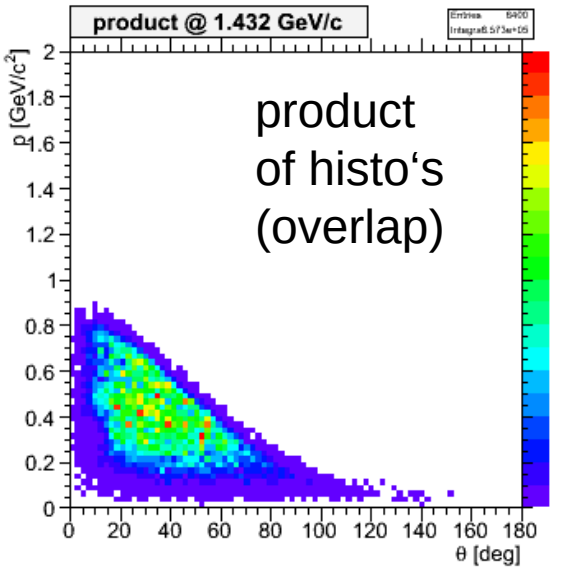
- Determine kinematic overlap regions and look how good separation power is there

p_{pbar} = 1.432 / 5.0 GeV/c

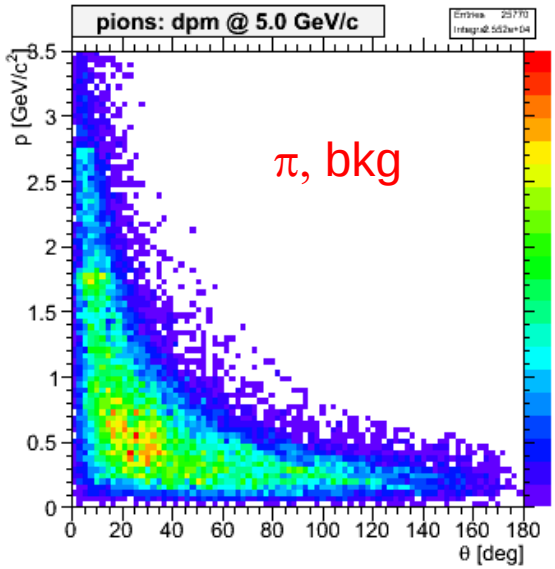
p = 1.432 GeV/c

