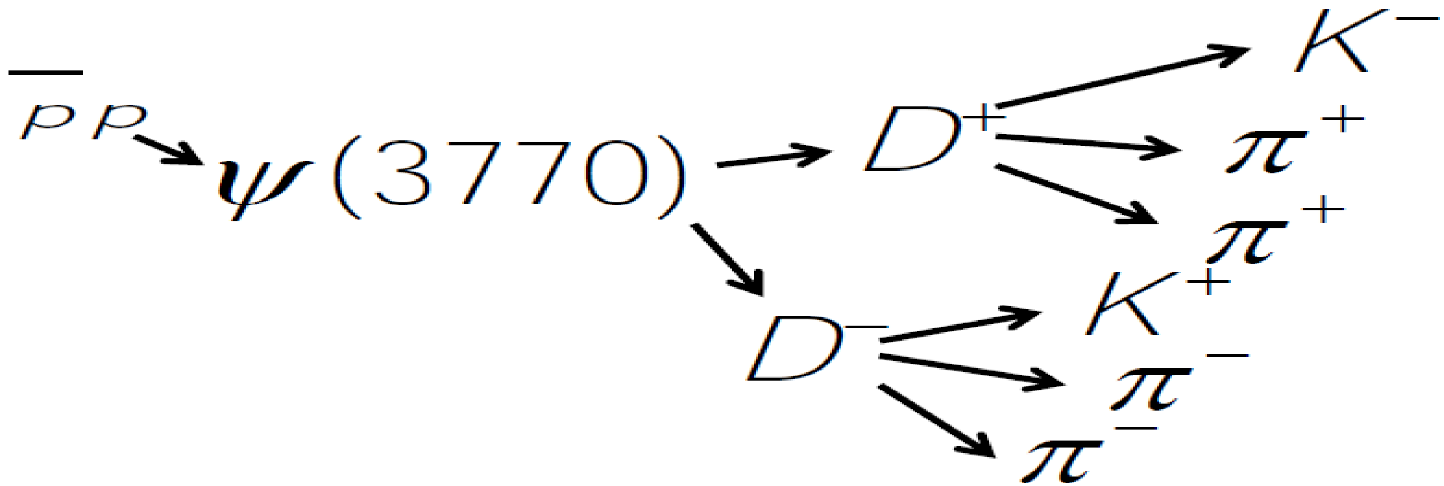
Reconstruction of $D^{\pm}$ mesons with extended target



Mattias Gustafsson

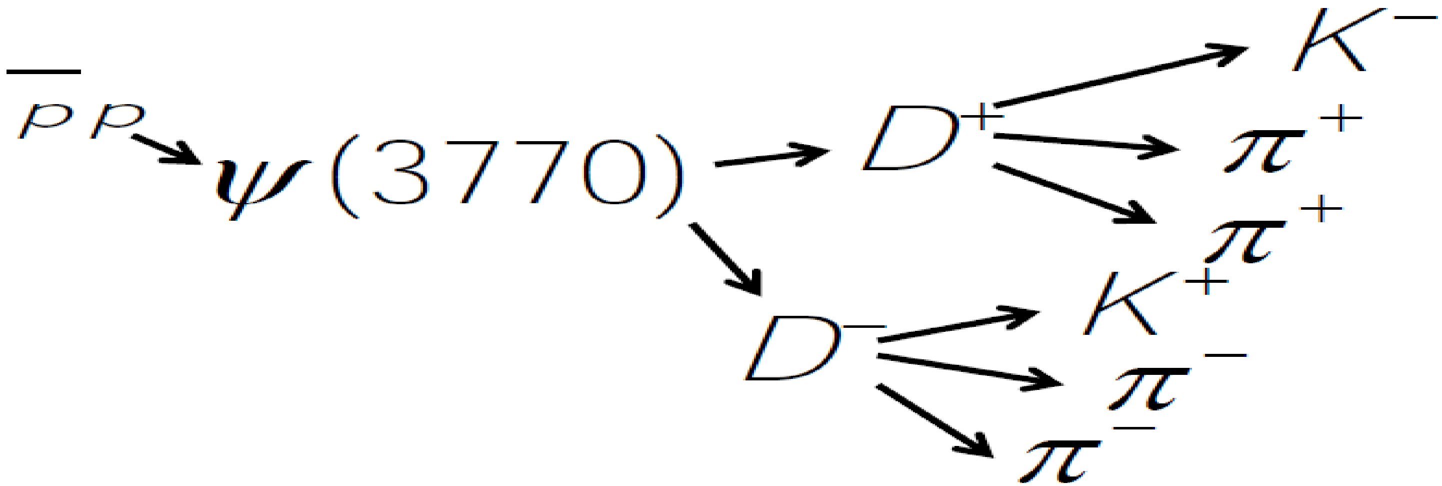
Uppsala University

PANDA collaboration Meeting, June 2014

Outline

- Introduction
- Previous study
- This work: Reconstruction of D mesons with updated target dimensions and realistic detector
- Summary & Conclusions
- Outlook

D-meson



- Many D-meson studies suffer from large background

- Weak decays -> production and decay vertices separated by typically a few mm

- **<u>Ambition</u>**: A **Trigger** that selects events with displaced vertices and rejects events where the particles come from IP.
  $\longrightarrow$ could reduce the background significantly!

