Particle Identification at PANDA

report of the PID TAG

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for the PID TAG

http://panda-wiki.gsi.de/cgi-bin/viewauth/Tagpid/WebHome

Plenary session, PANDA meeting
INFN Ferrara, Sept. 11, 2008

Content of the PID TAG report

1. introduction
2. requirements from physics
3. pid subsystems
4. tools
5. evaluation
6. global pid
7. conclusion

Content of the PID TAG report

2. requirements from physics

3. list of detectors
   - dimensions/material budget
     - θ angle covered
   - working principal
     - momentum covered

4. tools
   - separation power (Map)
   - parametrizations (+ specifics)
   - fast simulation
   - phase space plots

5. evaluation

PANDA: Physics Goal

Charm spectroscopy

- charmonium: Positronium of QCD
- charm hybrids
- |c>-states narrow, understood
- mass 4–4.5 GeV
  - |c c g> narrow
  - little interference between |ccg> and |cc>-states

Hypernuclei

- 3rd dimension in nuclear chart
- study interactions of nucleons in the nuclear potential
- Double Hypernuclei
  - production via Ξ- capture
  - Λ Λ interaction in nucleus

Charm in the Medium

- mesons in nuclear matter
- masses change in nuclei
- J/ψ absorption in nuclei

Electromagnetic formfactors

- Measure $\bar{p}p \rightarrow e^+e^-$
  - discrepancy between timelike and spacelike region

Generalized Parton Distributions

- wide angle Compton scattering
- hard exclusive meson production

Transverse nucleon spin

- Drell Yan Process

PANDA: Physics Goal

hidden charm physics

- concurrent detection of lepton pairs
- good K-identification
- low energy photon detection
- muon detection

hypernuclei

- good detection of antihyperons
- low momenta K+ in forward region

open charm physics

- rather high p_T
-
-

PID Particle Identification

PANDA PID Requirements:

- particle identification essential for PANDA
- momentum range 200 MeV/c – 10 GeV/c
- Extreme high rates $2 \cdot 10^7$
- concurrent lepton pairs
- good kaon–pion (K-π) separation
  between 0.6 and ≥ 4.5 GeV/c
  -> different processes for PID needed

PID Processes:

- **Cherenkov radiation:** above 1 GeV/c
  - radiators: quartz, aerogel, C_4F_{10}
- **energy loss:** below 1 GeV/c
  - best accuracy with TPC
- **Time of Flight**
  - problem: no start detector
- **electromagnetic showers:** EMC for e and γ

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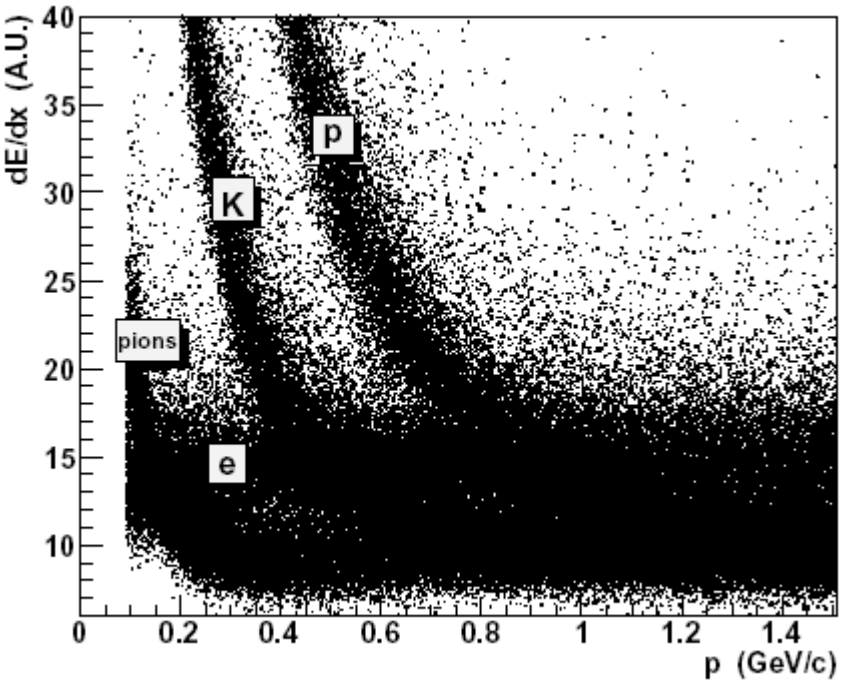
List of PID Detectors

particle momentum
0 2 4 6 GeV/c

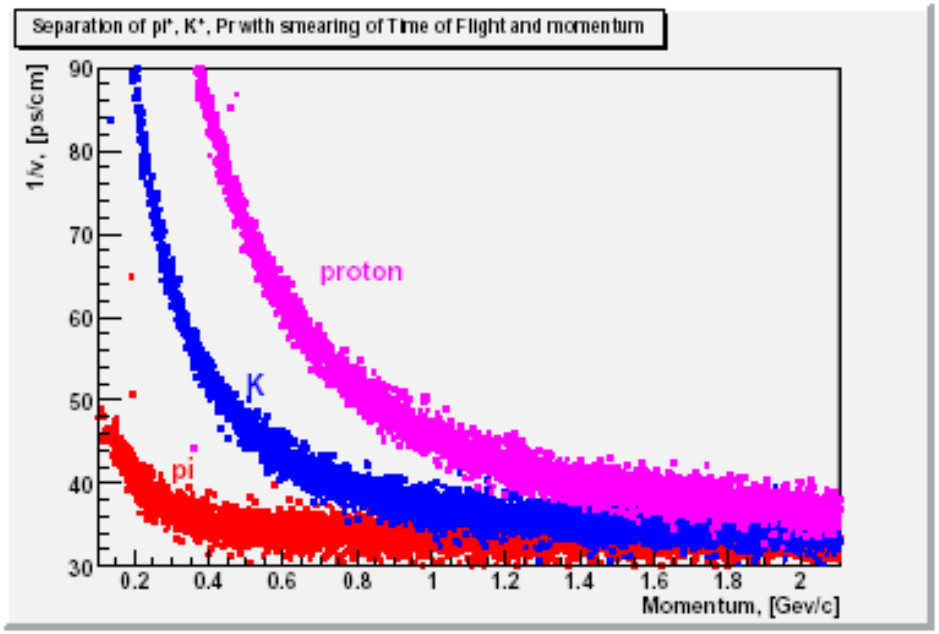
distance to the target

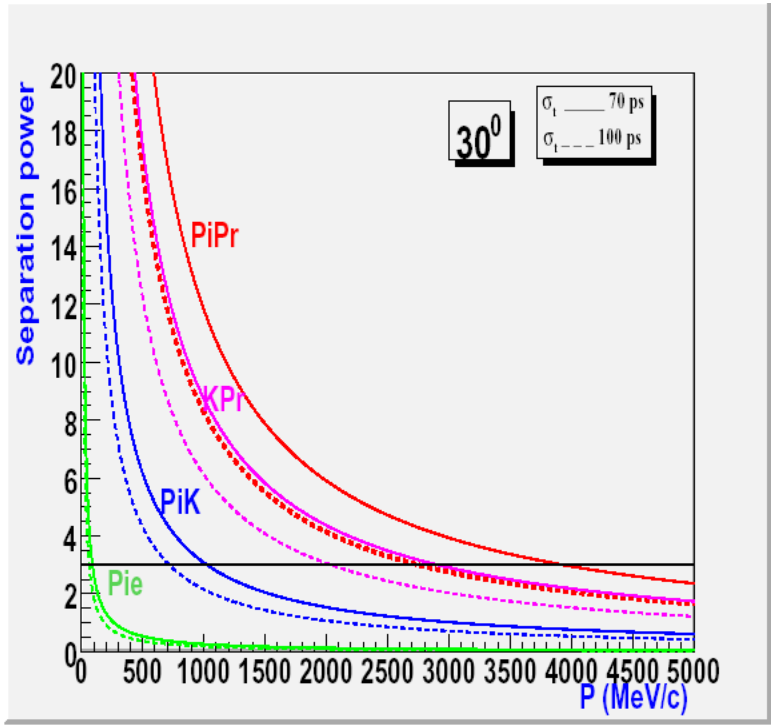
3.1 Micro Vertex Detector
3.2 Central Tracker
  3.2.1 Time Projection Chamber — **dE/dx**
  3.2.2 Straw Tube Tracker
3.3 Barrel Time of Flight
  3.3.1 Resistive Plate Chamber — **ToF**
  3.3.2 Scintillation Counter
3.4 Barrel DIRC
3.5 Endcap Cherenkov
  3.5.1 Focussing Light Guide Disc DIRC — **Ĉ**
  3.5.2 Time of Propagation Disc DIRC
  3.5.3 Proximity RICH
3.6 ElectroMagnetic Calorimeter — **shower**
3.7 Muon Counter — **absorption/range**
3.8 Forward RICH — **Ĉ**
3.9 Forward ToF — **ToF**
3.10 Forward Calorimeters — **shower**

