GSI, March 8th, 2010

STT pattern recognition improvements since last December meeting and performances

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Parametrization of the Helix trajectory

$x - x_0 = R\cos(Kz + \varphi_0)$

$y - y_0 = R\sin(Kz + \varphi_0)$

$\varphi = Kz + \varphi_0$

5 parameters :

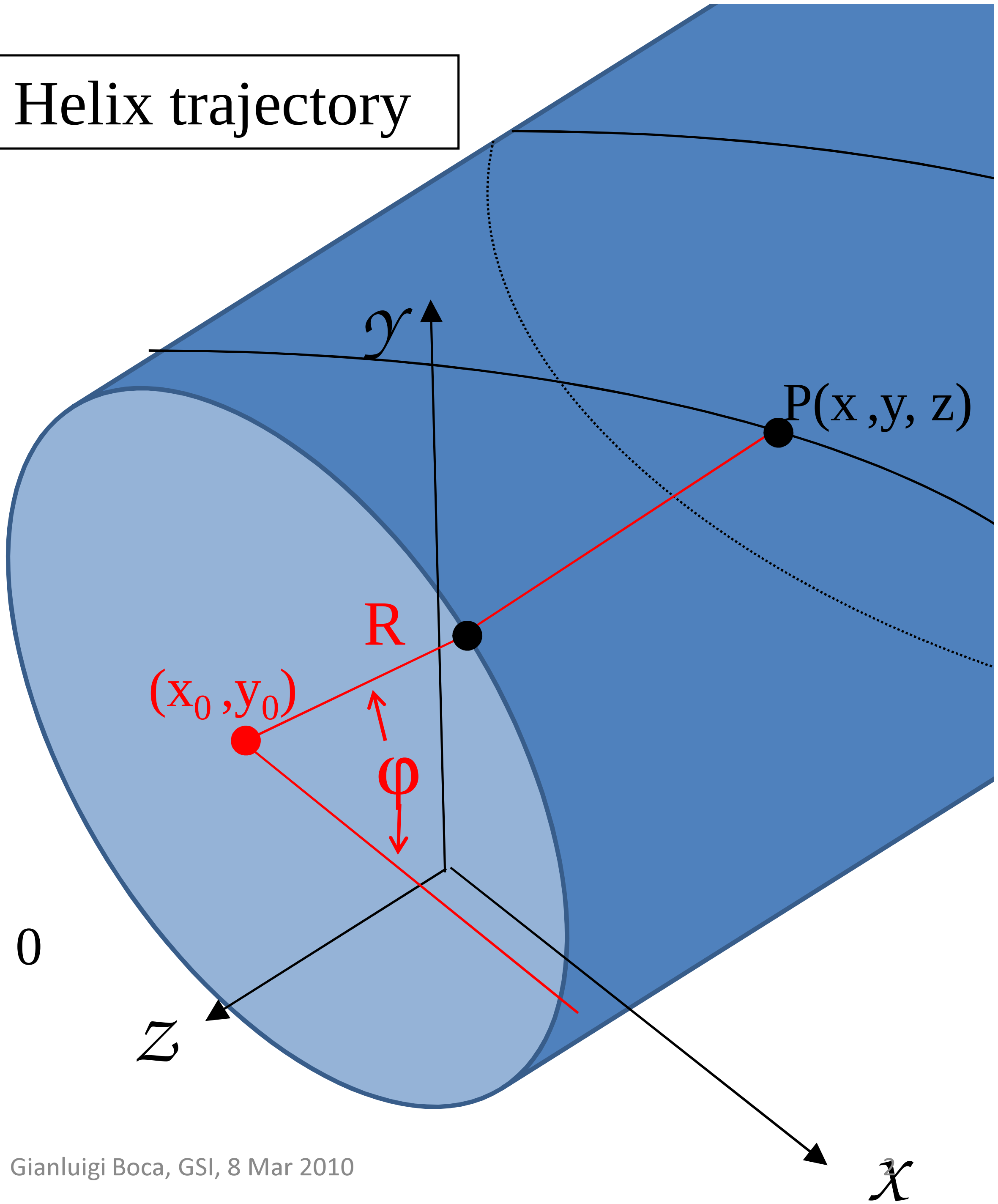
x_0 ≡ abscissa of center of cylinder

y_0 ≡ ordinate of center of cylinder

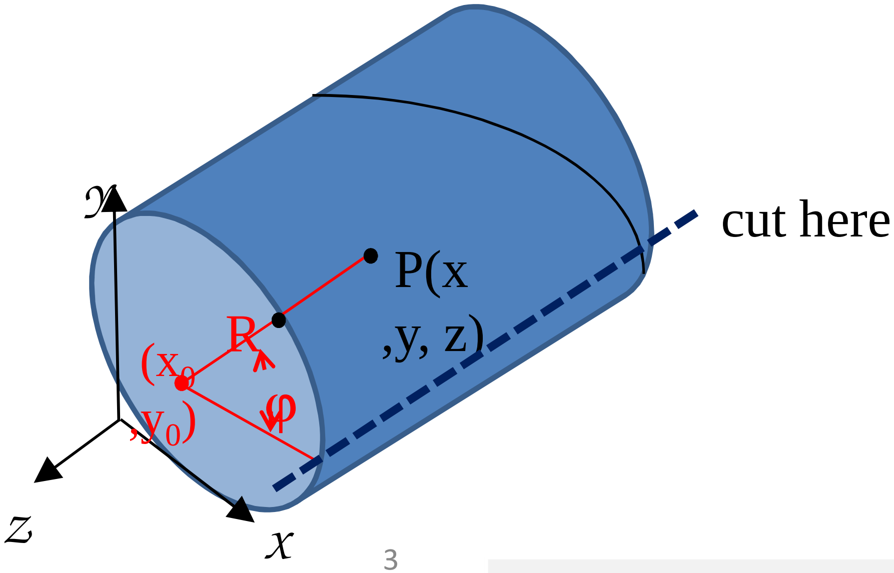
φ_0 ≡ azimuthal angle at $z = 0$

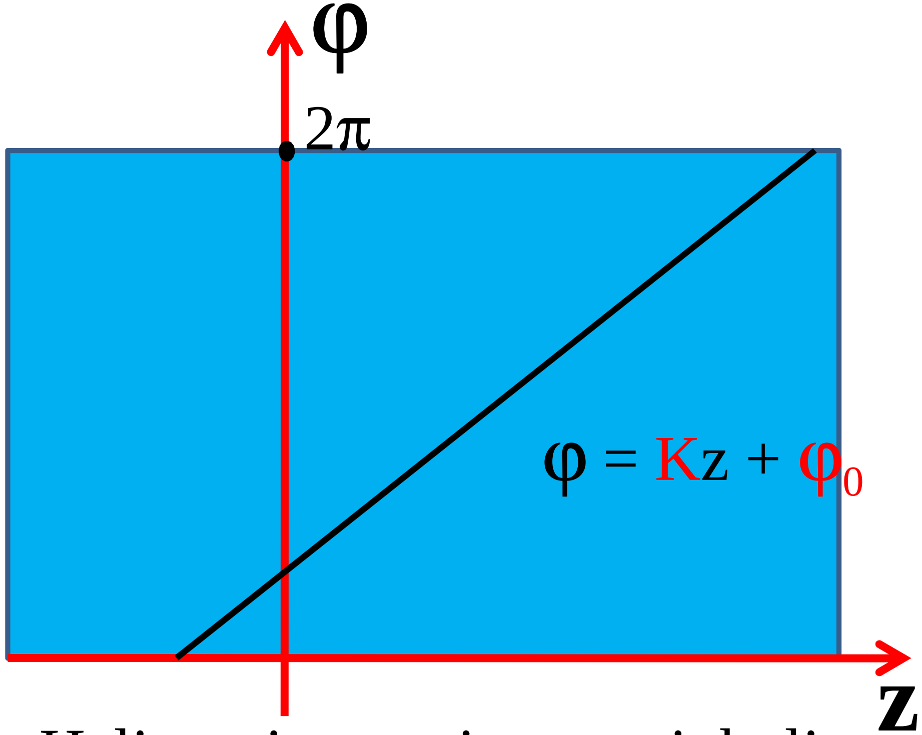
R ≡ radius of cylinder

K ≡ rate of increase of φ

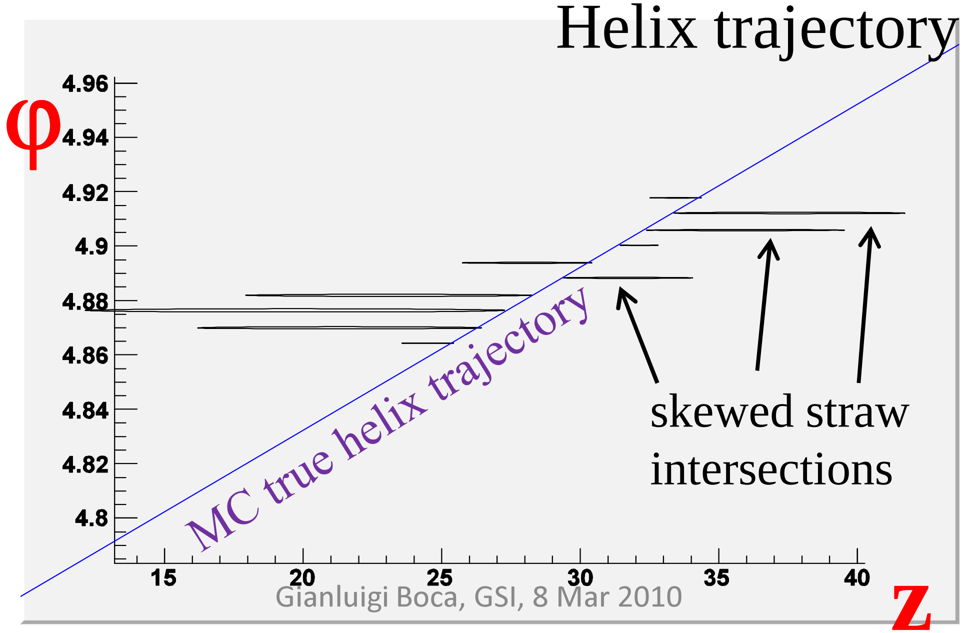


The φ z projection





Helix trajectory is a straight line



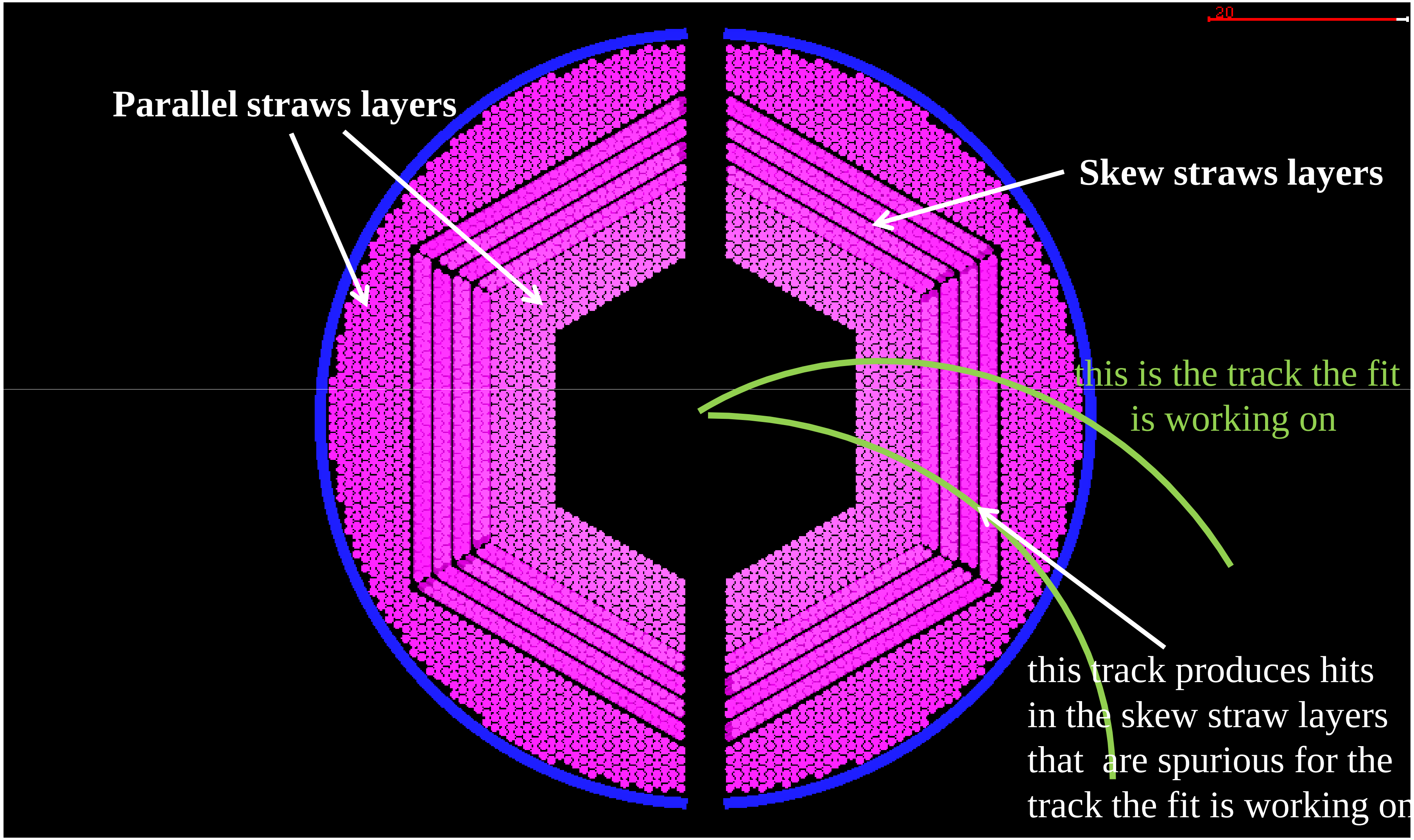
The main problem :
too many spurious hits

Status at the Julich meeting last September

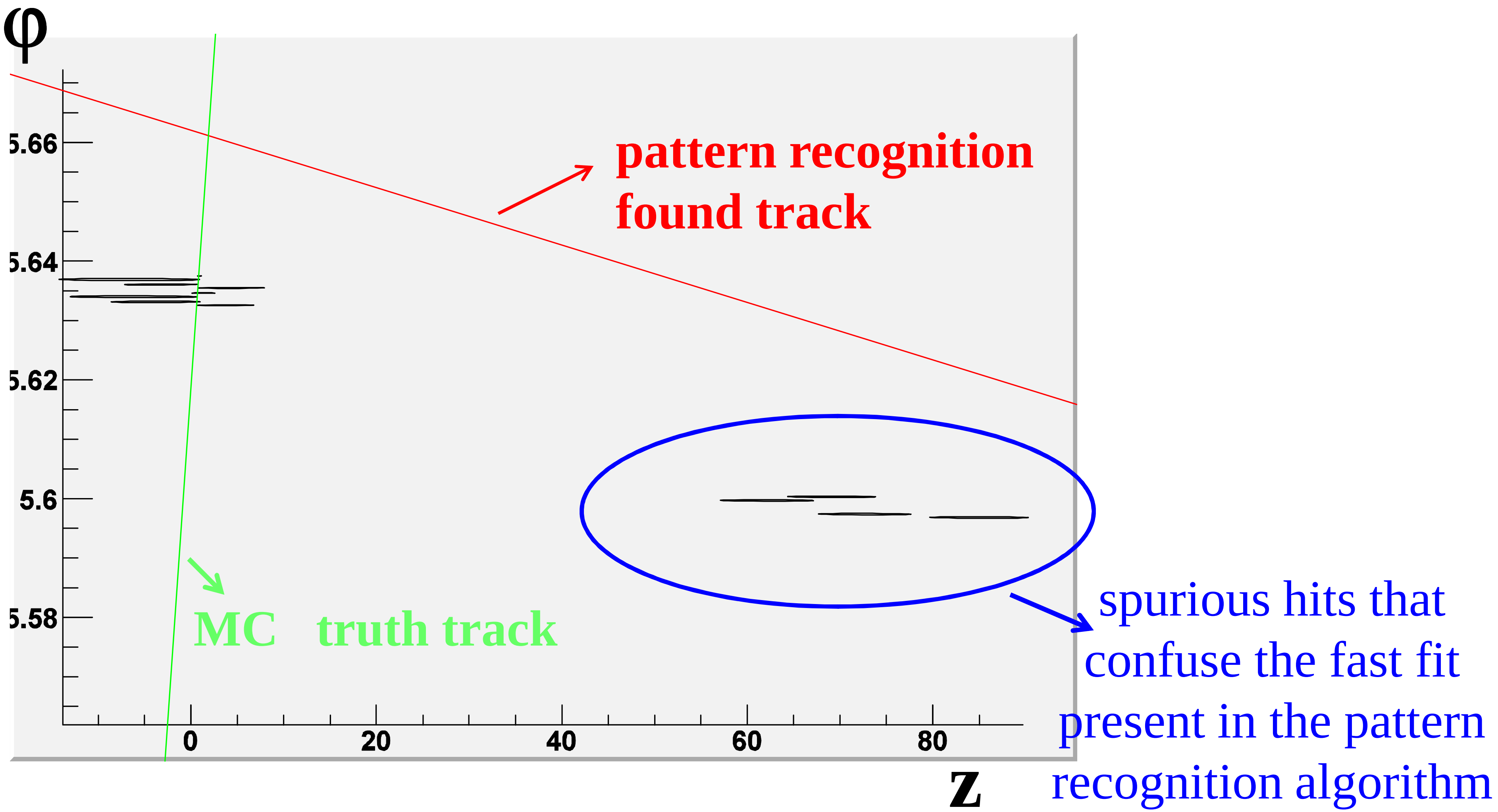
Summary table of Track Finder performance in terms of hits and tracks

Total P GeV/c	Generated tracks per event	Total # reasonable tracks generated	% of reconstructed tracks	Ghost tracks found (%)	Total generated hits parallel straws	% of found hits parallel straws	Wrong parallel hits associated (%)	Total generated hits in skew straws	% of found hits in skew straws	Wrong skew hits associated (%)
0.3	1	19	100	0	328	100	0.3	170	100	0
0.3	6	114	100	0	1910	98	8	1198	95	11.7
0.3	10	189	100	0	3205	96	14	2353	95	19.8
5.0	1	18	100	0	292	98.6	0	151	100	0
5.0	6	76	100	2.6	1244	98	9.8	816	98	40.6
5.0	10	142	100	2.8	2299	95	13	1503	99	37.9
10.0	1	19	100	0	318	98	0	149	100	3
10.0	6	87	100	5.7	1433	98.8	9.8	774	98.7	17
10.0	10	125	100	5.6	2031	93.7	12	1273	98	47

Typical problematic case



Typical problematic case



The solution

1)

Exploit the fact that the tracks comes from vertex near (0, 0) to determine curvature (and charge) and most importantly, a more precise region of space in which the hits of the track must be in. It helps rejecting both parallel and skew spurious hits