- **<u>But</u>:** If the beam-target overlap region is too large, most D-mesons will decay inside it.

D-meson

- <u>**Question 1**</u>: How is the data quality (efficiency, momentum resolution and vertex resolution) affected by different targets?

- <u>**Question 2**</u>: For a given target type, how many D-mesons will decay outside it?

Targets

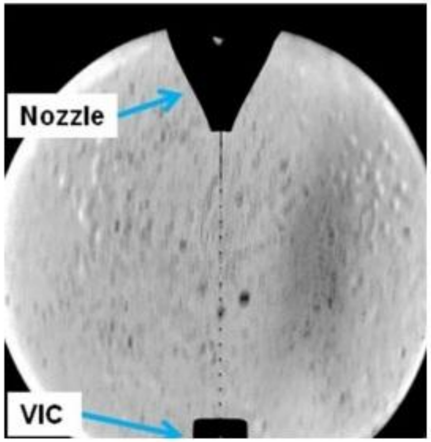


Figure 7.1: Production of hydrogen droplets and subsequent injection into vacuum in the triple-point chamber of the WASA pellet target.

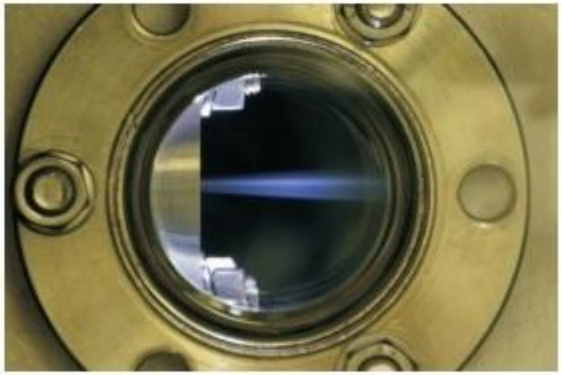


Figure 6.3: Image of a hydrogen cluster-jet beam directly after passing the nozzle. The cluster-jet is illuminated by an array of white LEDs in the vacuum chamber.

Pellet

- Frozen hydrogen droplets, size of a few µm
- High density of particles within the IP
- Information of IP, well defined
- Two different modes, PHL and PTR

Cluster-jet

- Hydrogen gas formed into clusters
- Can use more concentrated anti-proton beam
- Low density of particles within IP
- Information of IP will be limited

Previous study by Ö.Nordhage*

- “Ideal detection”, i.e. undistorted particle momenta.

- “Volume of interaction”,
i.e. beam-target overlap,
$V_{int} = \pi R_{xy}^2 \cdot Z_{int}$, $R_{xy} = (x^2 + y^2)^{½}$

- <u>Question</u>: How many particles decay outside the volume of interaction?

* Ö.Nordhage et al., NIMA 568, (2006) 561-565

Study by Ö.Nordhage: Target dimensions

Ideal	Cluster jet	PHL	PTR
$\sigma_x = 0$ mm	$\sigma_x = 0.1$ mm	$\sigma_x = 1$ mm	$\sigma_x = 1$ mm
$\sigma_y = 0$ mm	$\sigma_y = 0.1$ mm	$\sigma_y = 1$ mm	$\sigma_y = 1$ mm
$Z_w = 0$ mm	$Z_w = 15$ mm	$Z_w = 2$ mm	$Z_w = 0.1$ mm