PID Example: STT Straw Tube Tracker



PID Example: Barrel RPC Resistiv Plate Chamber





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List of PID Detectors

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distance to the target

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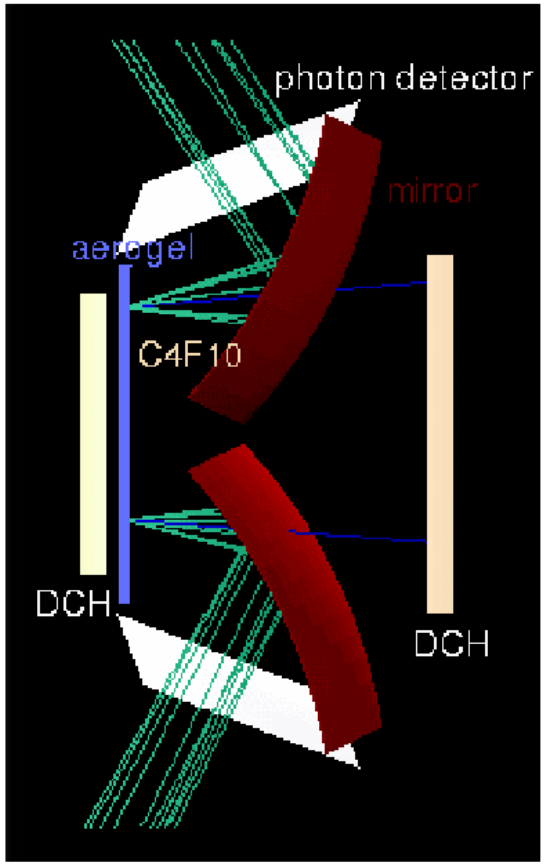
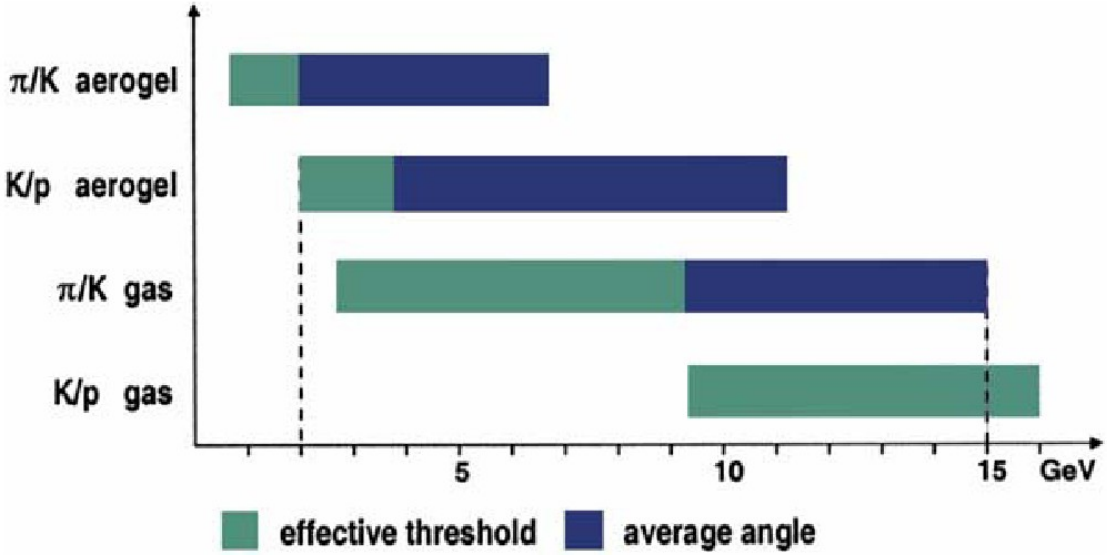
  3.5.3 Proximity RICH
3.6 ElectroMagnetic Calorimeter — **e, π**
3.7 Muon Counter — **π, μ**
3.8 Forward RICH — **K, π**
3.9 Forward ToF — **K, p, π from μ, e**
3.10 Forward Calorimeters — **e, π + Hadronen, Leptonen**

PID Example: Forward RICH





K: lower threshold for Cherenkov light

Forward RICH complementary to Forward ToF

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4. **tools**
   - separation power (Map)
   - parametrizations (+ specifics)
   - fast simulation
   - phase space plots

5. evaluation

Tools

- separation power
  - definition of performance

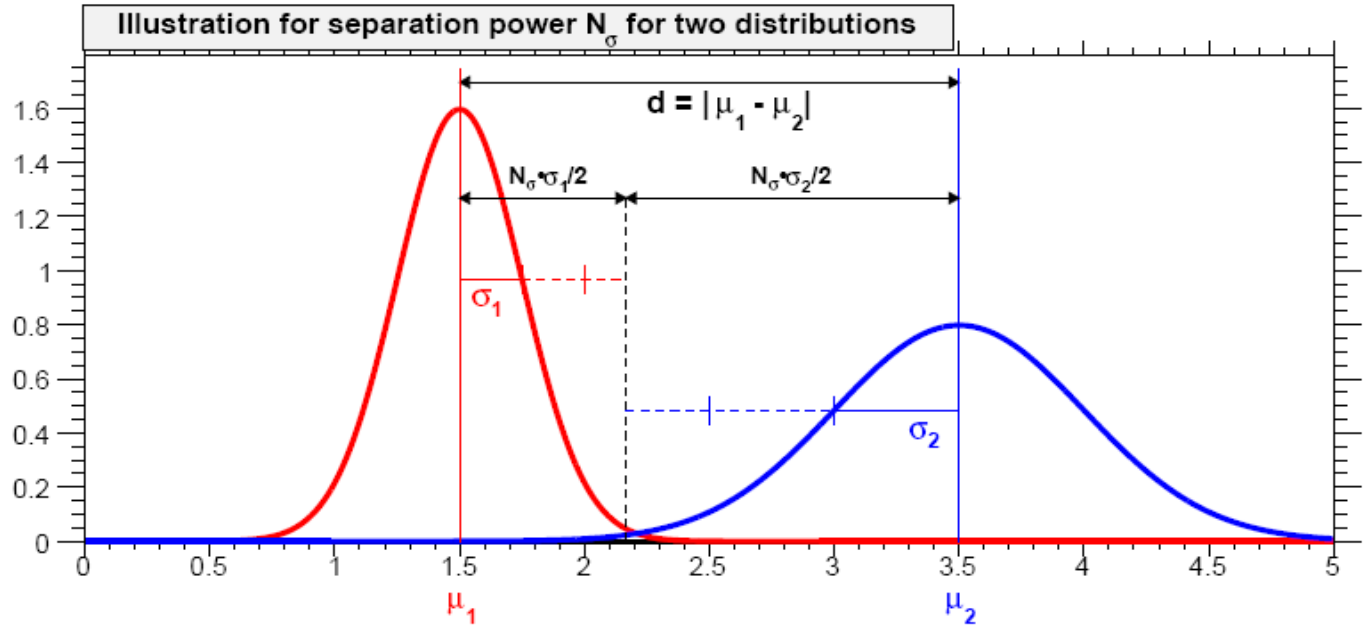
- parametrizations of PID processes

- fast simulation
  - input: - parametrizations
    - performance and dimensions
  - out put: - map of separation power
    - each θ-p bin has a N(σ)

- phase space plots
  - signals and background
  -> regions where PID needed

Separation Power definition

$$N_\sigma = \frac{|m_1 - m_2|}{\sigma_\beta} = \frac{|m_1 - m_2|}{(\sigma_1/2 + \sigma_2/2)}$$



4 σ separation:

$$I = \int_{-\infty}^{\mu+4\sigma/2} G(x;\mu,\sigma)\,dx = 0.9772$$

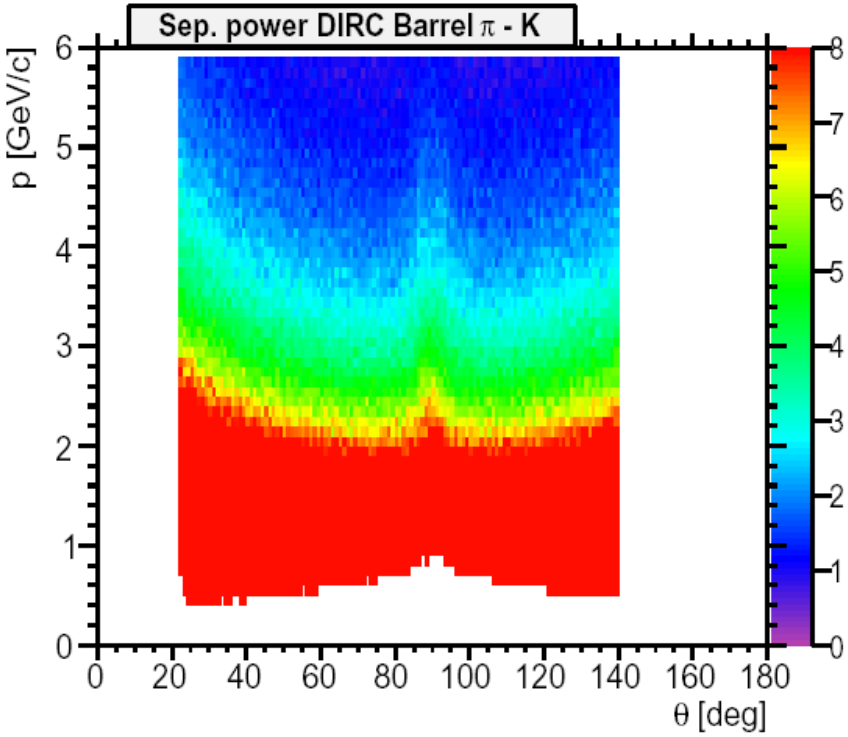
Separation Power definition

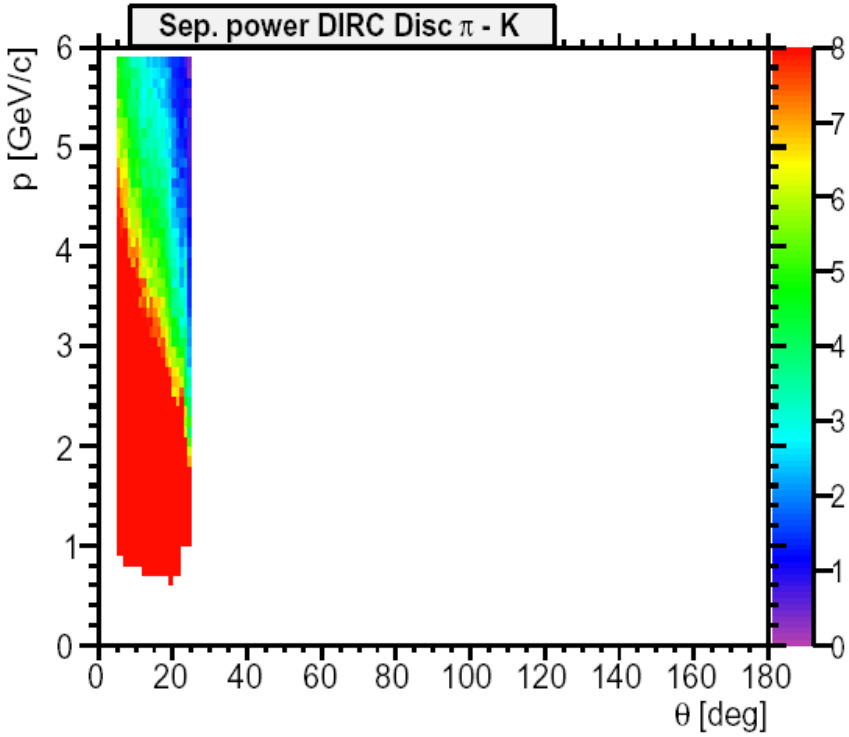
$$I = \int_{-\infty}^{\mu+4\sigma/2} G(x;\mu,\sigma)\,dx = 0.9772$$