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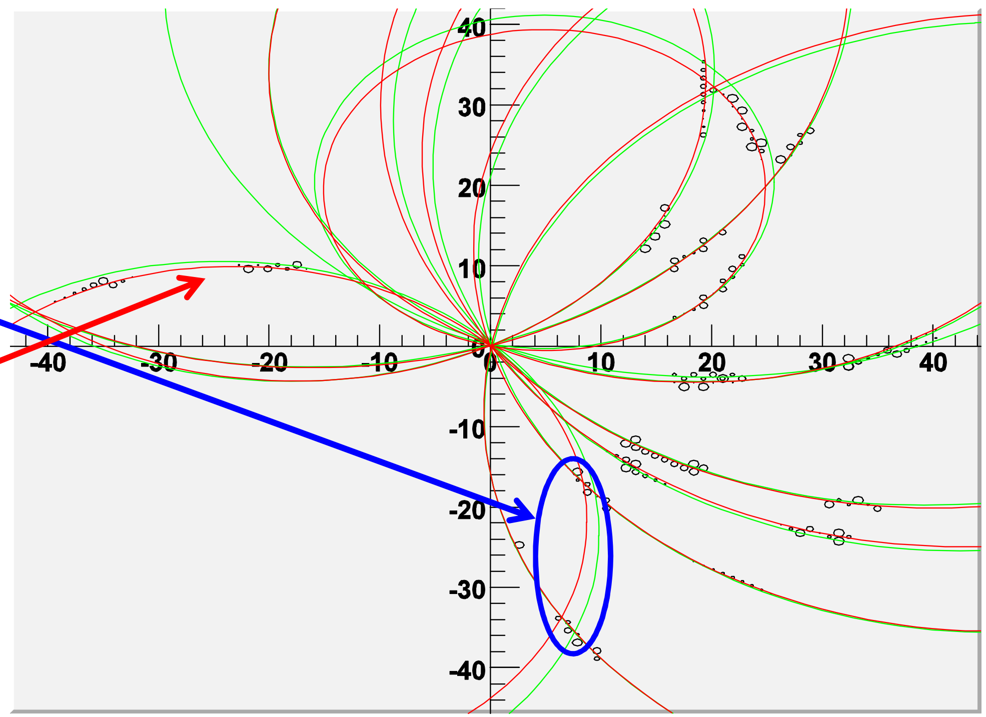
Exploit the fact that the tracks comes from vertex near (0, 0) to determine curvature (and charge) and most importantly, a more precise region of space in which the hits of the track must be in. It helps rejecting both parallel and skew spurious hits

green = true tracks

red = found tracks

these hits cannot belong

to this track



2)

Constrain the value of φ_0 in the fit in the φ Z plane (since the the radius and center of the Helix circle are known at this stage, and the particle originates essentially at (0,0) then φ_0 is also known)

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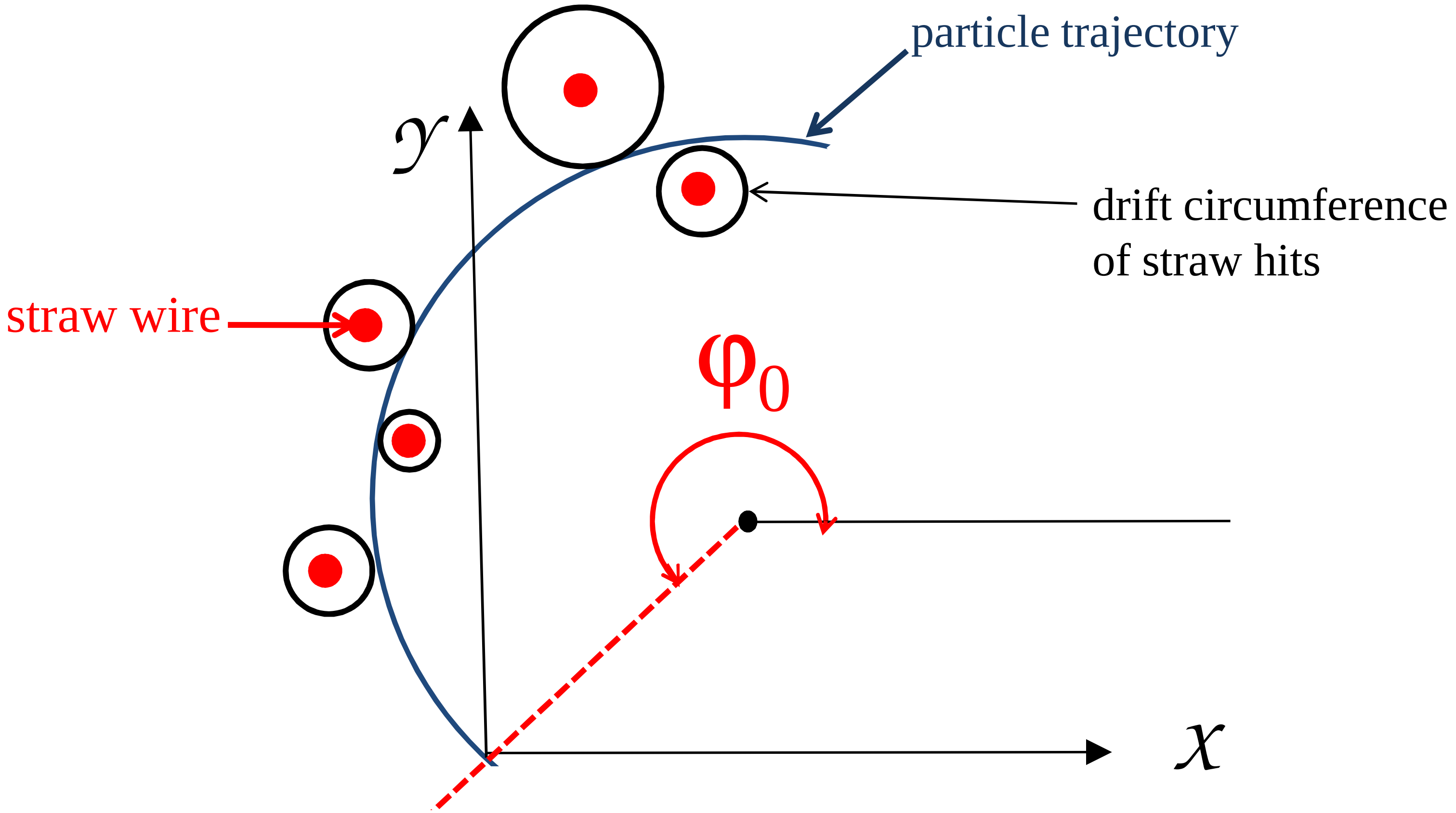
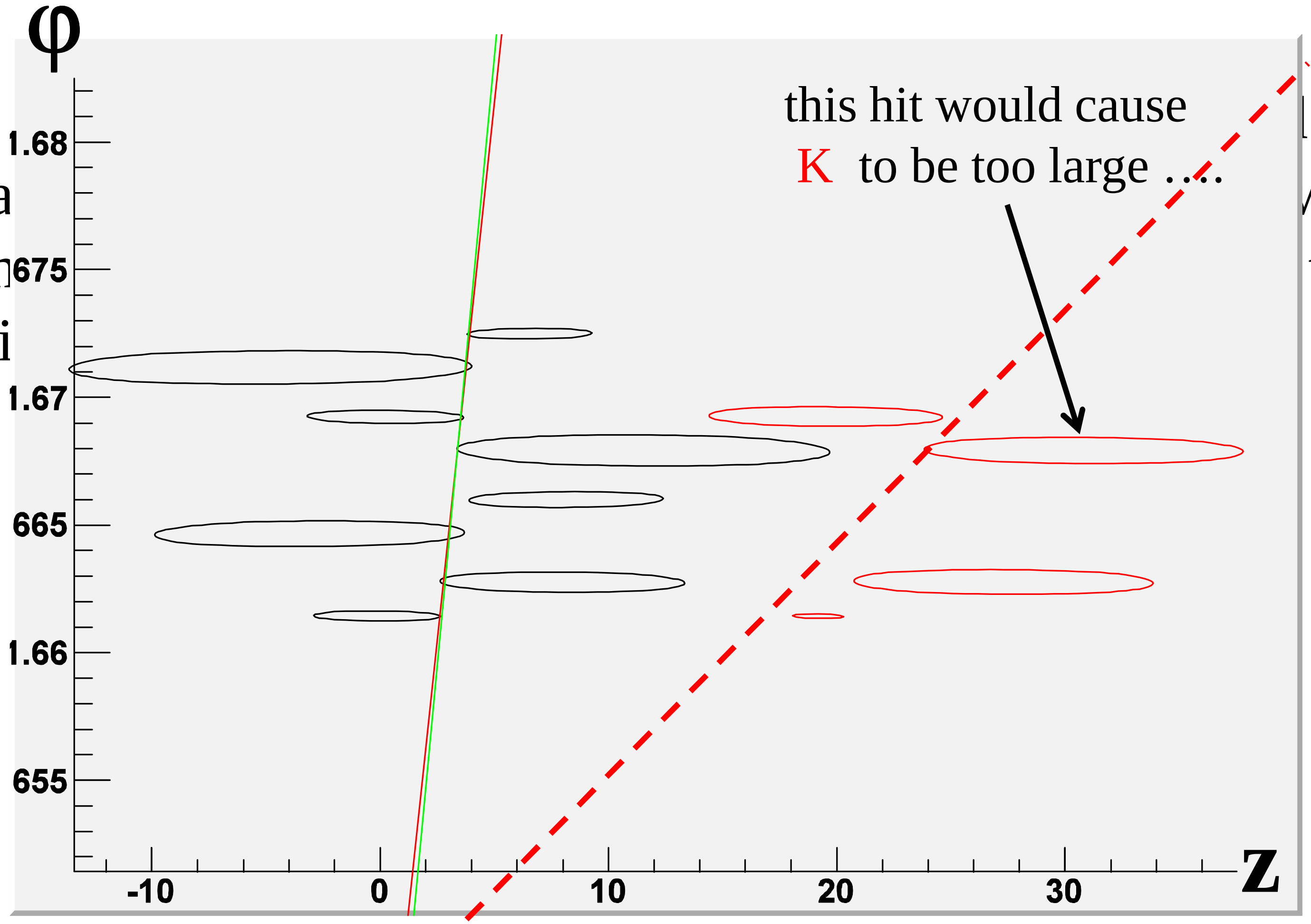


3)

Before the fit in the φ Z plane exclude the skew hits that would make the parameter K (rate increase of the Helix) too large. This would cause the exclusion of parallel hits that it is known to belong to the Helix trajectory