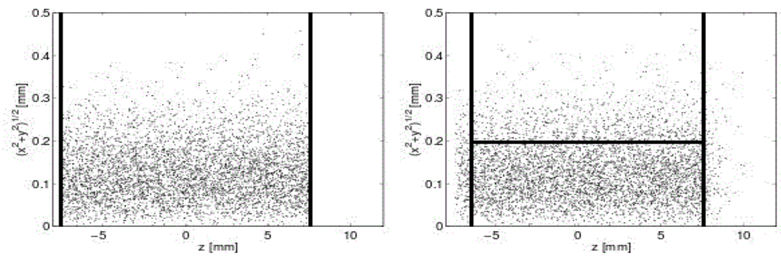
σ_x – beam width

σ_y – beam width

→ Gaussian distribution of the interaction region

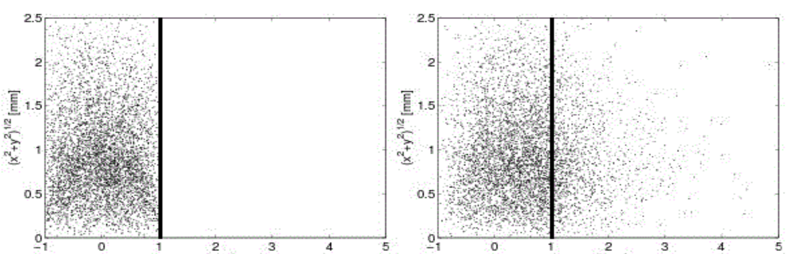
Z_w – target width

Cluster-jet



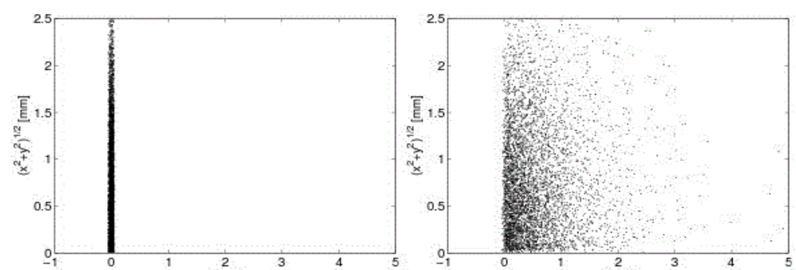
(a) Primary vertices. (b) *D*-decay vertices.

PHL



(c) Primary vertices. (d) *D*-decay vertices.

PTR



(e) Primary vertices. (f) *D*-decay vertices.

Results from Örjan Nordhage's thesis

	V_{int}							
	Z_{int}	R_{xy}	Cut 1	η	Cut 2	η	Cut 3	η
Cluster	± 7.5 mm	0.2 mm	|z|>7.5 mm	**4 %**	R_{xy}>0.2 mm	**16 %**		
PHL	± 2 mm	1 mm	|z|>1 mm	**23 %**	|z|>1.5 mm	**9%**		
PTR	± 0.1 mm	1 mm	|z|>50 µm	**91%**	|z|>200 µm	**69 %**	|z|>1 mm	**16 %**

Conclusion: Using tracked pellets, the volume of interaction can be chosen such that most D mesons decay outside it.

Difference between Nordhage's work and mine

Örjan Nordhage (2006)

- Ideal detector, without smearing
- Used kinematics and decay length
- Cuts on undistorted kinematical variables
- 5000 events

Mattias Gustafsson (2014)

- Using Pandaroot
- Taking detector resolution into account
- Using more realistic target dimensions*

* H.Calén, private communication

Tools

- Pandaroot
  - revision 24978
  - external packages apr13

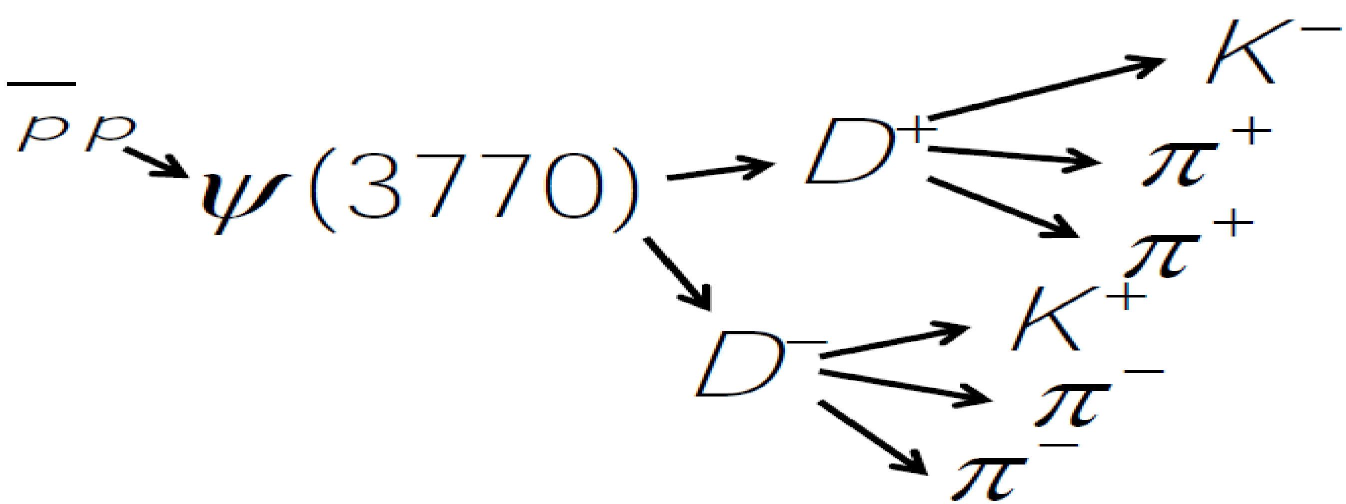
- Define extended target in FairPrimaryGenerator
  - → SmearVertexZ
  - → SmearGausVertexXY*

* S.Pflüger, private communication

Simulations

First Step: Repeating the previous study, with target dimensions used in 2006, to verify the method.