N_σ	mis-id (1s) [%]	mis-id (2s) [%]	mis-id [%]	N_σ (1s)	N_σ (2s)
1.0	30.854	61.708	10.000	2.6	3.3
2.0	15.769	31.538	5.000	3.3	3.9
3.0	6.681	13.361	1.000	4.6	5.1
4.0	2.254	4.507	0.500	5.1	5.6
5.0	0.621	1.242	0.100	6.2	6.6
6.0	0.133	0.266	0.050	6.6	7.0
7.0	0.023	0.047	0.010	7.4	7.8
8.0	0.003	0.006	0.005	7.8	8.1
9.0	0.000	0.001	0.001	8.5	8.8

Table 7: Relation between separation power and mis-id level

Separation Power Map

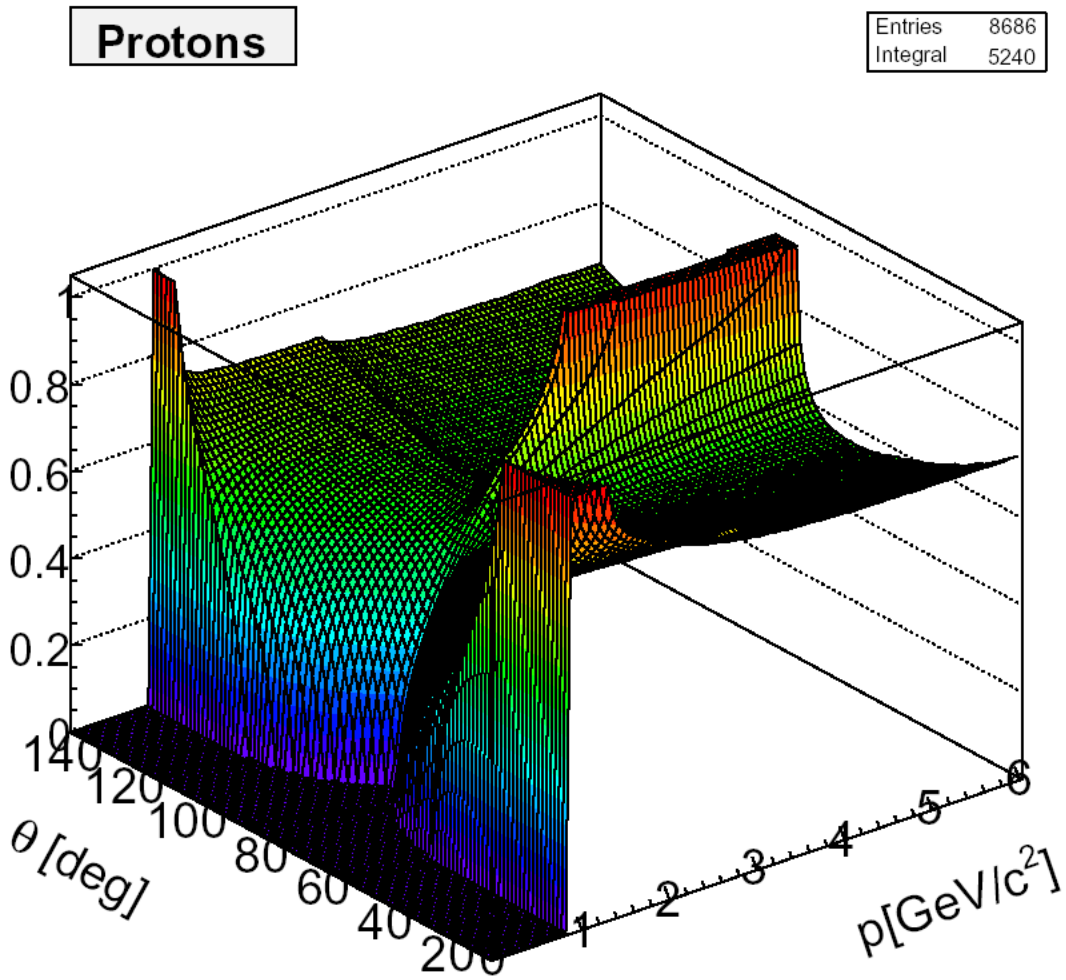




5 M isotropic distributed single track events

1. $e^{\pm} - \mu^{\pm}$, $e^{\pm} - \pi^{\pm}$, $e^{\pm} - K^{\pm}$, $e^{\pm} - p/\bar{p}$,
2. $\mu^{\pm} - \pi^{\pm}$, $\mu^{\pm} - K^{\pm}$, $\mu^{\pm} - p/\bar{p}$,
3. $\pi^{\pm} - K^{\pm}$, $\pi^{\pm} - p/\bar{p}$,
4. $K^{\pm} - p/\bar{p}$.

Barrel DIRC Trapping Fraction



Combined Separation Power

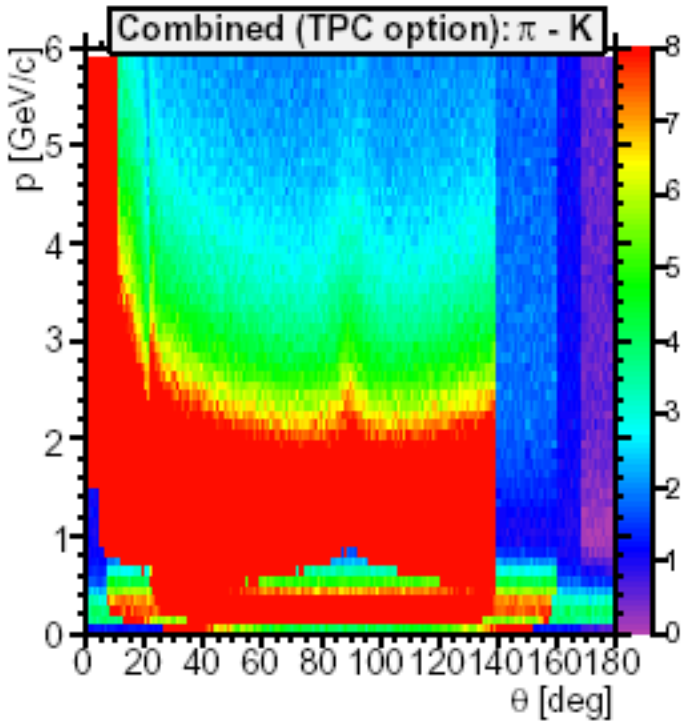
defined as:

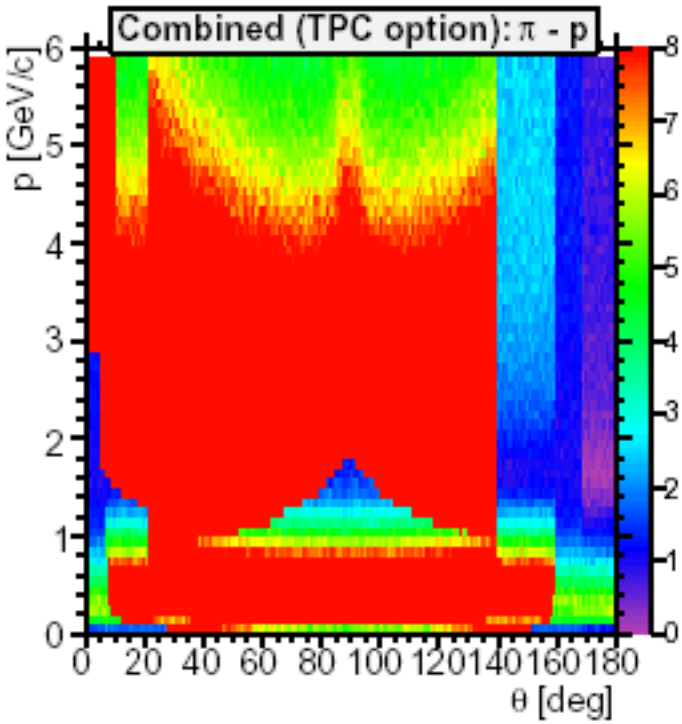
$$N_{\sigma,\mathrm{tot}} := \left(\sum_i N_{\sigma,i}^2 \right)^{1/2}$$

corresponse to:

$$P_{\mathrm{mis,tot}} = P_{\mathrm{mis}}(N_{\sigma,1}) \times \cdots \times P_{\mathrm{mis}}(N_{\sigma,n})$$

Separation Power Map





Phase Space Plots

Resonances @ 15 GeV/c

Signal	Background	$p_{\bar{p}}$ [GeV/c]	Fig.
$J/\psi 2\pi^0$	$\pi^+\pi^-2\pi^0$	5.609 / 6.232 /8.682	
		10.295 / 12.349	51
$J/\psi\pi^+\pi^-$	$2\pi^+2\pi^-$	5.609 / 6.232 / 6.988	
		8.682 / 10.295 / 12.349	-
	$2\pi^+2\pi^-\pi^0$	6.990 / 8.7	-
$J/\psi\eta$	$2\pi^+2\pi^-$	6.080 / 6.990 / 8.7	-
	$3\pi^+3\pi^-$	6.080 / 6.990 / 8.7	-
$\phi\phi$	$2\pi^+2\pi^-$	1.5 / 6.0 / 12.0 / 15.0	52
	$3\pi^+3\pi^-$	1.5 / 6.0 / 12.0 / 15.0	-
$\Lambda^0\bar{\Lambda}^0$	$\Sigma^0\bar{\Sigma}^0$	1.914 / 3.101 / 6.0	53
	DPM	1.460 / 8.0 / 10.0	-
e^+e^-	$\pi^+\pi^-$	1.7 / 3.3 / 7.9 / 10.9 / 15.0	54
$D_s^+D_{s0}^*(2317)^-$	DPM	8.847	55
	$3\pi^+3\pi^-\pi^0$	8.847	-
$D_s^+D_s^-\gamma$	$3\pi^+3\pi^-$	8.847	-
	DPM	7.361 / 7.746 / 8.0 / 12.0 / 15.0	-
$D^{*0}\bar{D}^{*0}\gamma$	DPM	7.746 / 8.0 / 12.0 / 15.0	-
$D^{*+}D^{*-}\gamma$	DPM	7.746 / 8.0 / 12.0 / 15.0	-
$D^0\bar{D}^0\gamma$	DPM	6.488 / 8.0 / 12.0 / 15.0	-
$D^+D^-\gamma$	DPM	6.488 / 8.0 / 12.0 / 15.0	-