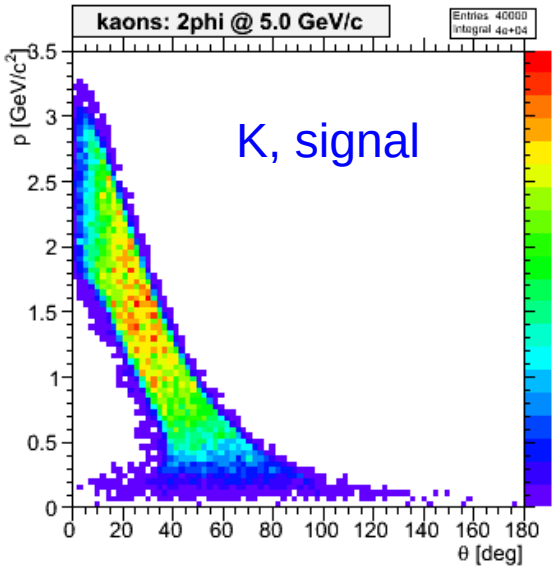


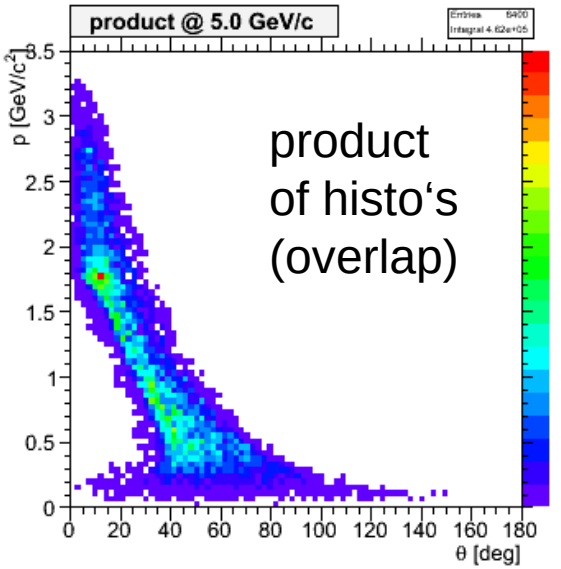




p = 5.0 GeV/c

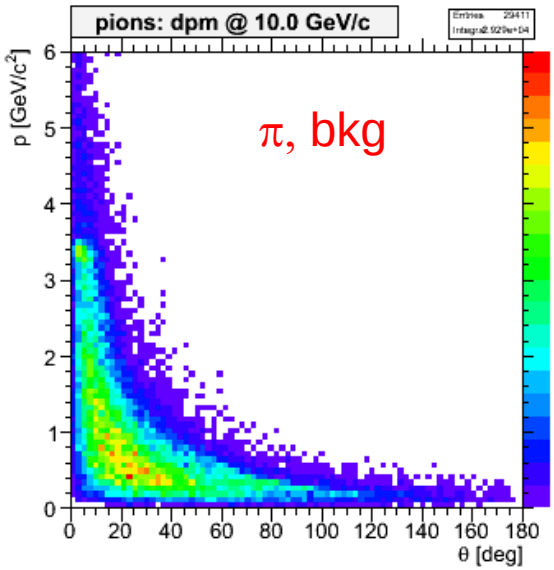


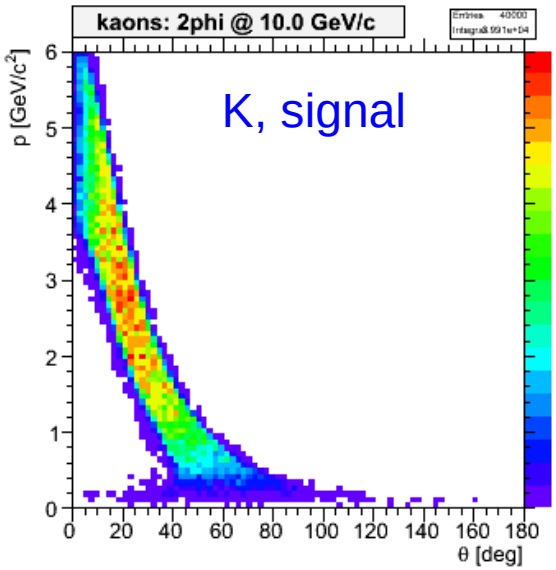


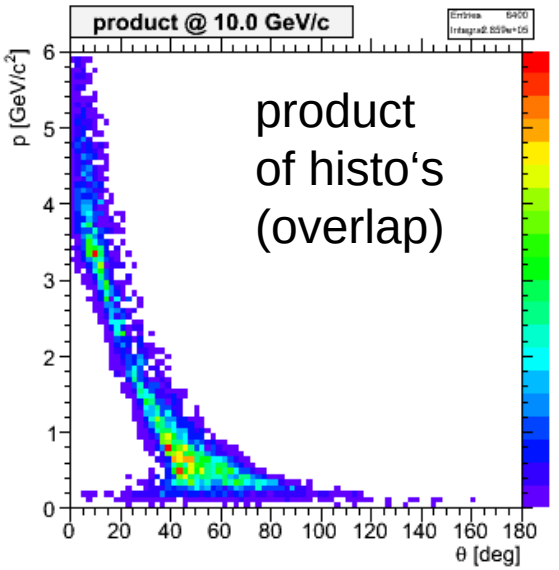


p_{pbar} = 10.0 / 15.0 GeV/c