1000 events were used.



Results

	V_{int}		Örjan's results					
	Z_{int}	R_{xy}	Cut 1	η	Cut 2	η	Cut 3	η
Cluster	± 7.5 mm	0.2 mm	|z|>7.5 mm	**4 %**	R_{xy}>0.2 mm	**16 %**		
PHL	± 2 mm	1 mm	|z|>1 mm	**23 %**	|z|>1.5 mm	**9%**		
PTR	± 0.1 mm	1 mm	|z|>50 μm	**91%**	|z|>200 μm	**69 %**	|z|>1 mm	**16 %**

	V_{int}		My results (reco)					
	Z_{int}	R_{xy}	Cut 1	η	Cut 2	η	Cut 3	η
Cluster	± 7.5 mm	0.2 mm	|z|>7.5 mm	**4 %**	R_{xy}>0.2 mm	**34 %**		
PHL	± 2 mm	1 mm	|z|>1 mm	**30 %**	|z|>1.5 mm	**12 %**		
PTR	± 0.1 mm	1 mm	|z|>50 μm	**92%**	|z|>200 μm	**71 %**	|z|>1 mm	**18 %**

⟶ Data consistent but not exact.

But: exact agreement not expected since I take detector into account

Results

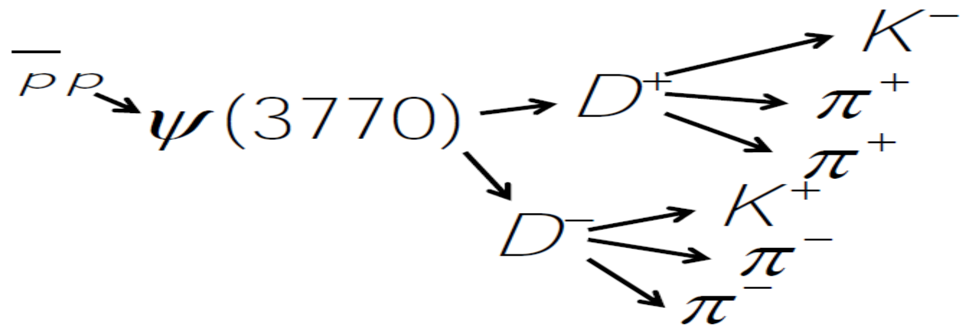
	V_{int}		Örjan's results					
	Z_{int}	R_{xy}	Cut 1	η	Cut 2	η	Cut 3	η
Cluster	± 7.5 mm	0.2 mm	|z|>7.5 mm	**4 %**	R_{xy}>0.2 mm	**16 %**		
PHL	± 2 mm	1 mm	|z|>1 mm	**23 %**	|z|>1.5 mm	**9%**		
PTR	± 0.1 mm	1 mm	|z|>50 µm	**91%**	|z|>200 µm	**69 %**	|z|>1 mm	**16 %**

	V_{int}		My results (MC truth)					
	Z_{int}	R_{xy}	Cut 1	η	Cut 2	η	Cut 3	η
Cluster	± 7.5 mm	0.2 mm	|z|>7.5 mm	**4 %**	R_{xy}>0.2 mm	**19 %**		
PHL	± 2 mm	1 mm	|z|>1 mm	**27 %**	|z|>1.5 mm	**11%**		
PTR	± 0.1 mm	1 mm	|z|>50 µm	**91%**	|z|>200 µm	**69 %**	|z|>1 mm	**16 %**

Conclusion: when MC truth/ideal detector is used, the agreement is very good.(within the statistical uncertainties)

Simulations with homogeneous target cylinder

•10000 events



• Using a homogeneous target cylinder for a more realistic interaction volume

• **<u>Question 1</u>:** How is the data quality(efficiency, momentum resolution and vertex resolution) affected by different targets?

• **<u>Question 2</u>:** For a given target type, how many D-mesons will decay outside it?