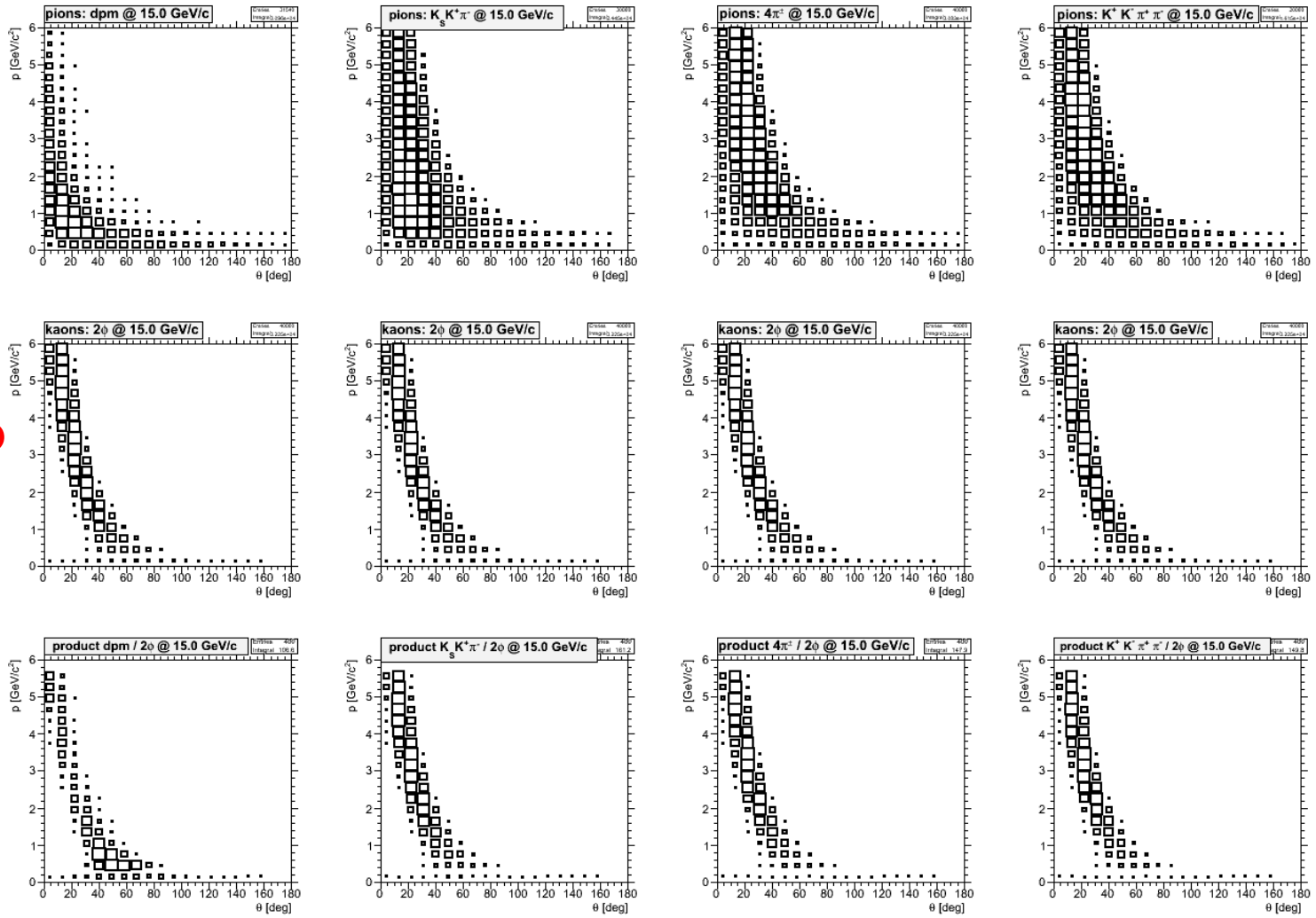
Table 9: Table of Phase Space Channels

Phase Space Plots

Resonances @ 15 GeV/c

DPM | K_s Kπ, $K_s \rightarrow \pi^+\pi^-$ | 4π | 2K 2π

ΦΦ



Evaluation

for the region where PID is needed

- definition of parameters

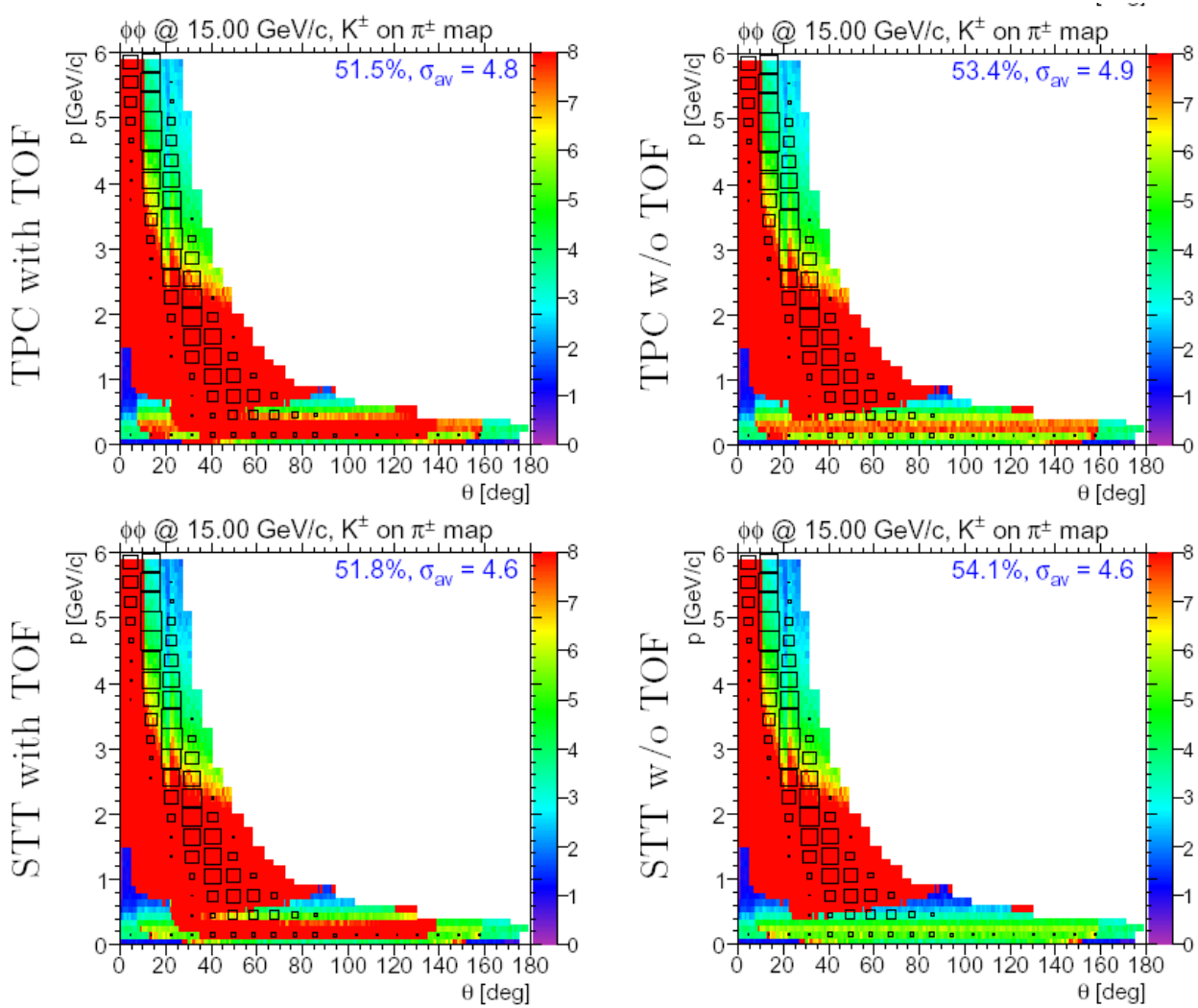
  f = fraction of bins with N(σ) < 8

  N(σ)_avg = Average N(σ)

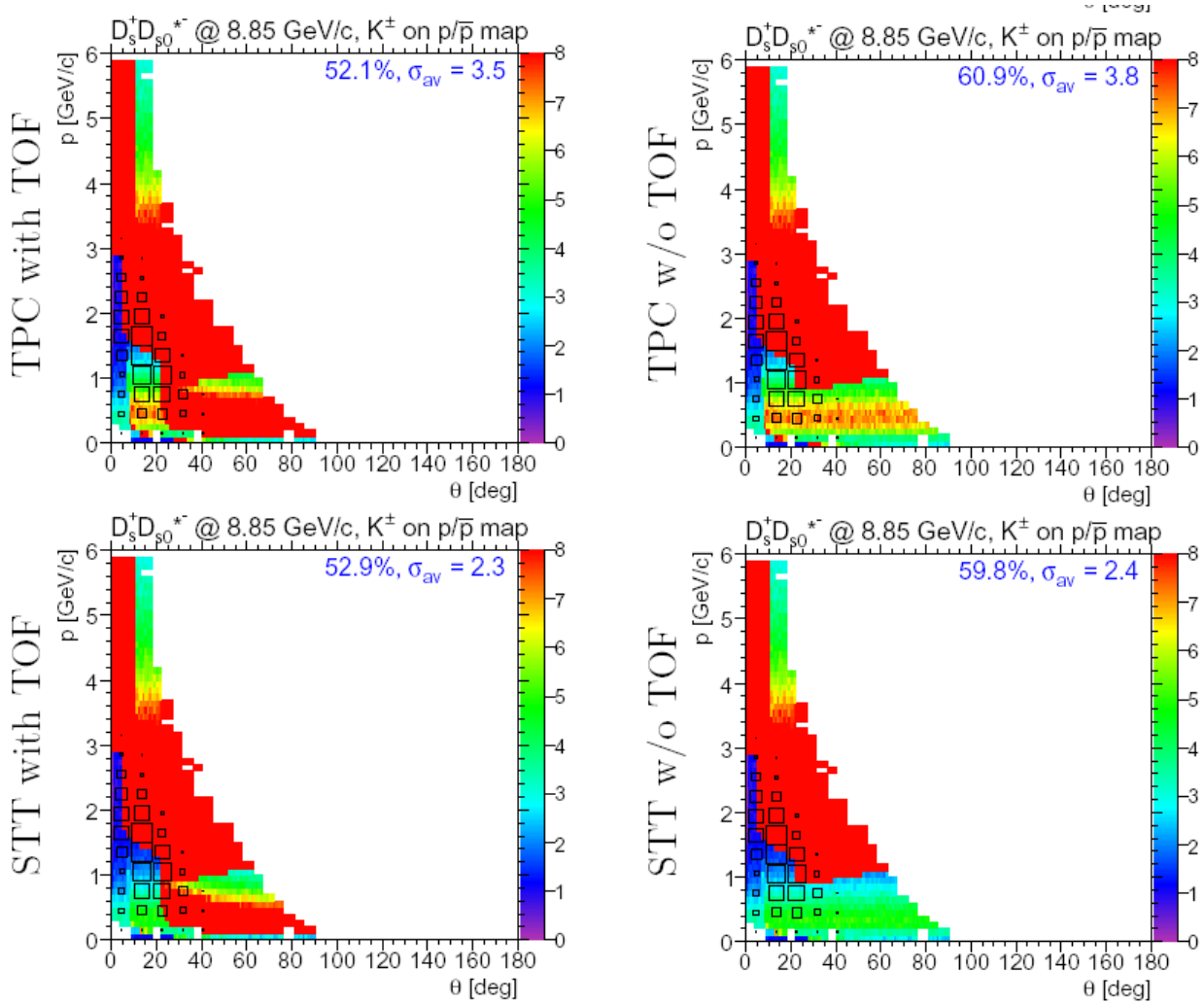
- four cases:

1) with STT with ToF
2) with TPC with ToF
3) with STT w/o ToF
4) with TPC w/o ToF

Evaluation


TPC with TOF
ϕϕ @ 15.00 GeV/c, K± on π± map
51.5%, σav = 4.8
TPC w/o TOF
ϕϕ @ 15.00 GeV/c, K± on π± map
53.4%, σav = 4.9
STT with TOF
ϕϕ @ 15.00 GeV/c, K± on π± map
51.8%, σav = 4.6
STT w/o TOF
ϕϕ @ 15.00 GeV/c, K± on π± map
54.1%, σav = 4.6
p [GeV/c]
θ [deg]

Evaluation


TPC with TOF
$D_s^+ D_{s0}^{*-}$ @ 8.85 GeV/c, $K^\pm$ on $p/\bar{p}$ map
52.1%, σ_{av} = 3.5
TPC w/o TOF
$D_s^+ D_{s0}^{*-}$ @ 8.85 GeV/c, $K^\pm$ on $p/\bar{p}$ map
60.9%, σ_{av} = 3.8
STT with TOF
$D_s^+ D_{s0}^{*-}$ @ 8.85 GeV/c, $K^\pm$ on $p/\bar{p}$ map
52.9%, σ_{av} = 2.3
STT w/o TOF
$D_s^+ D_{s0}^{*-}$ @ 8.85 GeV/c, $K^\pm$ on $p/\bar{p}$ map
59.8%, σ_{av} = 2.4
p [GeV/c]
θ [deg]

Fast Simulation

- acceptance filtering
- effective parametrization

- no microscopic simulation
- no exact geometry

> accuracy is limited

but computation time
100 – 1000 x faster

> high statistics possible

Fast Simulation

Meaning	Quantifier	Value
Global		
Magnetic Field Strength	$B = B_z$	2 T
Relative Momentum Resolution	σ_p/p	1 %
Micro Vertex Detector (MVD)		
Angular Acceptance	$[\theta_{\min}; \theta_{\max}]$	$[0.0°; 180.0°]$
Relative dE/dx Resolution	$\sigma_{dE/dx}$	22 %
Straw Tube Tracker (STT)		
Angular Acceptance	$[\theta_{\min}; \theta_{\max}]$	$[7.765°; 159.44°]$
Relative dE/dx Resolution	$\sigma_{dE/dx}$	20 %
Inner Radius	R_I	15 cm
Time Projection Chamber (TPC)		
Angular Acceptance	$[\theta_{\min}; \theta_{\max}]$	$[7.765°; 159.44°]$
Relative dE/dx Resolution	$\sigma_{dE/dx}$	8 %
Inner Radius	R_I	15 cm
Barrel DIRC		
Angular Acceptance	$[\theta_{\min}; \theta_{\max}]$	$[22.0°; 140.0°]$
Inner Radius	R_I	48 cm
Single Photon Resolution	σ_{ph}	10 mrad
Thickness of Slab	d_S	1.7 cm
Refractive Index of Quarz	n_Q	1.472
Total Photon Detector Efficiency	ϵ_{PD}	7.5 %
Disc DIRC		
Angular Acceptance	$[\theta_{\min}; \theta_{\max}]$	$[5.0°; 22.0°]$
Single Photon Resolution	σ_{ph}	10 mrad
Thickness of Disc	d_D	1.7 cm
Refractive Index of Quarz	n_Q	1.472
Total Photon Detector Efficiency	ϵ_{PD}	7.5 %
Ring Image Cherenkov Detector (RICH)		
Angular Acceptance	$\theta_{\min}$	0.0°
	$\alpha_{\max}$ (vert.)	5.0°
	$\alpha_{\max}$ (hor.)	10.0°
Single Photon Resolution	σ_{ph}	10 mrad
Thickness of Radiator	d_D	1 m
Refractive Index of Radiator	n_R	1.05
Total Photon Detector Efficiency	ϵ_{PD}	7.5 %
Time of Flight system (TOF)		
Angular Acceptance	$[\theta_{\min}; \theta_{\max}]$	$[22.0°; 140.0°]$
Inner Radius	R_I	38 cm
Total Time Resolution	σ_t	141 ps

Table 10: Parameter Settings used for the Fast Simulation

Evaluation

Parameters

f = fraction of bins with N(σ) < 8

N(σ)_avg = Average N(σ)

f	=	$0 \ldots 30$	$\ldots 40$	$\ldots 50$	$\ldots 60$	$\ldots 70$	$\ldots 80$	$\ldots 90$	$\ldots 100$	%
σ_{avg}	=	$0 \ldots 1.5$	$\ldots 2.0$	$\ldots 2.5$	$\ldots 3.0$	$\ldots 3.5$	$\ldots 4.0$	$\ldots 4.5$	$\ldots 5.0$	σ

Evaluation

Tabel of Results

5 EVALUATION 80

$p_{\bar{p}}$ [GeV/c]	Signal	PID	f_1 [%]	σ_1	f_2 [%]	σ_2	f_3 [%]	σ_3	f_4 [%]	σ_4
8.700	$J/\psi\eta$	e - π	90	5.6	91	5.5	90	5.6	90	5.5
8.847	$D_s^+ D_{s0}^{*-}$	π - p	5	4.4	9	5.0	11	5.2	20	4.5
		K - p •	53	3.4	53	2.3	59	3.8	61	2.4
10.000	$\Lambda^0 \bar{\Lambda}^0$	π - K	17	4.0	20	3.1	28	5.0	28	3.4
		π - p	32	3.5	43	3.4	41	4.3	71	4.3
		p - π	17	5.6	19	5.4	19	5.5	23	5.0
		K - p	22	5.1	24	5.0	29	5.3	29	4.3
	$D^{*+}D^{*-}\gamma$	π - K	31	4.4	32	3.4	34	4.5	33	3.4
		π - p	24	4.4	37	5.1	27	4.8	45	5.1
		K - p	22	4.9	24	4.6	30	5.2	30	4.0
	$\phi\phi$	K - π	41	5.3	42	5.1	44	5.3	44	5.0
12.349	$J/\psi 2\pi^0$	e - π	93	5.6	93	5.5	93	5.6	93	5.5
		μ - π	98	1.3	98	1.2	98	1.3	98	1.2
	$J/\psi\pi^+\pi^-$	e - π	93	5.6	93	5.5	93	5.6	93	5.5
		μ - π	98	1.3	98	1.2	98	1.3	98	1.2
15.000	$D^+D^-\gamma$	π - μ	22	3.3	22	3.2	22	3.2	23	3.3
		π - p	17	3.5	20	3.4	22	4.3	35	4.1
		K - p	24	4.1	26	3.5	30	4.3	31	3.2
	e^+e^-	e - π	90	5.6	89	5.4	89	5.6	90	5.5
	$D^{*+}D^{*-}\gamma$	π - μ	30	3.6	30	3.6	31	3.6	30	3.7
15.000	$D^{*0}\bar{D}^{*0}\gamma$	K - p	19	5.1	20	4.8	25	5.3	25	4.2
	$\phi\phi$	K - π •	51	4.8	52	4.7	54	4.9	53	4.6
	$D_s^+ D_s^-\gamma$	π - μ	23	3.4	22	3.3	22	3.4	23	3.4
		π - p	17	3.9	22	3.8	22	4.4	36	4.3
		K - p	30	3.3	30	2.8	34	3.7	34	2.7
	$\phi\phi$	K - π	51	4.8	52	4.6	53	4.9	53	4.5
	$D^0D^0\gamma$	K - π	24	5.4	24	5.1	25	5.4	26	5.0
		K - p	18	5.0	20	4.6	24	5.2	24	4.1

Table 12: Table of projection results (2). Marked channels (•) appear in figs. 58 – 60.

Conclusion

the PID TAG report
based on Fast Simulations

- provides
  - informations
  - methods of evaluation
  - numbers

- is a **tool**
  available to the
  PANDA collaboration

Outlook

a common microscopic simulation for all subdetectors could answer more detailed questions

Thanks for a very good collaboration within the PID TAG and the contributions to the report:

List of the PID TAG

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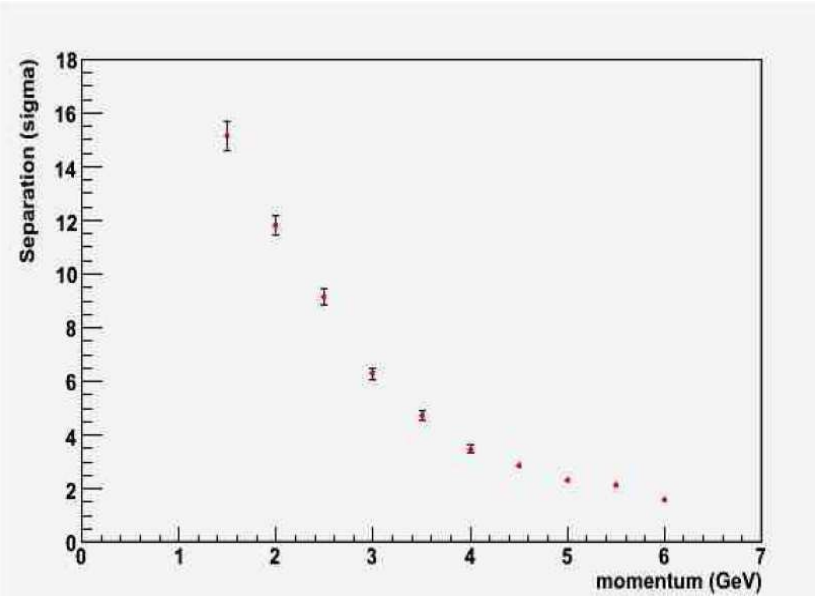
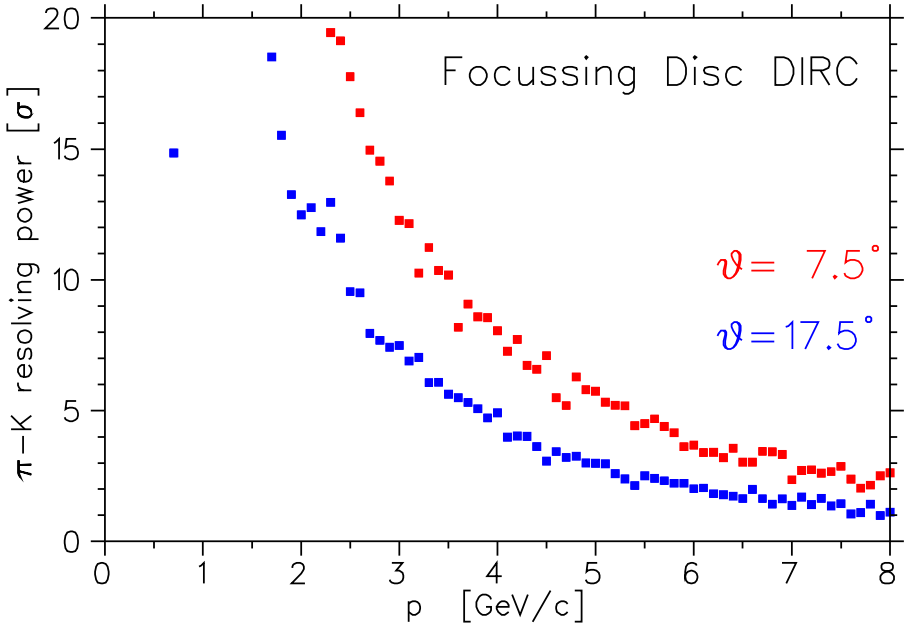
Back up slides

List of Detectors

- Endcap Cherenkov
  - Focussing Light Guide Disc DIRC
  - Time of Propagation Disc DIRC
  - Proximity RICH