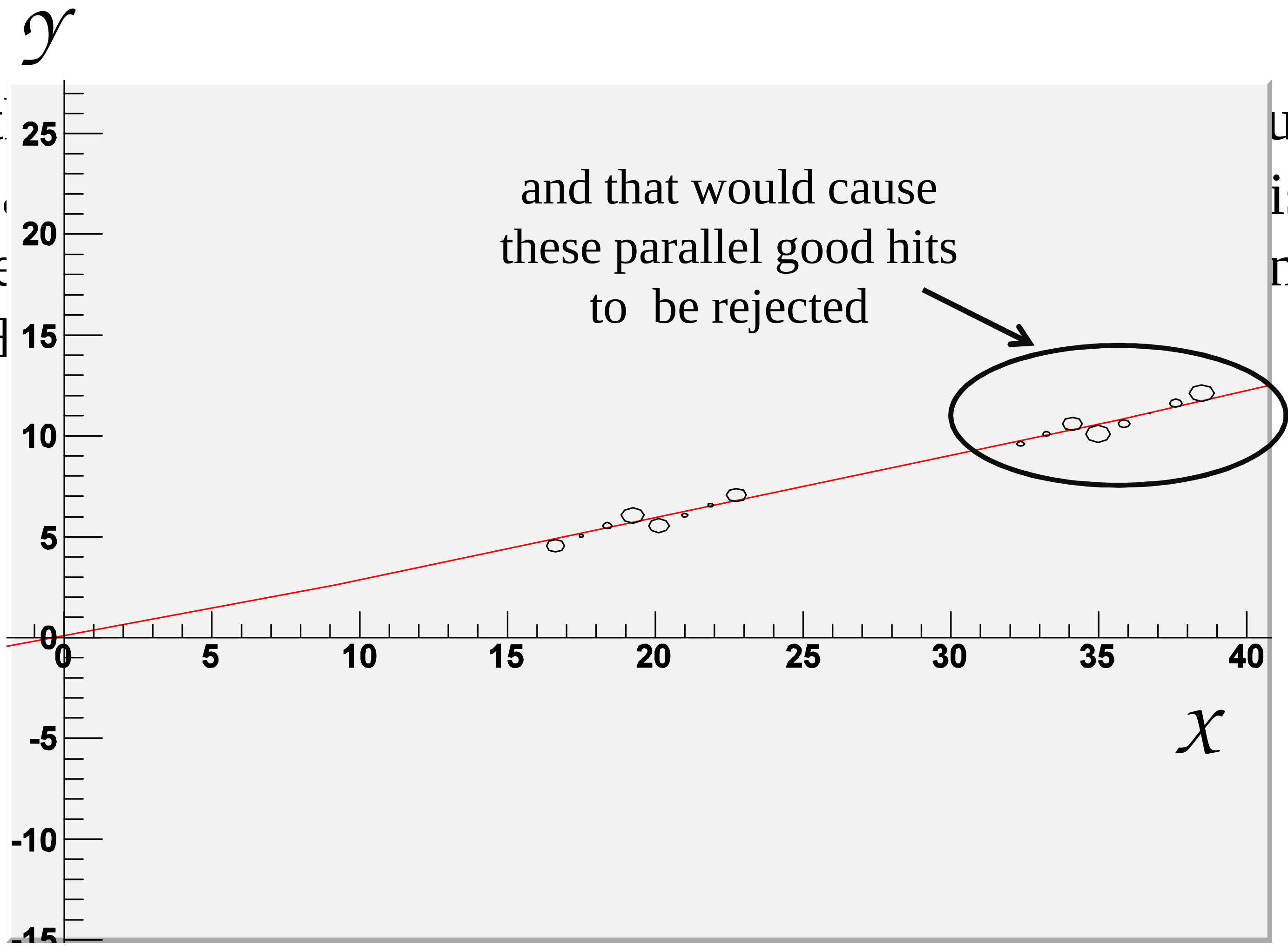
3)

Before the ... make the para... would cause th... to the Heli...



3)

Before t… …uld make
the p… …is would
cause… …ng to
the H…



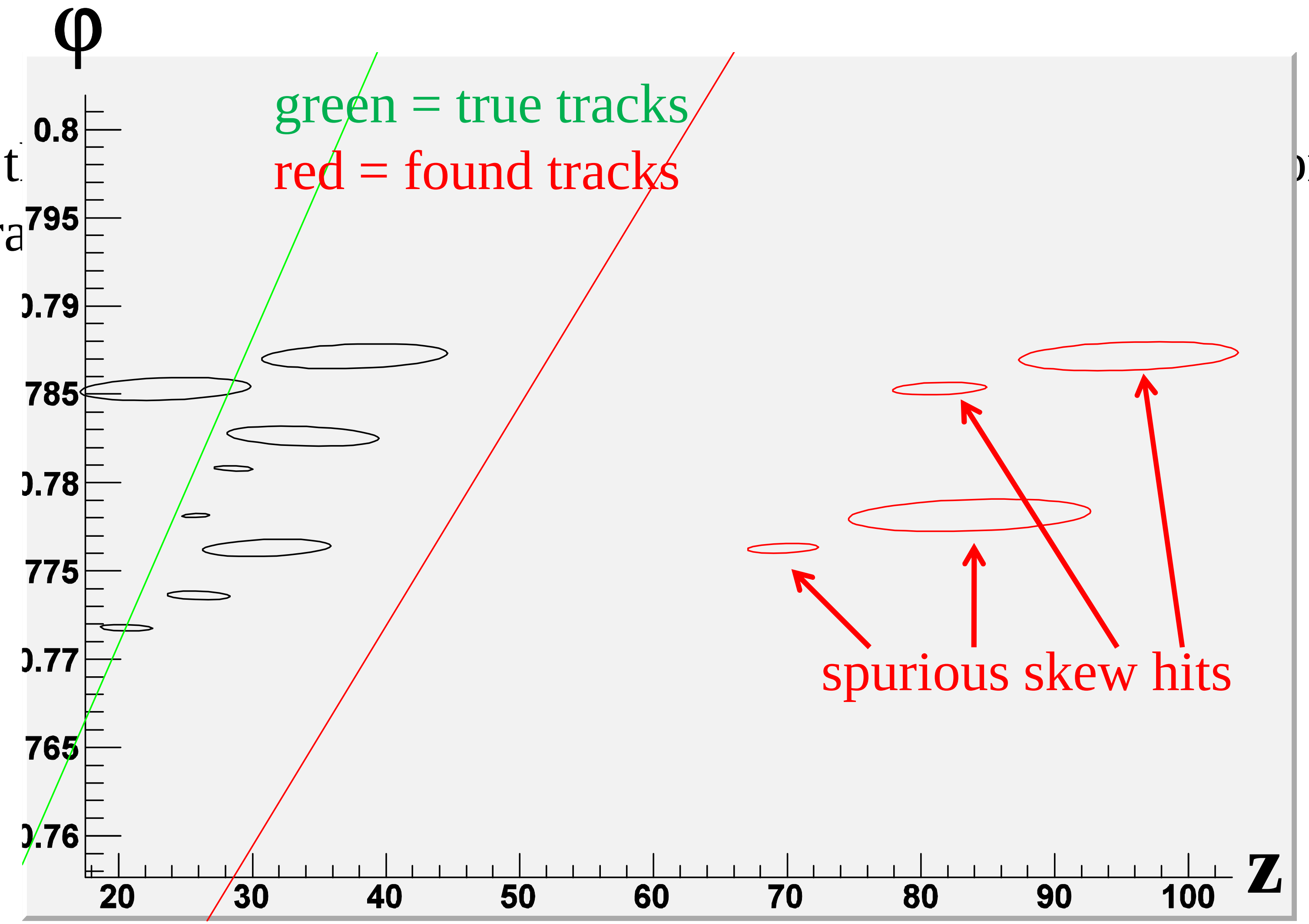
4)

After the fit in the φ Z plane exclude those skew hits too far from trajectory

4)

After t... ...om

tra



Present status, finding efficiency and spurious rejection

Total P GeV/c	Generated tracks per event	Total # reasonable tracks generated	% of reconstructed tracks	Ghost tracks found (%)	Total generated hits parallel straws	% of found hits parallel straws	Wrong parallel hits associated (%)	Total generated hits in skew straws	% of found hits in skew straws	Wrong skew hits associated (%)
0.3	1	18	100	0	310	100	0.3	162	100	0
0.3	6	98	100	0	1652	99	1.8	817	97	8
0.3	10	149	100	0	2549	100	3.8	1285	93	16.6
5.0	1	18	100	0	292	97	0	151	100	0
5.0	6	39	100	2.3	621	99	2.2	308	99	12.9
5.0	10	80	100	2.5	1149	98	3	560	96	8.5
10.0	1	19	100	0	318	100	0	152	99	1.3
10.0	6	73	100	0	1115	100	0.9	543	97	6
10.0	10	49	100	2	772	100	3.7	386	98	17.9

Present status, finding efficiency and spurious rejection

Total P GeV/c	Generated tracks per event	Total # reasonable tracks generated	% of reconstructed tracks	Ghost tracks found (%)	Total generated hits parallel straws	% of found hits parallel straws	Wrong parallel hits associated (%)	Total generated hits in skew straws	% of found hits in skew straws	Wrong skew hits associated (%)
1	1	28	100	0	459	100	0	226	98	0
1	6	105	100	0	1668	100	2.2	851	97	11
1	10	165	100	1.8	2563	100	2	1274	96	11.6
2	1	27	100	0	458	100	0	220	100	0
2	6	107	100	3.7	1715	100	0.5	856	95	10.8
2	10	165	100	1.8	2570	100	1.9	1219	95	11

X, Y, Z positions of the hit resolutions
and
$P_\perp$, P_z resolutions of the tracks found