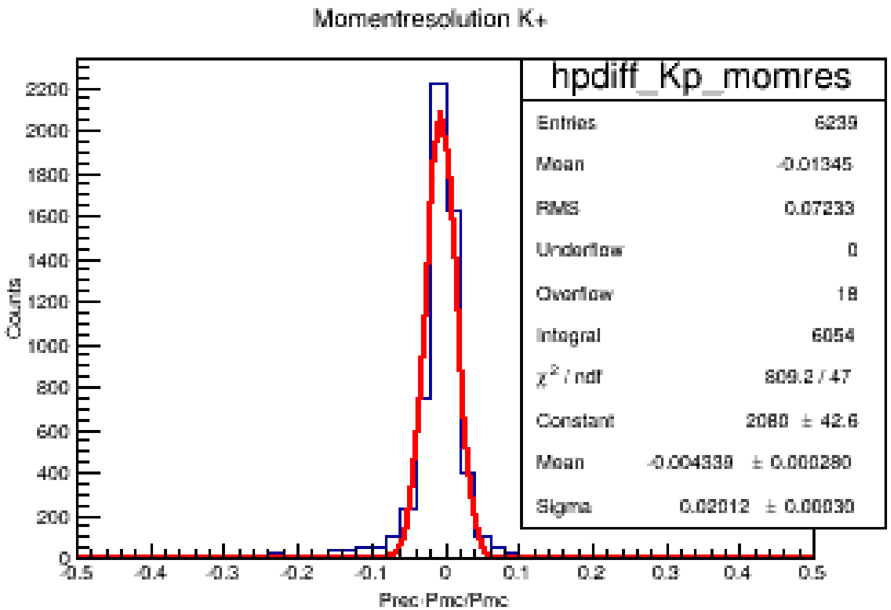
Dimensions for cylindrical distribution

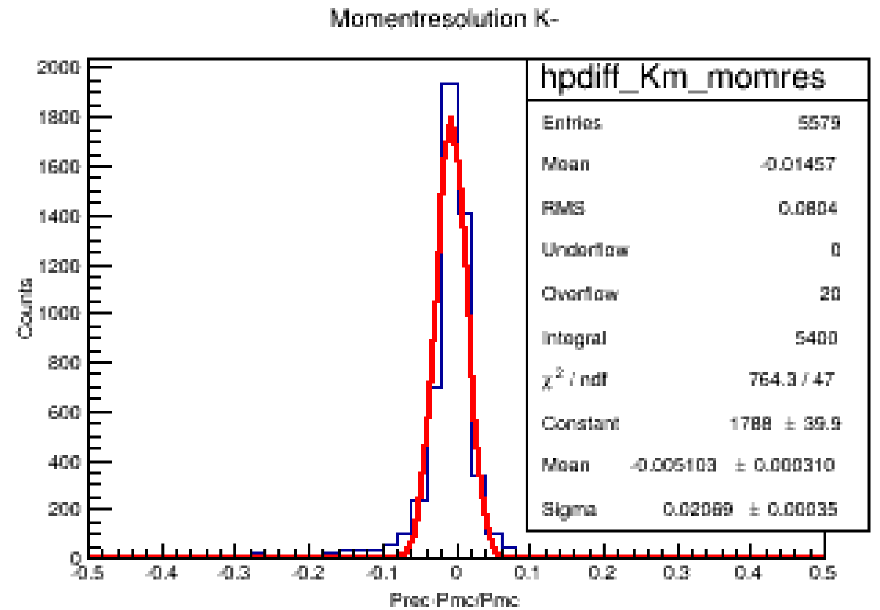
Target	R_beam [mm]	Target width [mm]
Ideal	0	0
Cluster-jet	0.4	13.1
PHL	1.5	2.5
PTR	2.5	3

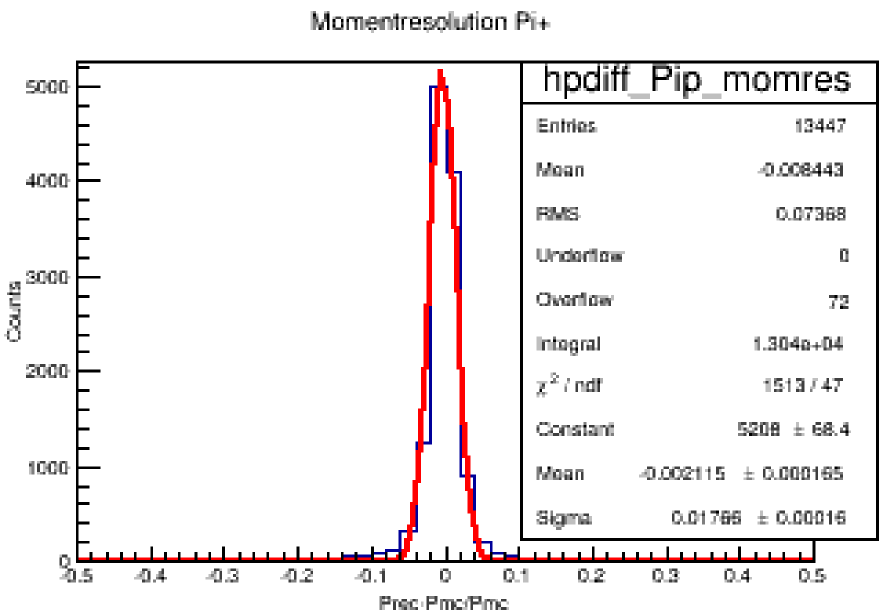
R_beam – Radius of the anti-proton beam at IP