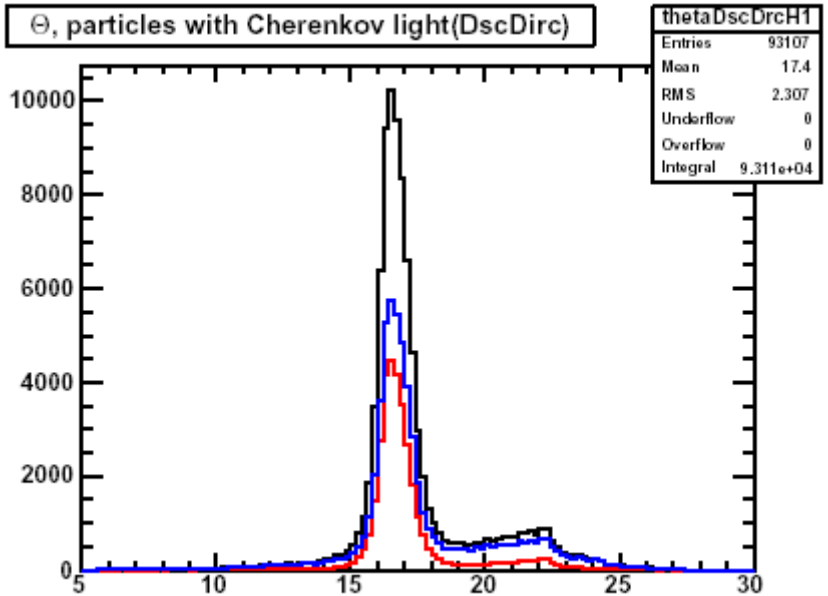


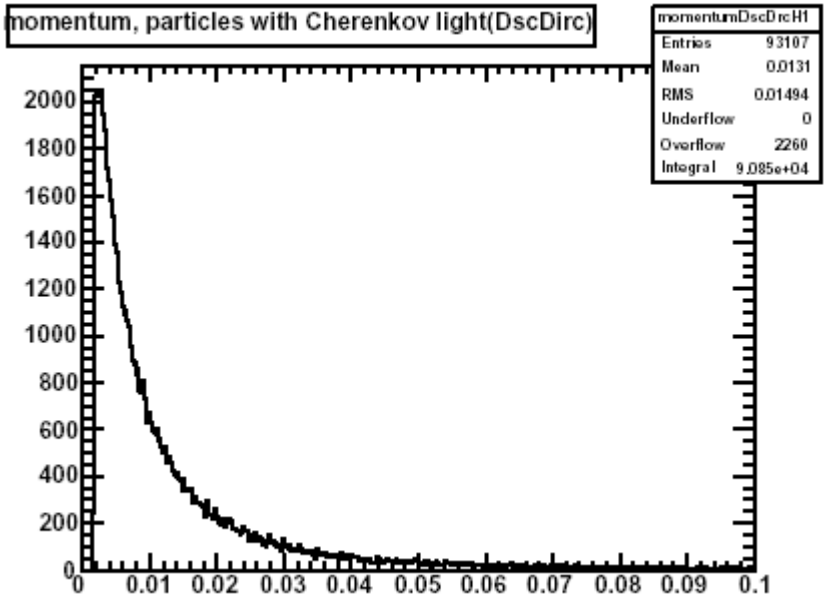


List of Detectors

ElectroMagnetic Calorimeter

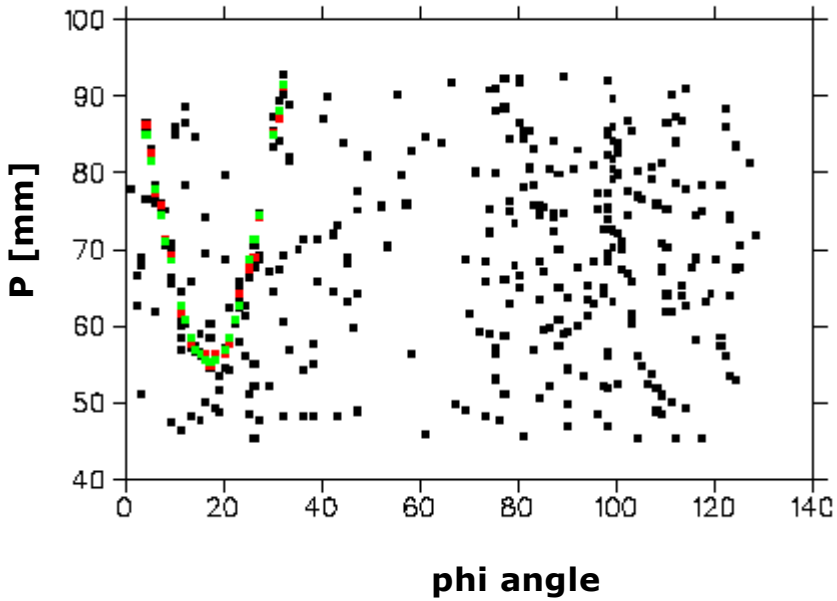
Background to the Disc DIRC

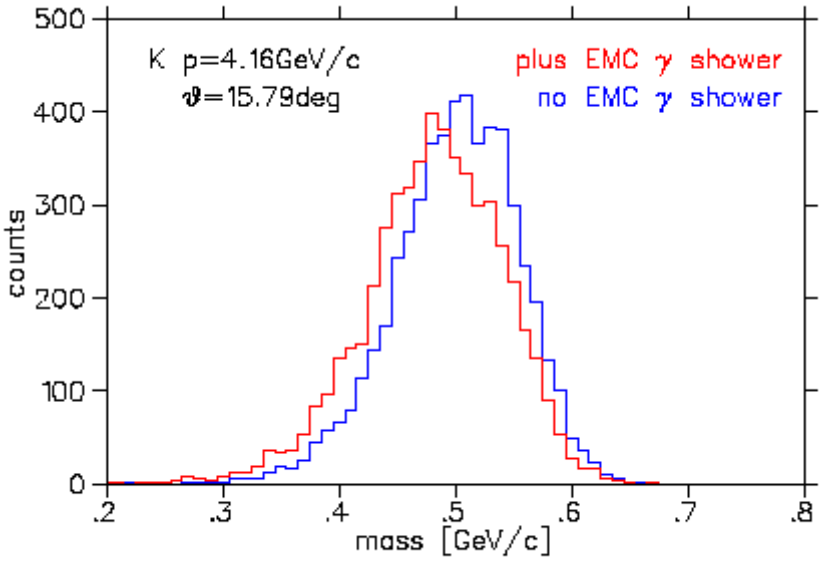




List of Detectors

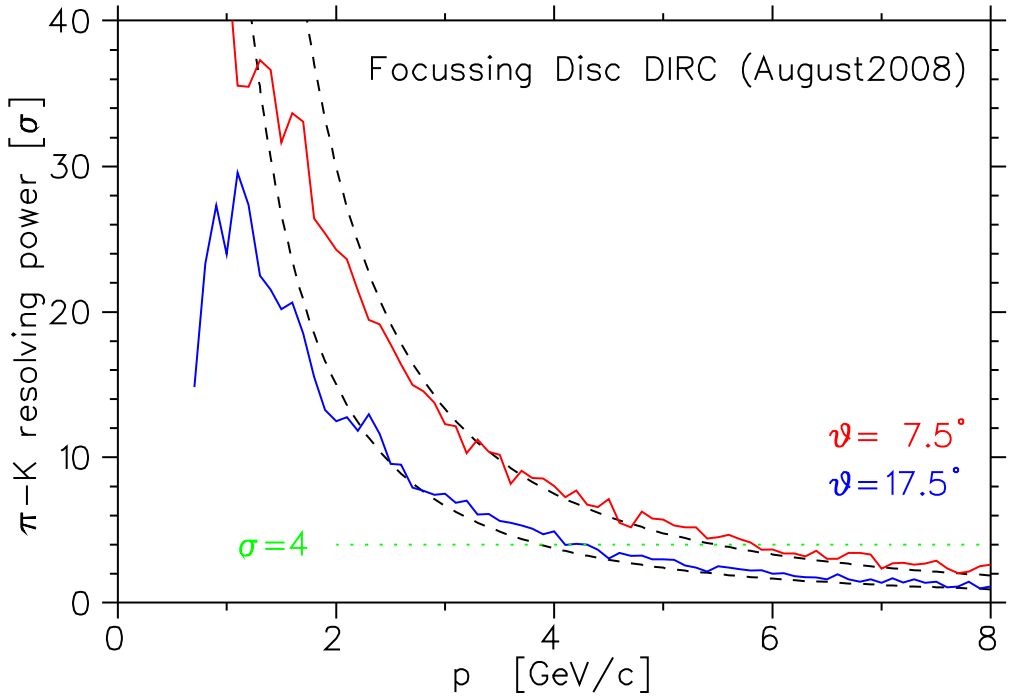
- Endcap Disc DIRC - response





List of Detectors

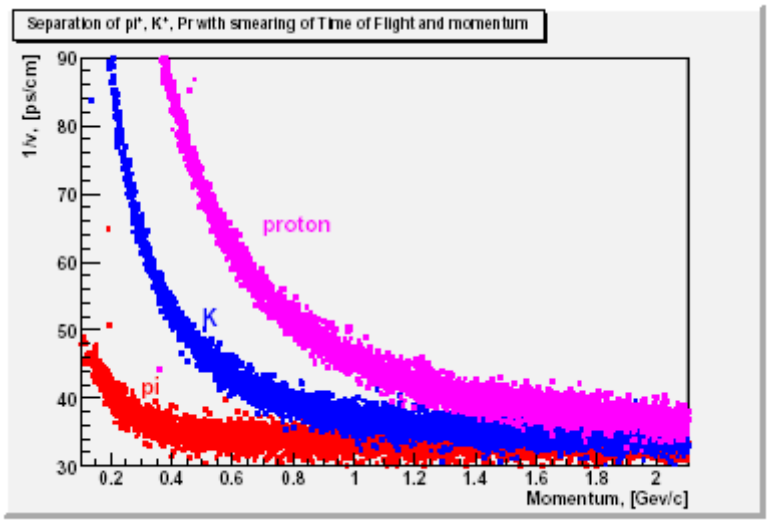
- Endcap Cherenkov
  - Focussing Light Guide Disc DIRC
  - Time of Propagation Disc DIRC
  - Proximity RICH

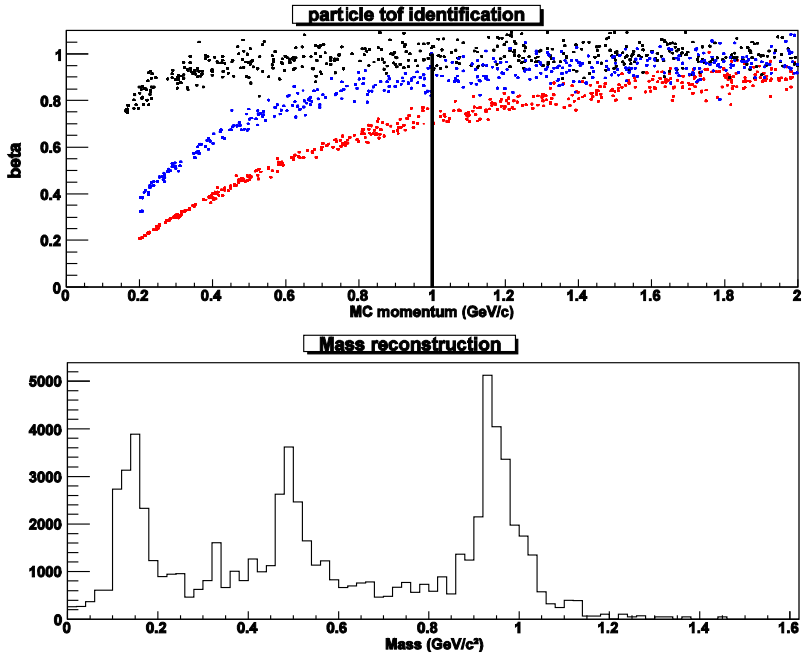


List of Detectors

- Barrel Time of Flight
  - Resistive Plate Counter
  - Scintillation Counter

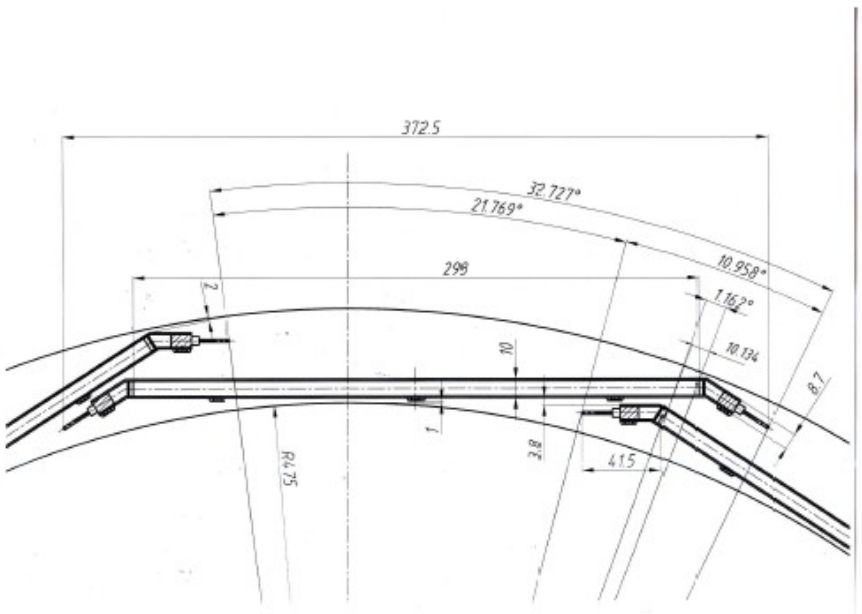
Dubna-Prodvino group
ITEP-TOF group Alexander Akindinov