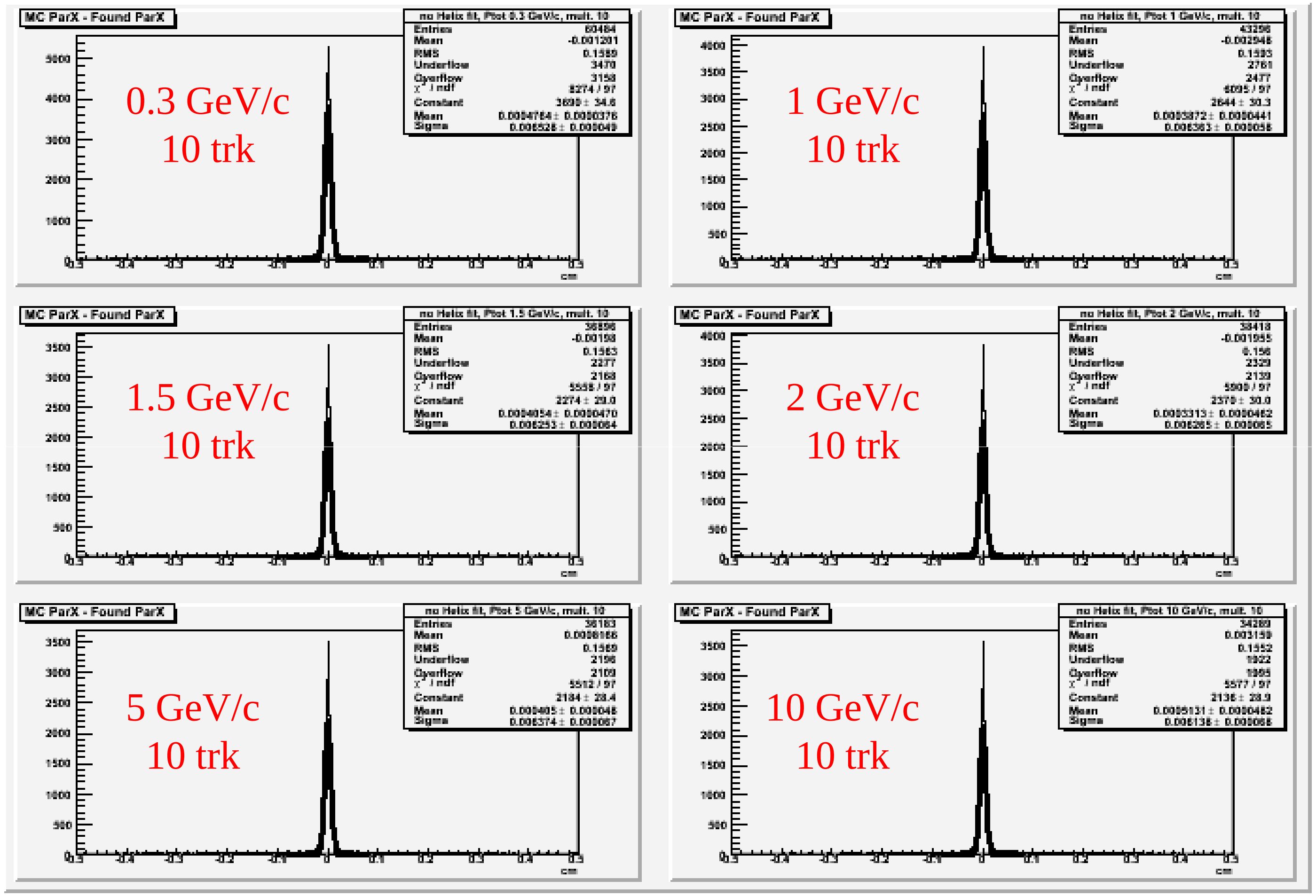
This pattern recognition can determine not only the hits belonging to a track but also, as a nice byproduct, the X, Y, Z positions of the hits belonging to a track, and $P_\perp$ and P_z of the track.

In order to try improve further these parameters, I also tried a fit with a helix (NO Kalman filter, NO Lhetrack, NO Genfit) .
This fit is authored by Lia & Pavia people and originally used Minuit. But now Lia has produced a verision that doesn’t use Minuit any more with the track constrained to come from (0,0,0), and this is MUCH FASTER.

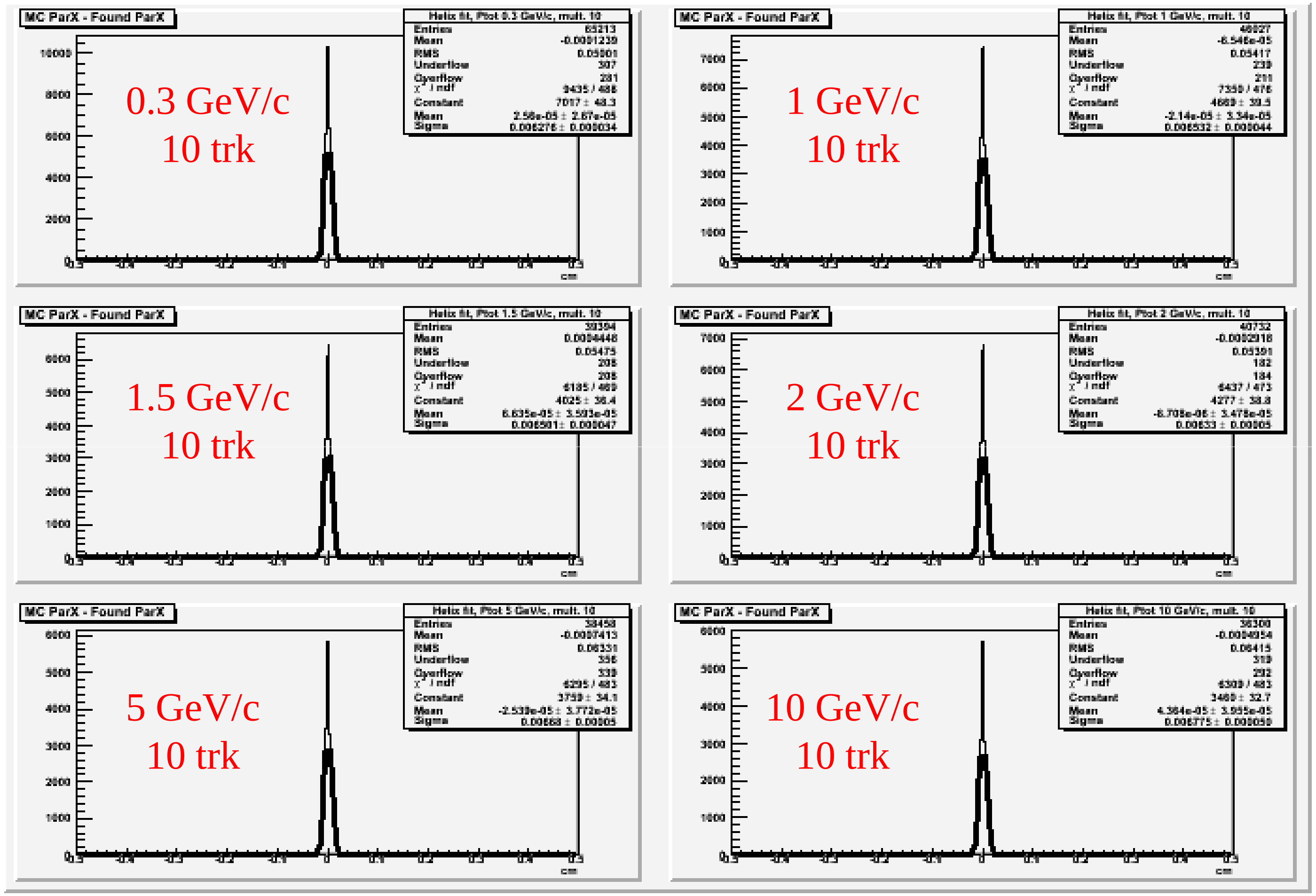
So in summary here I present the resolutions as I get them directly from the Pattern Recognition (PR) and with the PR + fit

Hits
X, Y, Z resolutions
and
comparisons
between
PR alone
and
PR + fit

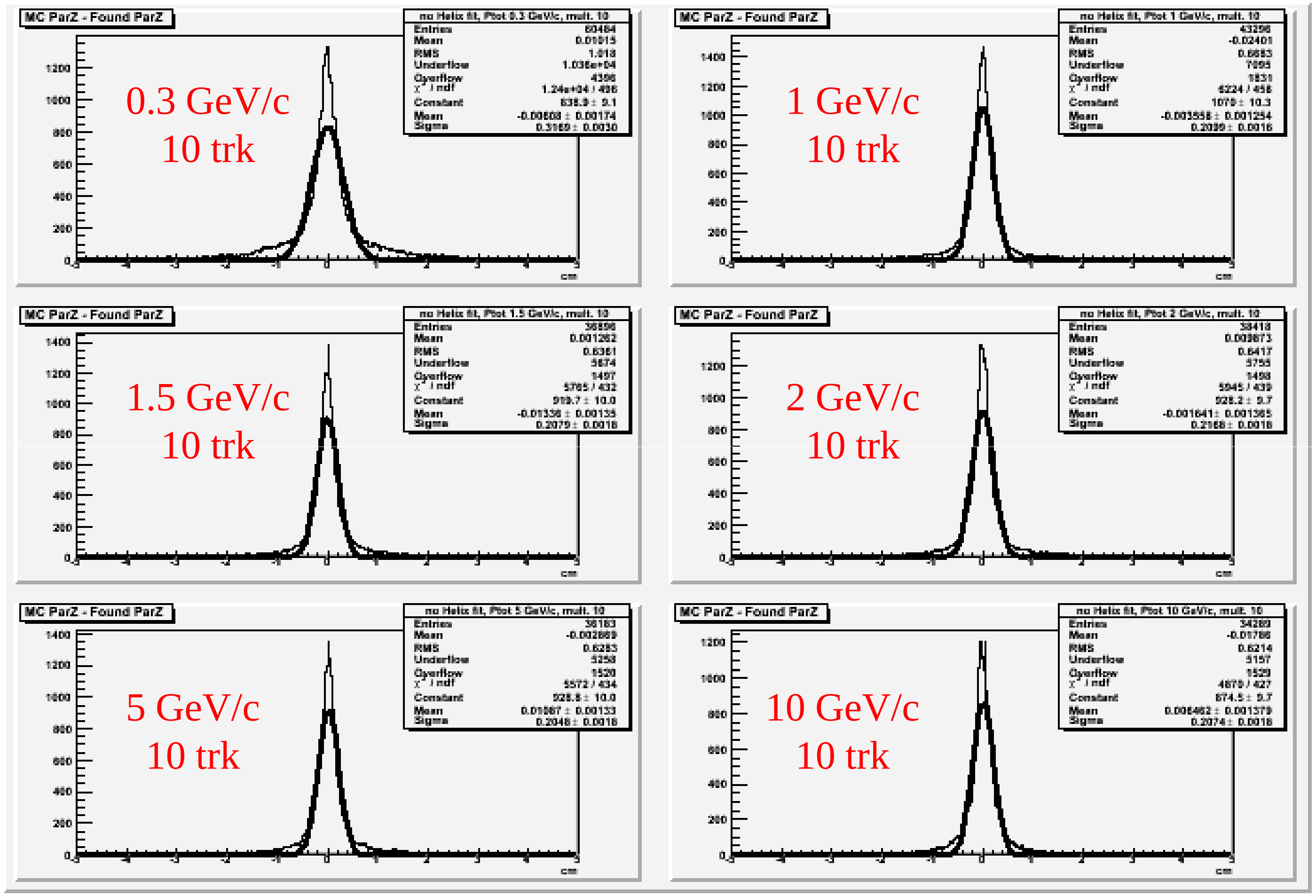
X of hits in parallel straws, only Pattern Recognition