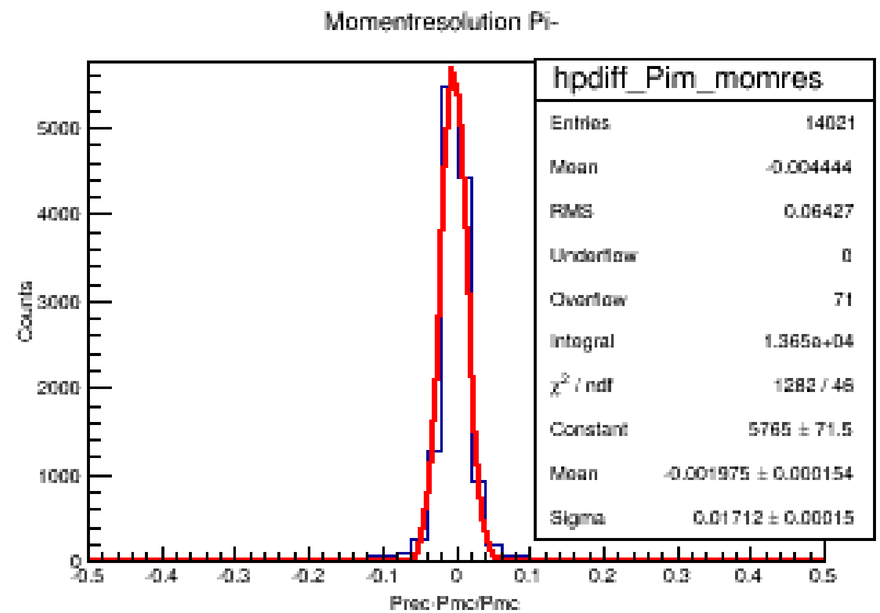
Target width – Target extension along z-axis