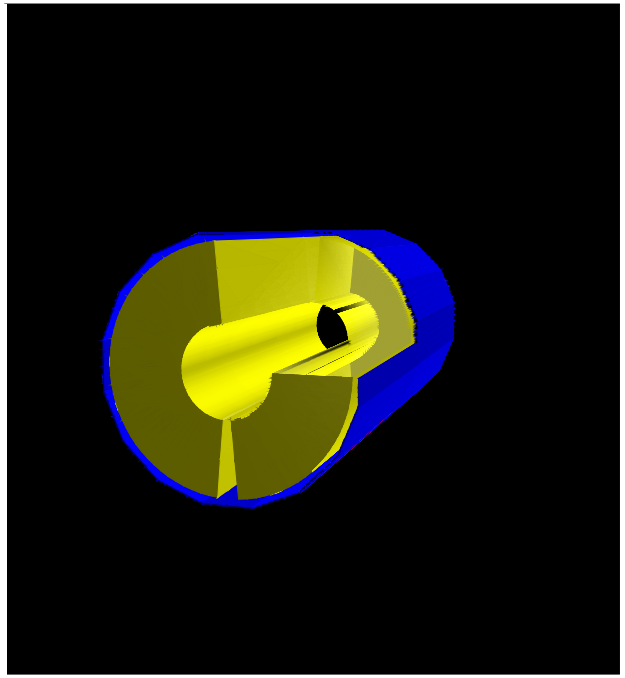




List of Detectors

- Barrel Time of Flight
  - Resistive Plate Counter
  - Scintillation Counter

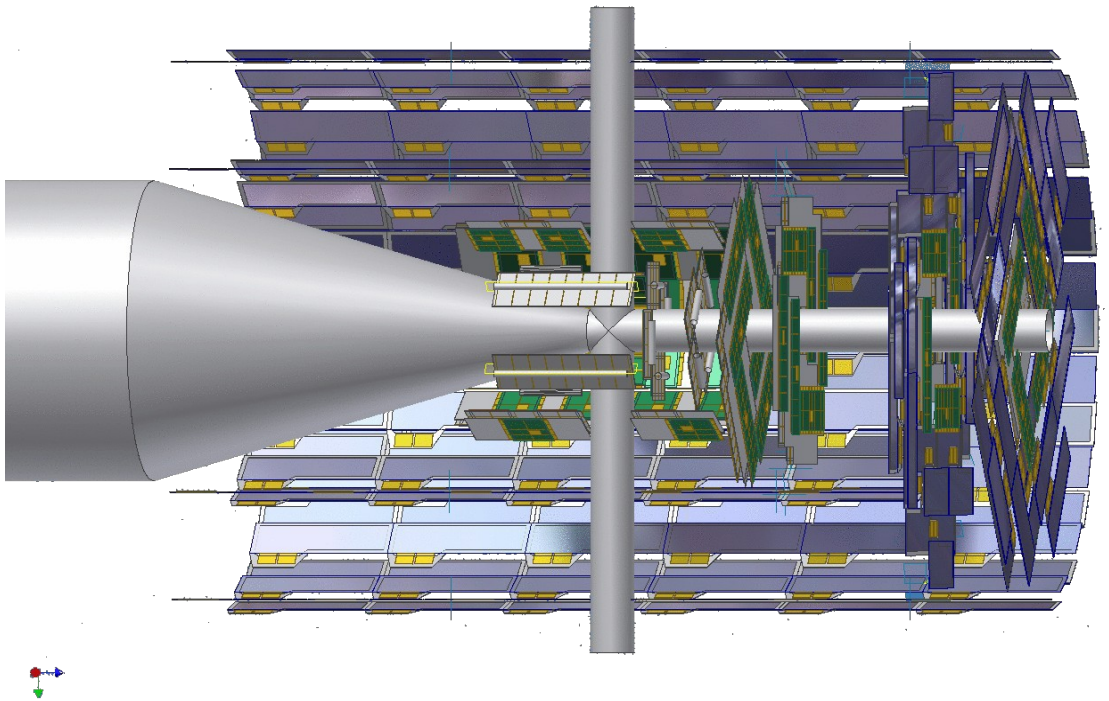




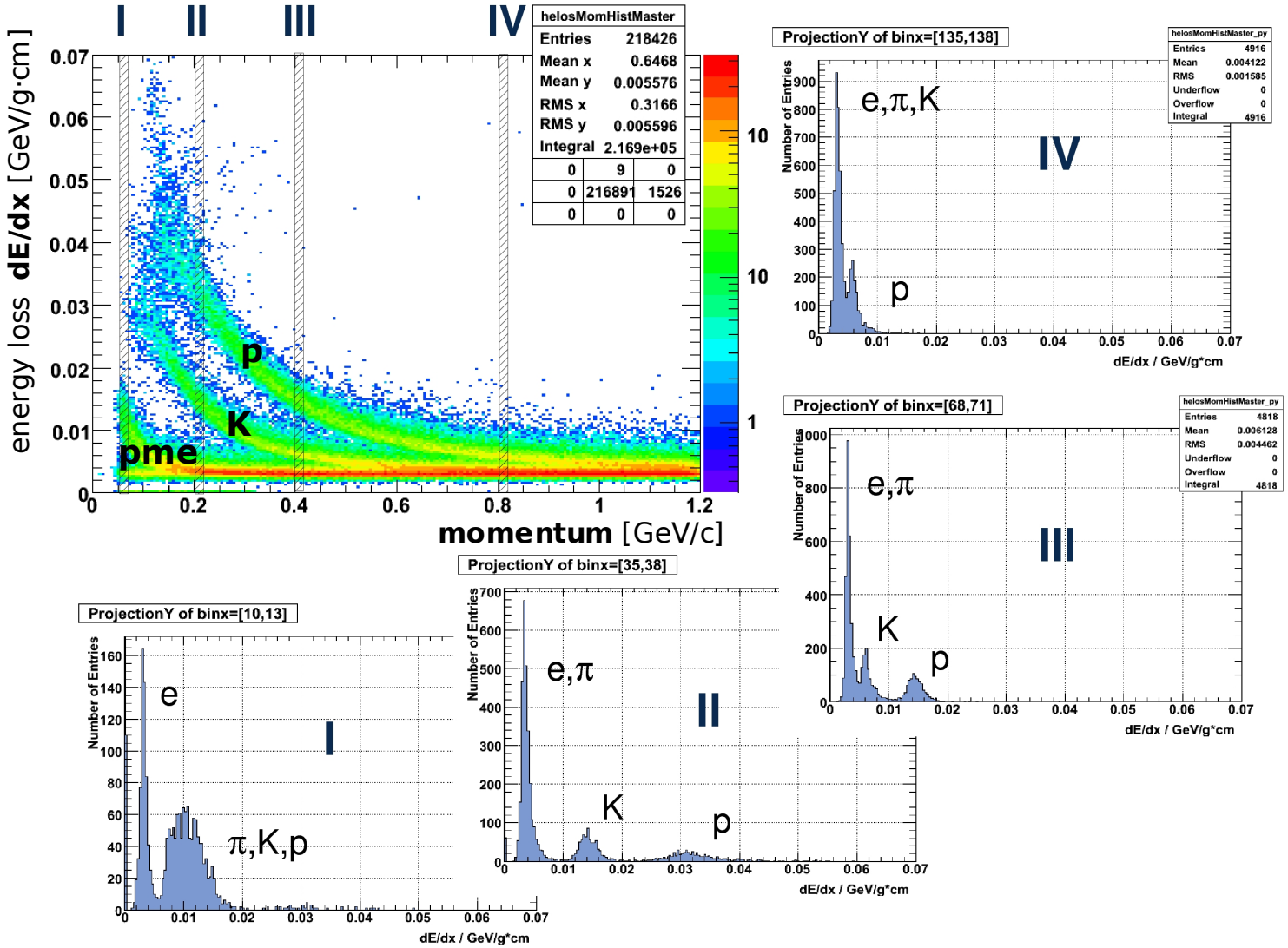
PID Example: MVD Multivertex Detector

Layout of MVD

- **General structure:**
  - 4 barrels & 8 disks
  - inner layers pixels
  - outer layers strips
  - (forward mixed)
- **Pixel part:**
  - hybrid pixels 100 x100 μm^2
  - 140 modules
  - 13 M channels
  - 0.15 m^2
- **Strip part:**
  - double sided silicon
  - 400 modules
  - 70k channels
  - 0.5 m^2



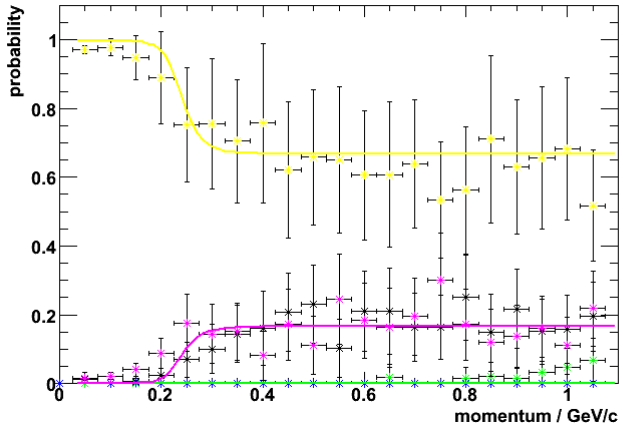
PID Example: MVD Multivertex Detector



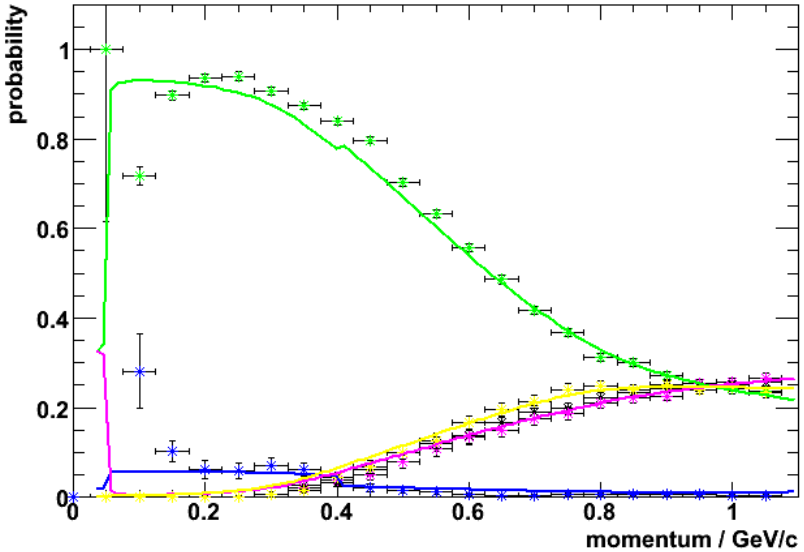
PID Example: MVD Multivertex Detector

Probabilities

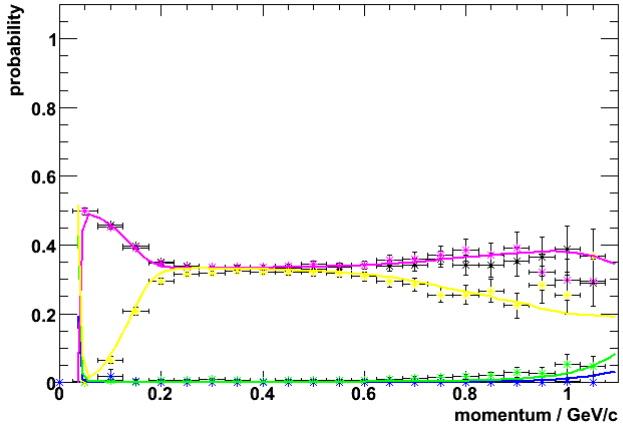
e-selector



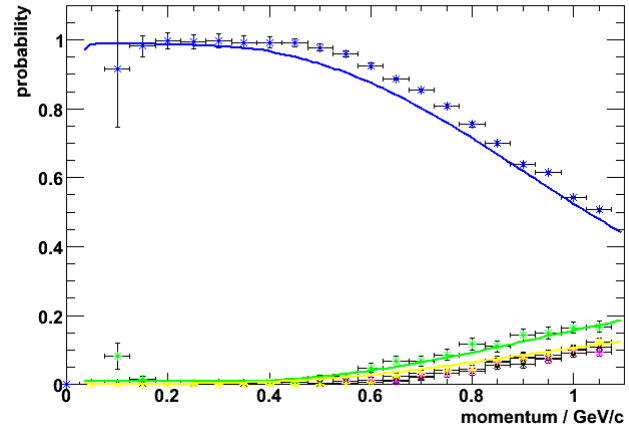
K-selector



pi-selector



p-selector



EMC Parametrization

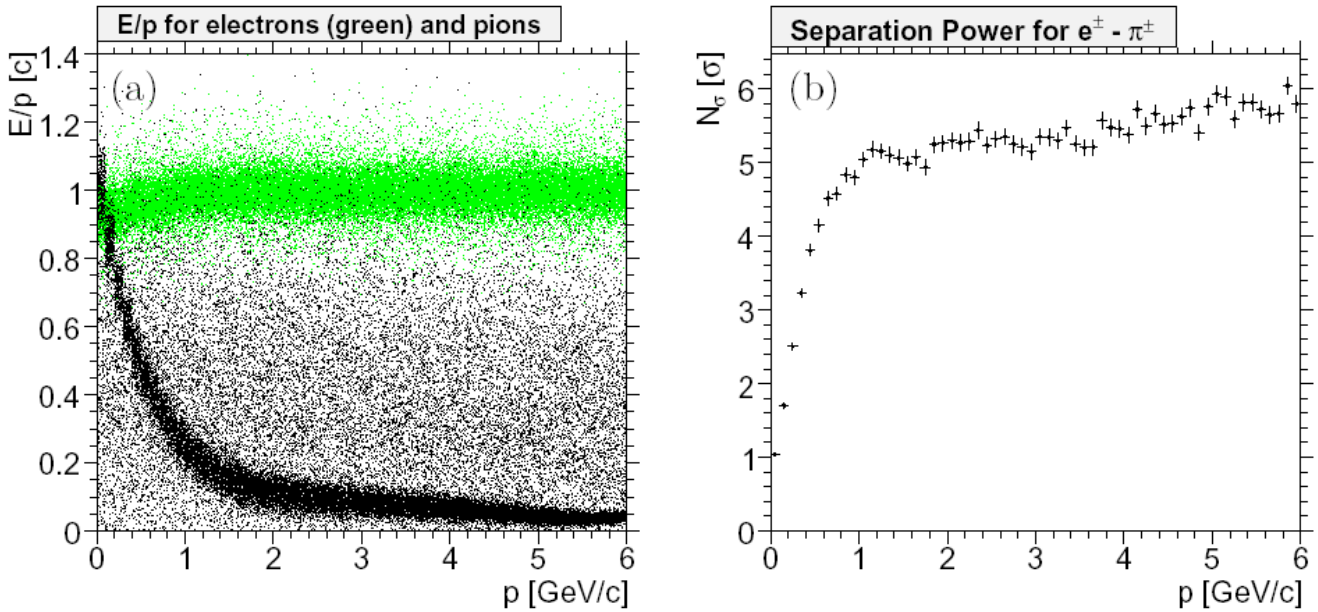


Figure 43: (a) Parameterized distribution of E_{clus}/p for electrons and pions and (b) the resulting separation power N_σ as function of the track momentum p.