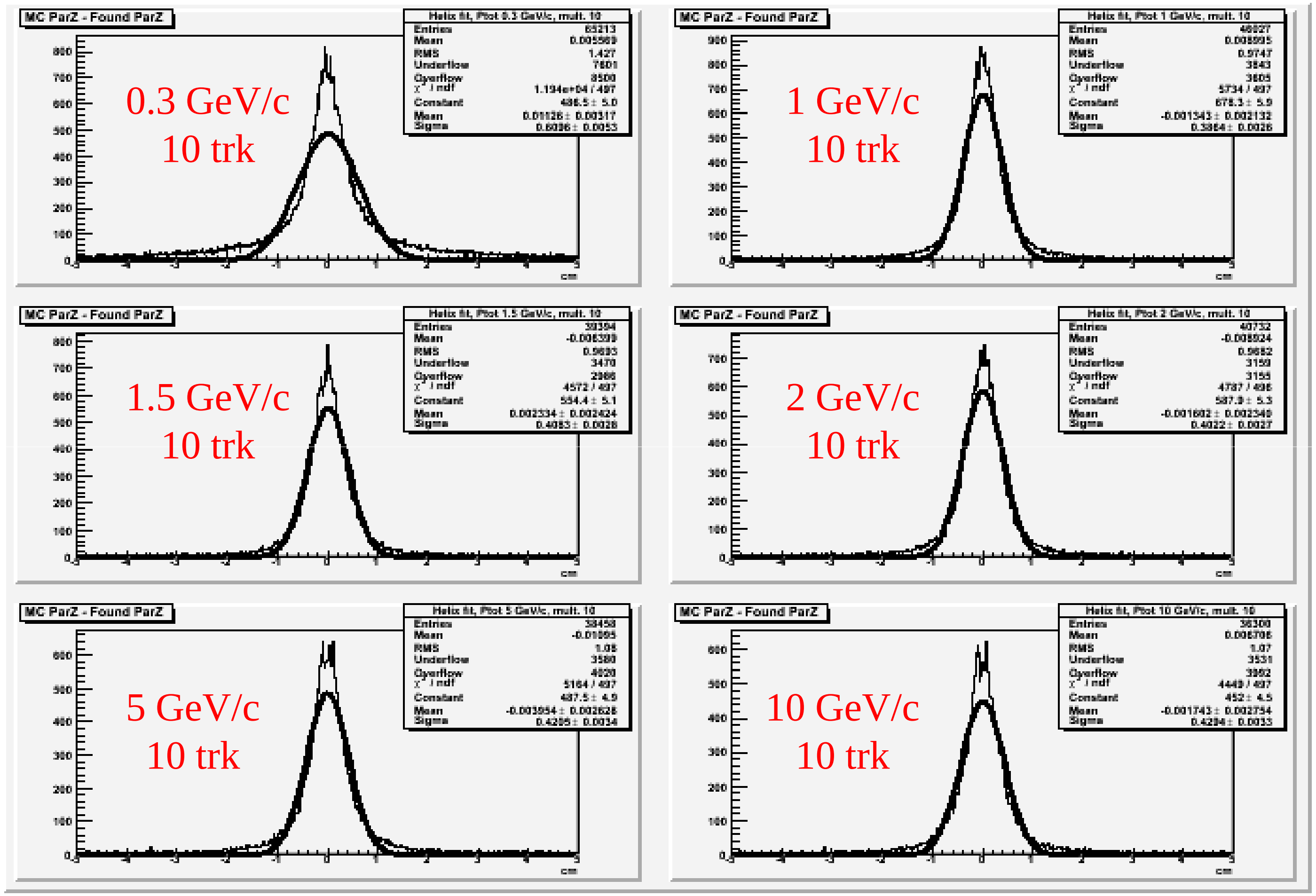
X of hits in parallel straws, Pattern Recognition and fit



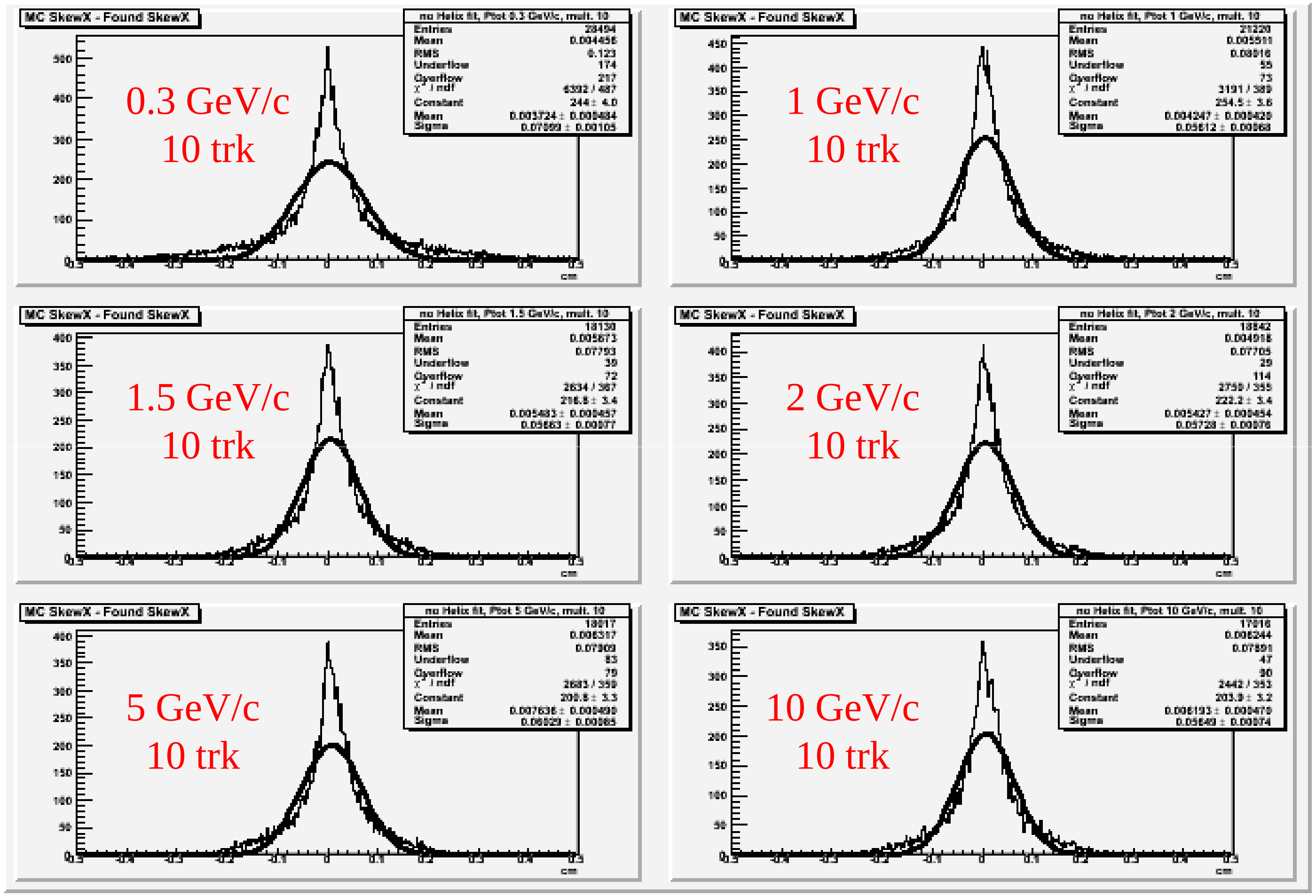
Z of hits in parallel straws, only Pattern Recognition