Data quality: Ideal target









Data quality: final state particles

Ideal target

FS	η [%]	δp/p
K+	61 ± 0.8	2.0
K-	54 ± 0.7	2.1
π+	66 ± 0.8	1.8
π-	68 ± 0.8	1.7

Cluster-jet

FS	η [%]	δp/p
K+	59 ± 0.8	2.0
K-	54 ± 0.7	2.0
π+	64 ± 0.8	1.8
π-	67 ± 0.8	1.7

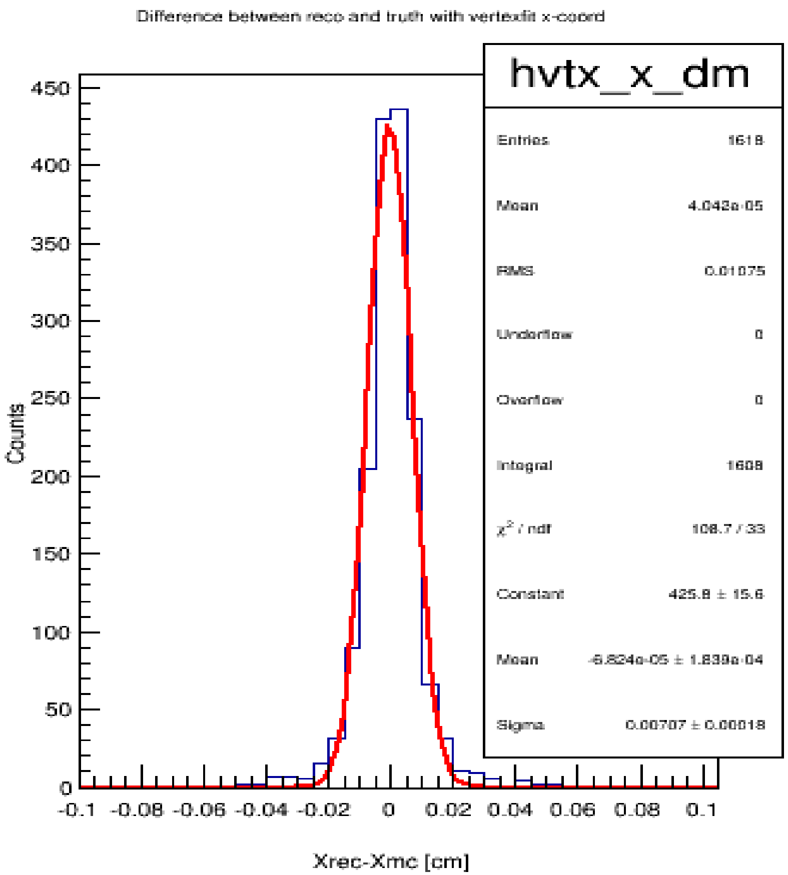
PHL

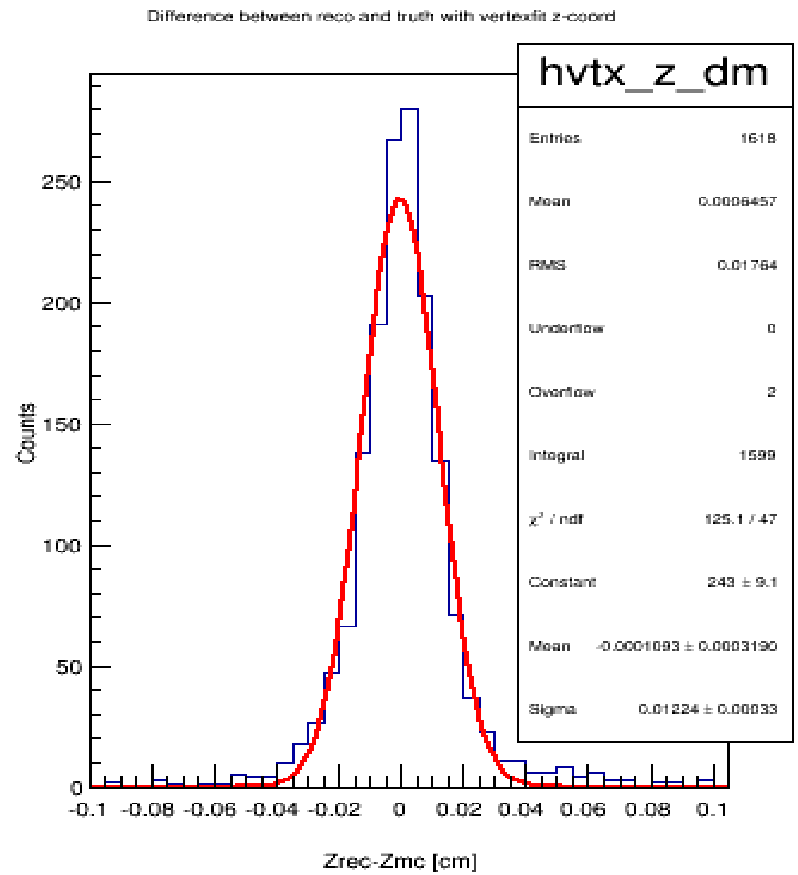
FS	η [%]	δp/p
K+	60 ± 0.8	2.0
K-	54 ± 0.7	2.1
π+	65 ± 0.8	1.8
π-	68 ± 0.8	1.7