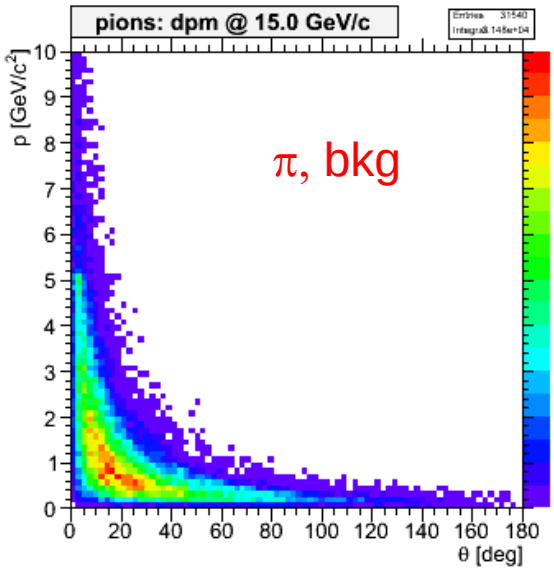
p = 10.0 GeV/c

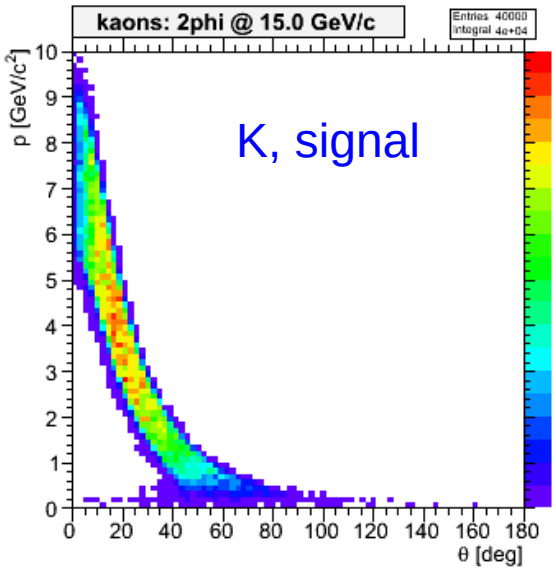


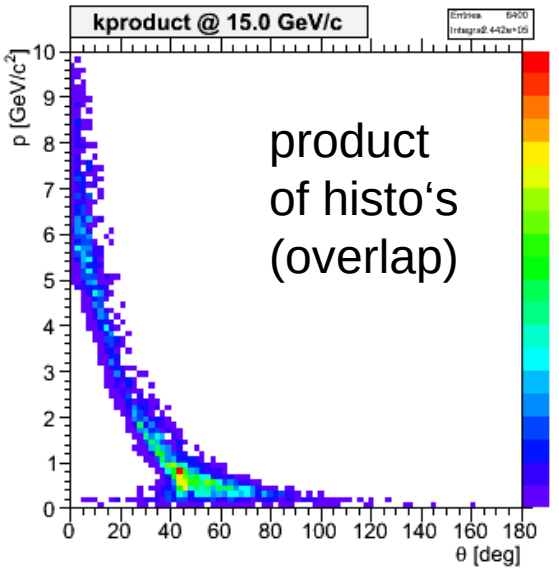




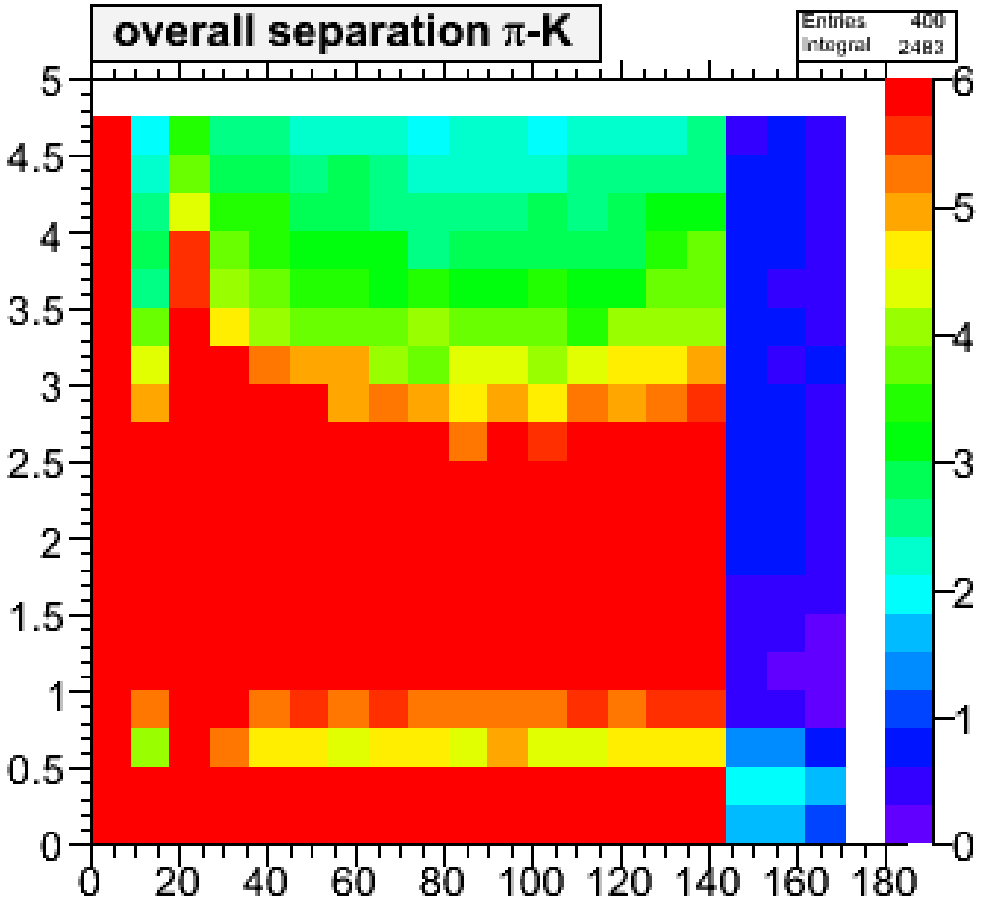
p = 15.0 GeV/c