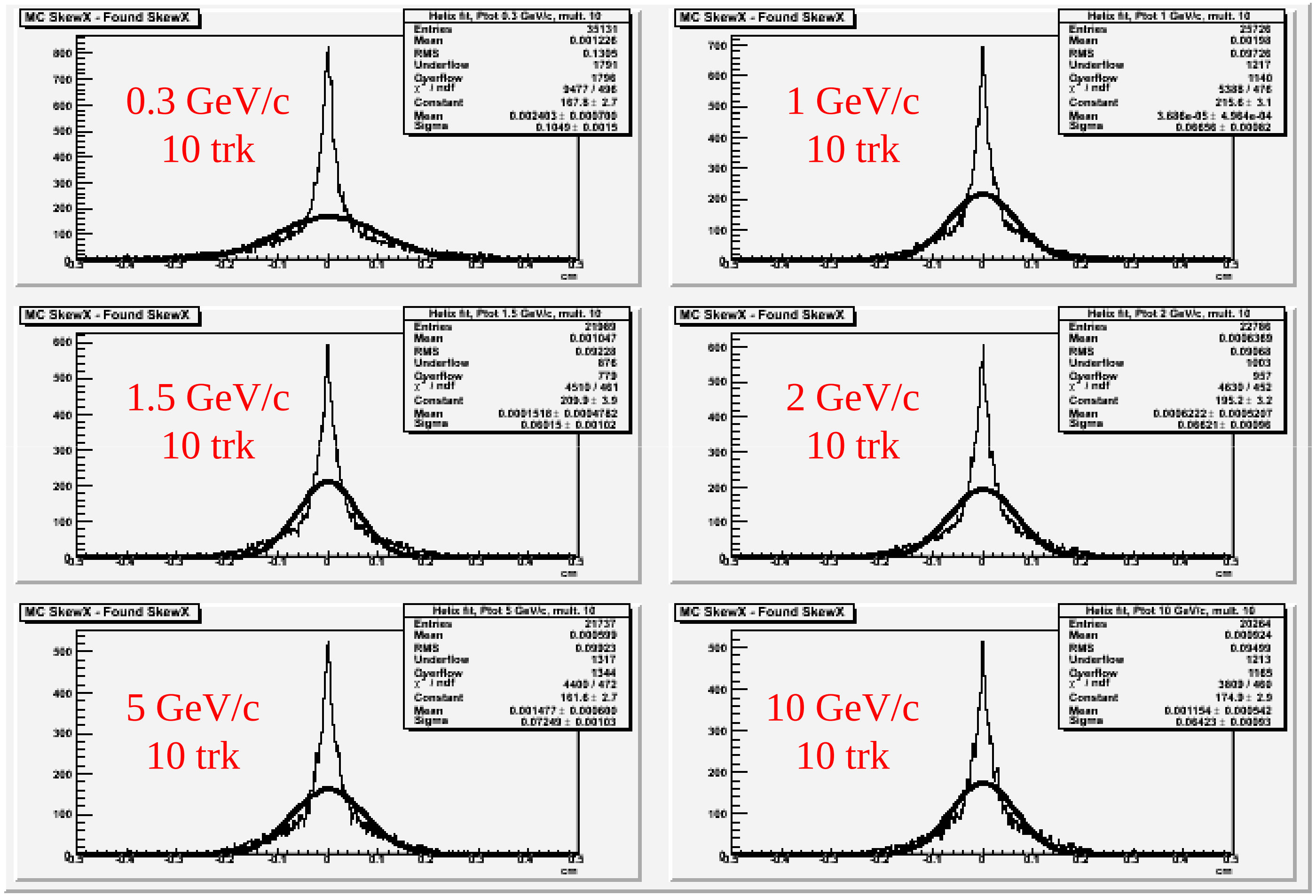
Z of hits in parallel straws, Pattern Recognition and fit



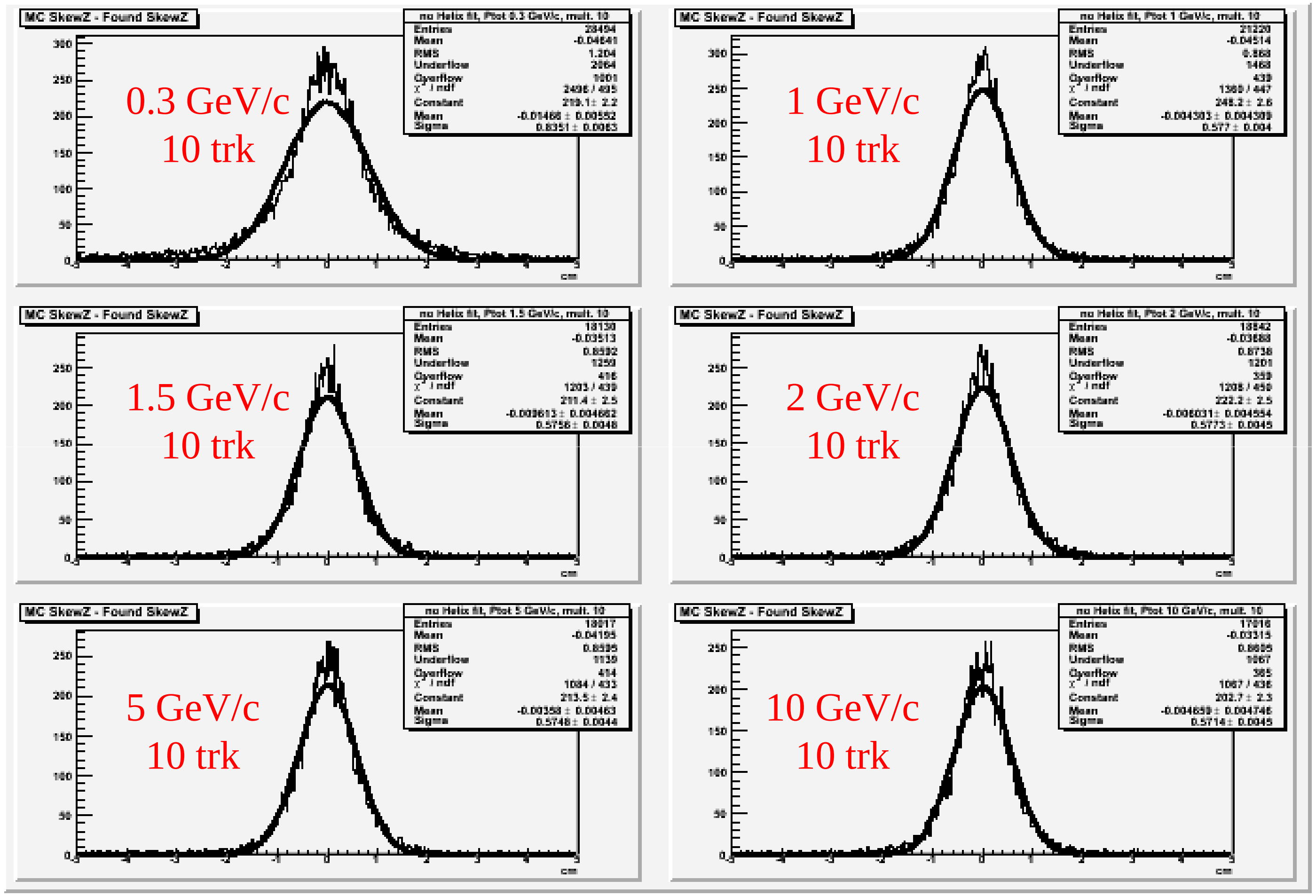
X of hits in skew straws, only Pattern Recognition



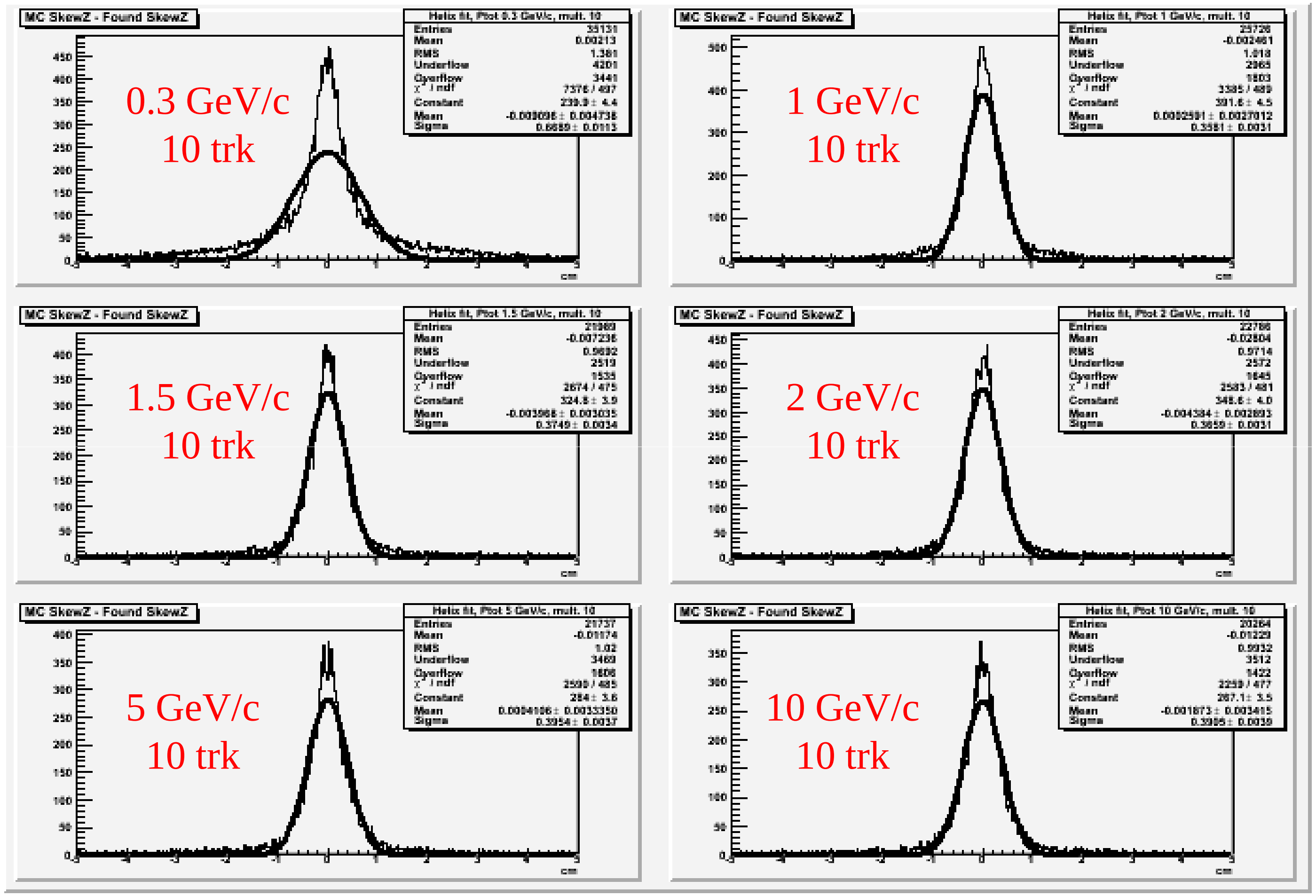
X of hits in skew straws, Pattern Recognition and fit



Z of hits in skew straws, only Pattern Recognition



Z of hits in skew straws, Pattern Recognition and fit



It would be too optimistic to consider as resolution of the X, Y and Z coordinates , the σ of the fits in the distributions just shown.

In the following Table the RMS of the distributions is considered instead.