PTR

FS	η [%]	δp/p
K+	60 ± 0.8	2.0
K-	55 ± 0.7	2.2
π+	65 ± 0.8	1.8
π-	68 ± 0.8	1.7

Data quality: Ideal target
D^- vertex resolution



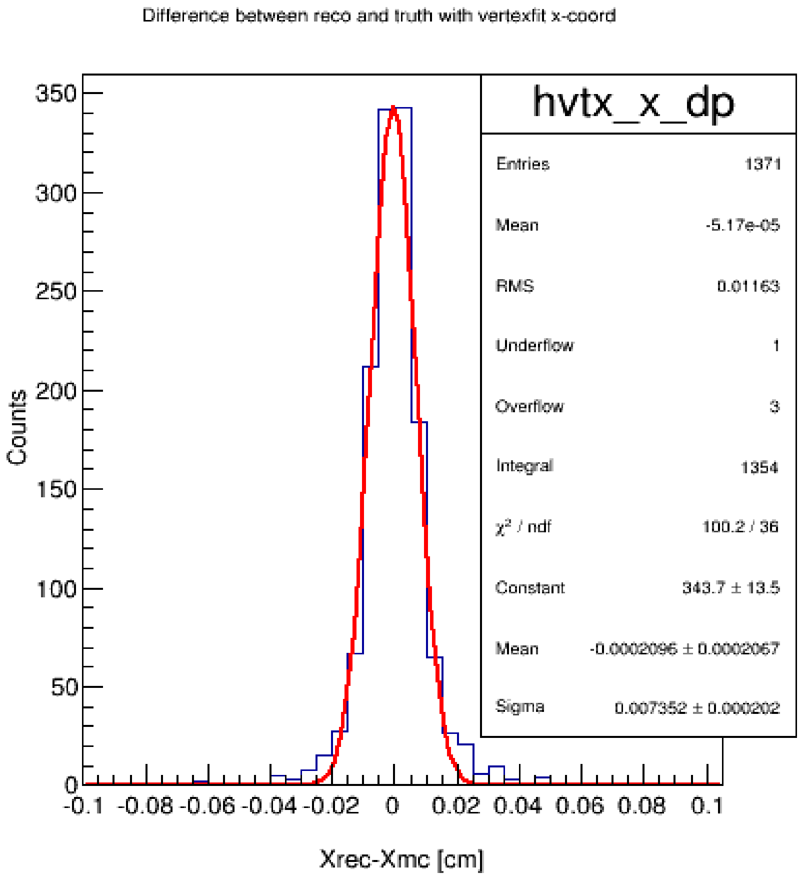


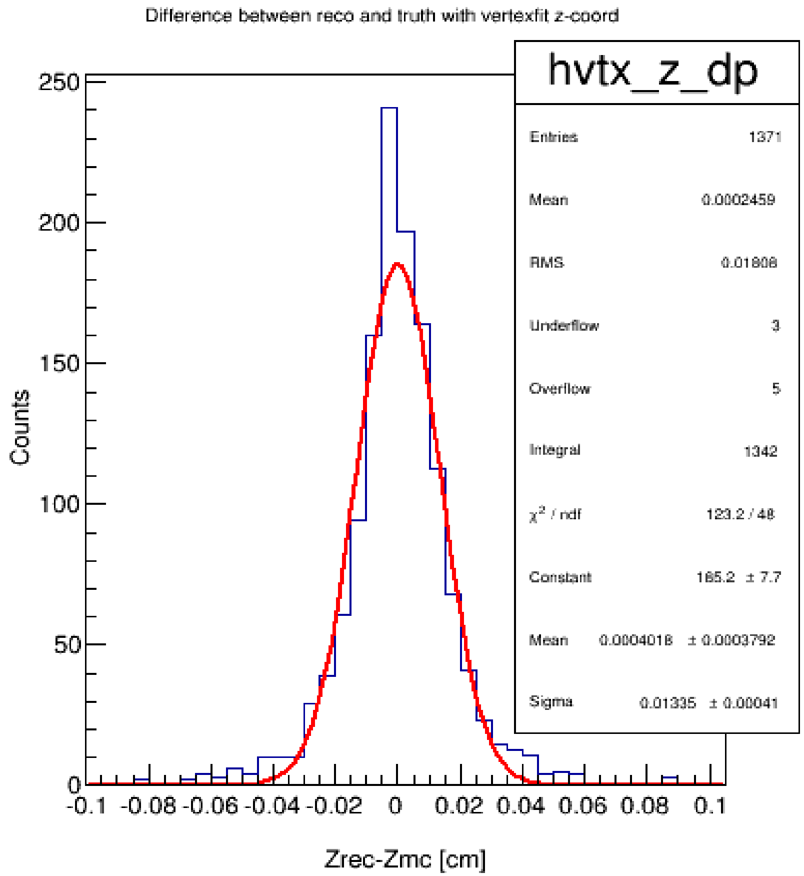
$\sigma_x = 71 \pm 2\ \mu m$

$\sigma_z = 122 \pm 3\ \mu m$

$\eta = 16 \pm 0.4\ \%$

Data quality: Ideal target
D^+ vertex resolution





$\sigma_x = 74 \pm 2\ \mu m$

$\sigma_z = 134 \pm 4\ \mu m$

$\eta = 14 \pm 0.4\ \%$

Data quality: vertex resolution

Ideal target			
Particle	**η % (±0.4)**	**σ_x [μm]**	**σ_z [μm]**
D+	**14**	74 ± 2	134 ± 4
D-	**16**	71 ± 2	122 ± 3

Cluster-jet			
Particle	**η % (±0.4)**	**σ_x [μm]**	**σ_z [μm]**
D+	**13**	76 ± 2	136 ± 4
D-	**15**	76 ± 2	132 ± 4

PHL			
Particle	**η % (±0.4)**	**σ_x [μm]**	**σ_z [μm]**
D+	**13**	71 ± 2	126 ± 4
D-	**16**	73 ± 2	122 ± 3

PTR			
Particle	**η % (±0.4)**	**σ_x [μm]**	**σ_z [μm]**
D+	**14**	71 ± 2	124 ± 4
D-	**16**	71 ± 2	132 ± 4

Data quality

Conclusion: The difference in data quality is not significant between target types!

For a given target type, how many D-mesons will decay outside it?

	V_{int}		Results					
	Z_{int}	R_{xy}	Cut 1	η	Cut 2	η	Cut 3	η
Cluster	± 6.55 mm	0.8 mm	|z|>6.55 mm	**8 %**	R_{xy} > 0.8 mm	**9 %**	|z|>6.7 mm	**7%**
PHL	± 1.25 mm	1.5 mm	|z|>1.25 mm	**23 %**	R_{xy} > 1.5 mm	**26 %**	|z|>1.5 mm	**15 %**
PTR	± 1.5 mm	2.5mm	|z|>1.5 mm	**20 %**	R_{xy} >2 mm	**22 %**	|z|>1.75m	**14 %**

It is possible to choose a volume of interaction such that ~ 20 % of the events decay outside it, if a pellet target is used.

Summary

- Using target dimensions from 2006, both MC truth data and reconstructed events reproduce nicely the results from Örjan Nordhage's thesis from 2006.

- No significant changes of resolution or reconstruction efficiency between different targets, difference is within the statistical error.

- The result shows that almost **20%** of D-mesons will decay outside the interaction region for **pellet targets**.
- For a **cluster-jet** only **8%** decay outside.

Outlook

- Background studies using e.g. DPM.
- Include rest-gas into the simulations for background studies
- Pandaroot issue: In about 4-5% of the events, two reconstructed tracks are associated with the same MC truth track.

Thank you!