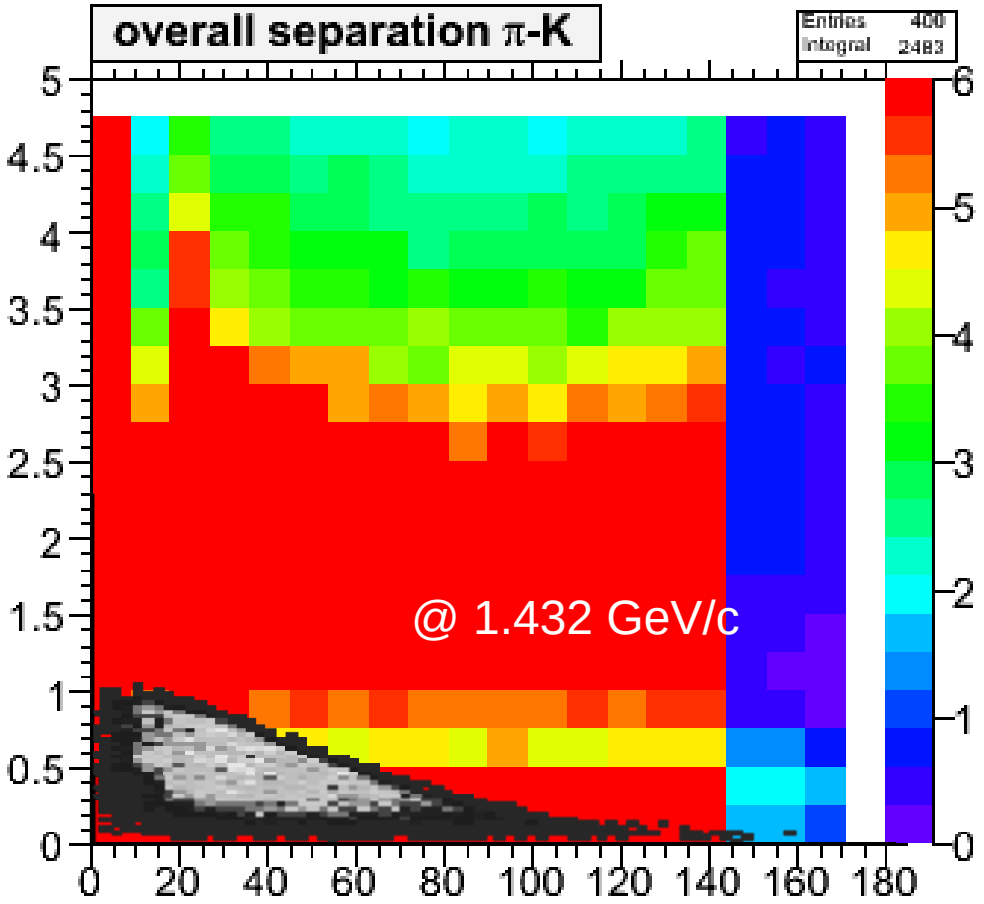




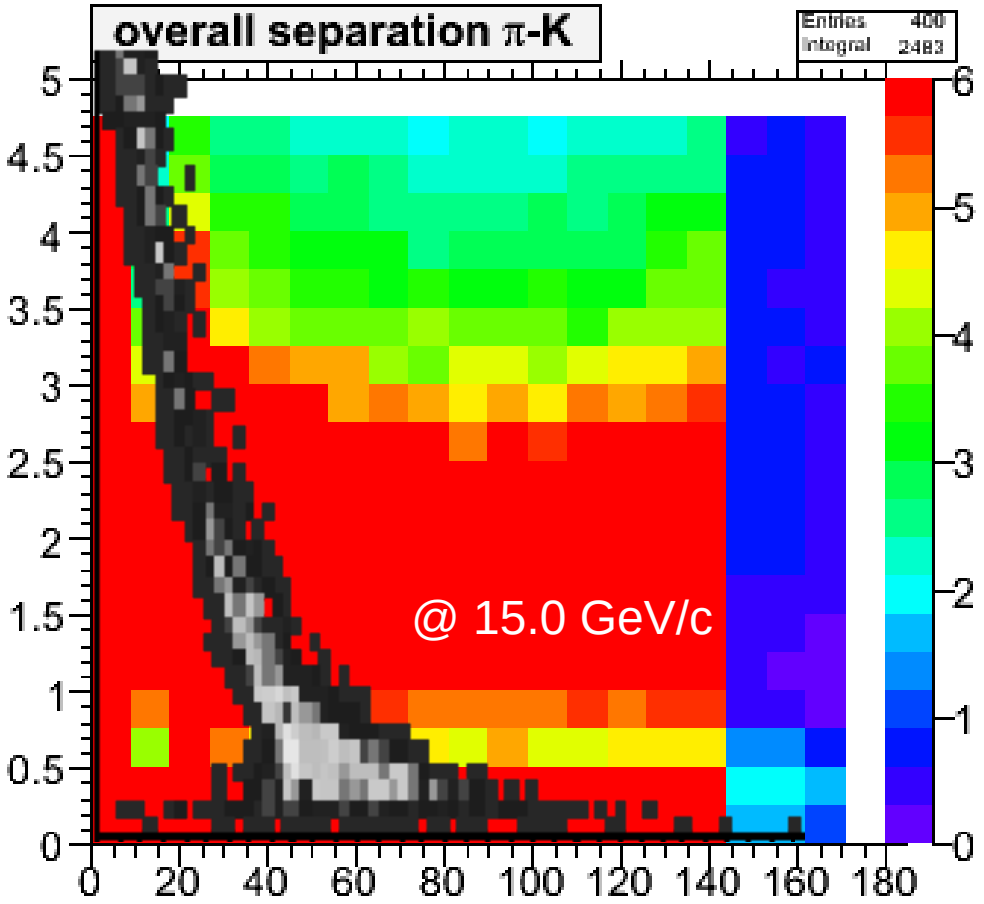
Combining information



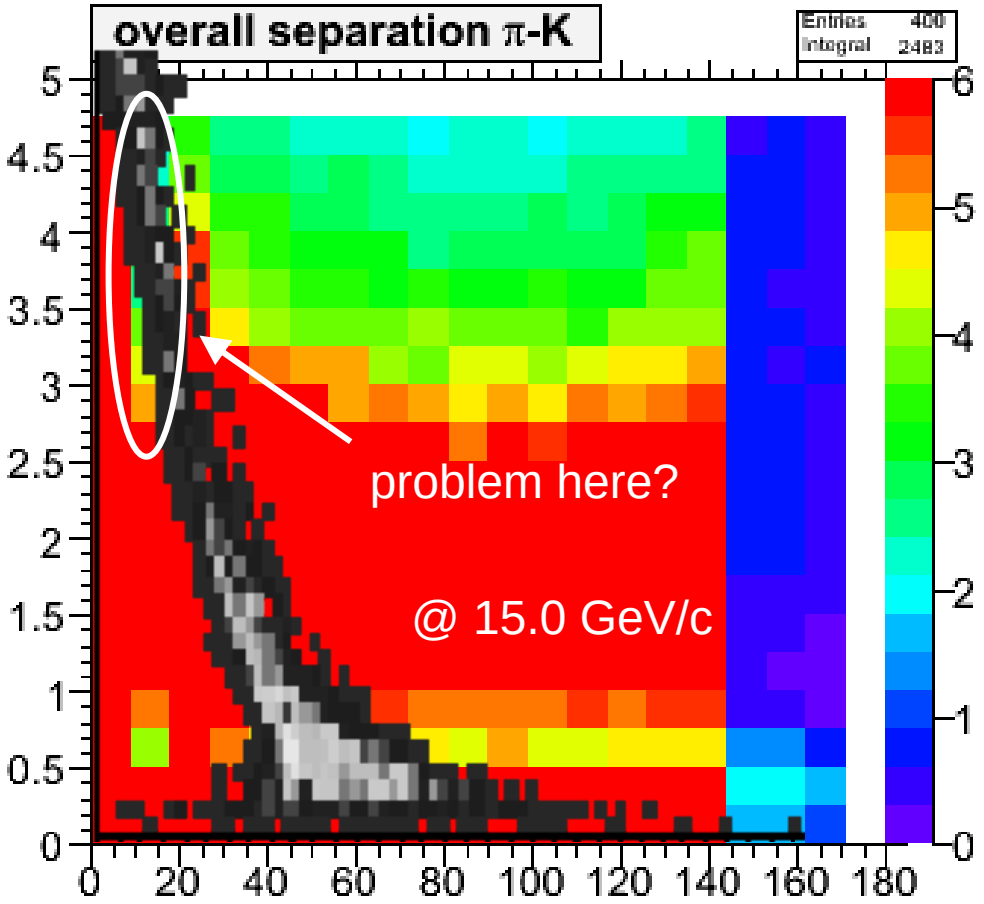
Combining information



Combining information



Combining information



Summary

- Task: Recommendation for minimum set of PID detectors

- Attempt to determine
  - Separation power p-θ dependent
  - Regions, where it‘s acctually needed
- Limitations
  - Information based on parametrizations only
  - No EMC informations so far
  - Dsitributions are not gaussian
    $\rightarrow$ does our definition of sep. power make sense here
  - Due to finite granularity (bin width) $\rightarrow$ artifacts in the map
  - Is the estimate for the total $n_{\sigma,tot}$ correct?