Hit X, Y, Z position resolutions
Comparison pure Pattern Recognition & Pattern Recognition+fit with Helix

	δX Paral. RMS (cm) Pure PR	δX Paral. RMS (cm) PR & Fit	δY Paral. RMS (cm) Pure PR	δY Paral. RMS (cm) PR & Fit	δZ Paral. RMS (cm) Pure PR	δZ Paral. RMS (cm) PR & Fit	δX Skew RMS (cm) Pure PR	δX Skew RMS (cm) PR & Fit	δY Skew RMS (cm) Pure PR	δY Skew RMS (cm) PR & Fit	δZ Skew RMS (cm) Pure PR	δZ Skew RMS (cm) PR & Fit
0.3 / 1 trk	0.15	0.02	0.16	0.03	0.98	1.25	0.12	0.12	0.11	0.11	1.14	1.19
0.3 / 6 trk	0.16	0.04	0.16	0.04	0.99	1.36	0.12	0.13	0.11	0.12	1.16	1.30
0.3 / 10 trk	0.16	0.05	0.16	0.05	1.01	1.43	0.12	0.13	0.11	0.13	1.20	1.39
1 / 1 trk	0.16	0.06	0.16	0.06	0.56	0.90	0.07	0.08	0.07	0.09	0.72	0.78
1 / 6 trk	0.16	0.06	0.17	0.07	0.65	1.04	0.07	0.10	0.07	0.10	0.84	0.94
1 / 10 trk	0.16	0.05	0.17	0.05	0.67	0.97	0.08	0.10	0.07	0.10	0.87	1.01

Hit X, Y, Z position resolutions
Comparison pure Pattern Recognition & Pattern Recognition+fit with Helix

	δX Paral. RMS (cm) Pure PR	δX Paral. RMS (cm) PR & Fit	δY Paral. RMS (cm) Pure PR	δY Paral. RMS (cm) PR & Fit	δZ Paral. RMS (cm) Pure PR	δZ Paral. RMS (cm) PR & Fit	δX Skew RMS (cm) Pure PR	δX Skew RMS (cm) PR & Fit	δY Skew RMS (cm) Pure PR	δY Skew RMS (cm) PR & Fit	δZ Skew RMS (cm) Pure PR	δZ Skew RMS (cm) PR & Fit
1.5 / 1 trk	0.16	0.03	0.17	0.03	0.51	0.74	0.07	0.08	0.06	0.07	0.67	0.64
1.5/ 6 trk	0.16	0.05	0.17	0.05	0.59	0.88	0.08	0.08	0.07	0.09	0.80	0.91
1.5 / 10 trk	0.16	0.05	0.17	0.05	0.64	0.97	0.08	0.09	0.07	0.10	0.86	0.97
2 / 1 trk	0.16	0.04	0.16	0.04	0.52	0.78	0.07	0.08	0.07	0.08	0.71	0.68
2 / 6 trk	0.16	0.05	0.16	0.05	0.61	0.84	0.07	0.08	0.07	0.08	0.81	0.81
2 / 10 trk	0.16	0.05	0.16	0.05	0.64	0.97	0.08	0.09	0.07	0.10	0.87	0.97

Hit X, Y, Z position resolutions
Comparison pure Pattern Recognition & Pattern Recognition+fit with Helix

	δX Paral. RMS (cm) Pure PR	δX Paral. RMS (cm) PR & Fit	δY Paral. RMS (cm) Pure PR	δY Paral. RMS (cm) PR & Fit	δZ Paral. RMS (cm) Pure PR	δZ Paral. RMS (cm) PR & Fit	δX Skew RMS (cm) Pure PR	δX Skew RMS (cm) PR & Fit	δY Skew RMS (cm) Pure PR	δY Skew RMS (cm) PR & Fit	δZ Skew RMS (cm) Pure PR	δZ Skew RMS (cm) PR & Fit
5 / 1 trk	0.16	0.05	0.17	0.06	0.56	0.97	0.07	0.08	0.06	0.08	0.74	0.74
5 / 6 trk	0.16	0.06	0.17	0.06	0.63	1.00	0.07	0.09	0.08	0.10	0.81	0.92
5 / 10 trk	0.16	0.06	0.16	0.07	0.63	1.08	0.08	0.10	0.07	0.11	0.86	1.02
10 / 1 trk	0.16	0.06	0.16	0.06	0.56	0.90	0.07	0.08	0.07	0.09	0.72	0.78
10 / 6 trk	0.16	0.06	0.17	0.07	0.65	1.04	0.07	0.10	0.07	0.10	0.84	0.94
10 / 10 trk	0.16	0.06	0.17	0.07	0.62	1.07	0.08	0.09	0.07	0.11	0.86	0.99

Hit X, Y, Z position resolutions
Comparison pure Pattern Recognition & Pattern Recognition+fit with Helix

	δ X Par.	δ Y Par.	δ Z Par.	δ X Skew	δ Y Skew	δ Z Skew
0.3 / 1 trk	Fit	fit	NO	=	=	NO
0.3 / 6 trk	fit	fit	NO	NO	NO	NO
0.3 / 10 trk	fit	fit	NO	NO	NO	NO
1 / 1 trk	fit	fit	NO	NO	NO	NO
1 / 6 trk	fit	fit	NO	NO	NO	NO
1 / 10 trk	fit	fit	NO	NO	NO	NO
1.5 / 1 trk	fit	fit	NO	NO	NO	fit
1.5 / 6 trk	fit	fit	NO	=	NO	NO
1.5 / 10 trk	fit	fit	NO	NO	NO	NO

NO = best reult with Pattern Recognition alone, no fit

fit = best result with Pattern Recognition AND fit

= = same result with PR alone or PR & fit

Hit X, Y, Z position resolutions

Comparison pure Pattern Recognition & Pattern Recognition+fit with Helix

	δ X Par.	δ Y Par.	δ Z Par.	δ X Skew	δ Y Skew	δ Z Skew
2 / 1 trk	Fit	fit	NO	NO	NO	=
2 / 6 trk	fit	fit	NO	NO	NO	NO
2 / 10 trk	fit	fit	NO	NO	NO	NO
5 / 1 trk	fit	fit	NO	NO	NO	NO
5 / 6 trk	fit	fit	NO	NO	NO	NO
5 / 10 trk	fit	fit	NO	NO	NO	NO
10 / 1 trk	fit	fit	NO	NO	NO	NO
10 / 6 trk	fit	fit	NO	NO	NO	NO
10 / 10 trk	fit	fit	NO	NO	NO	NO

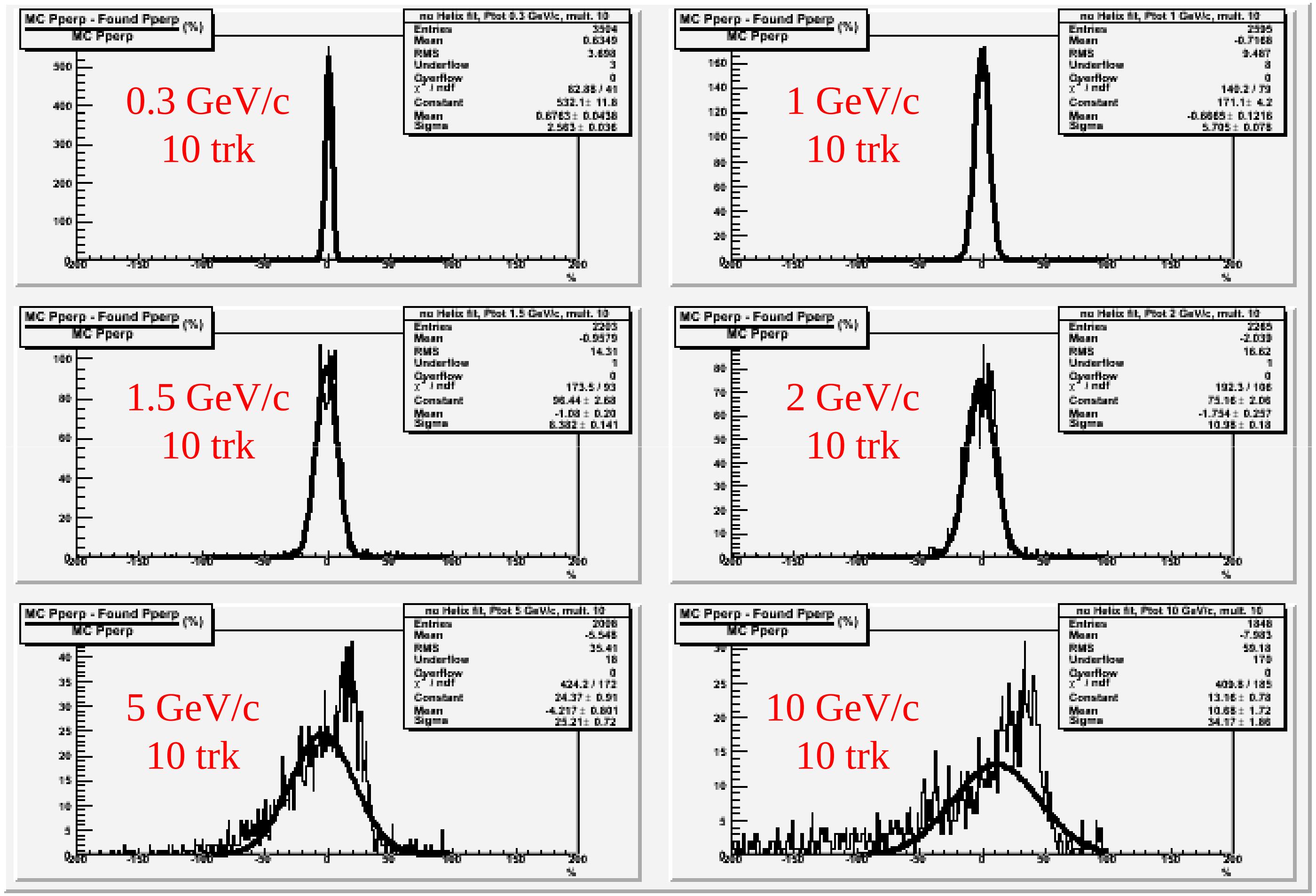
NO = best reult with Pattern Recognition alone, no fit

fit = best result with Pattern Recognition AND fit

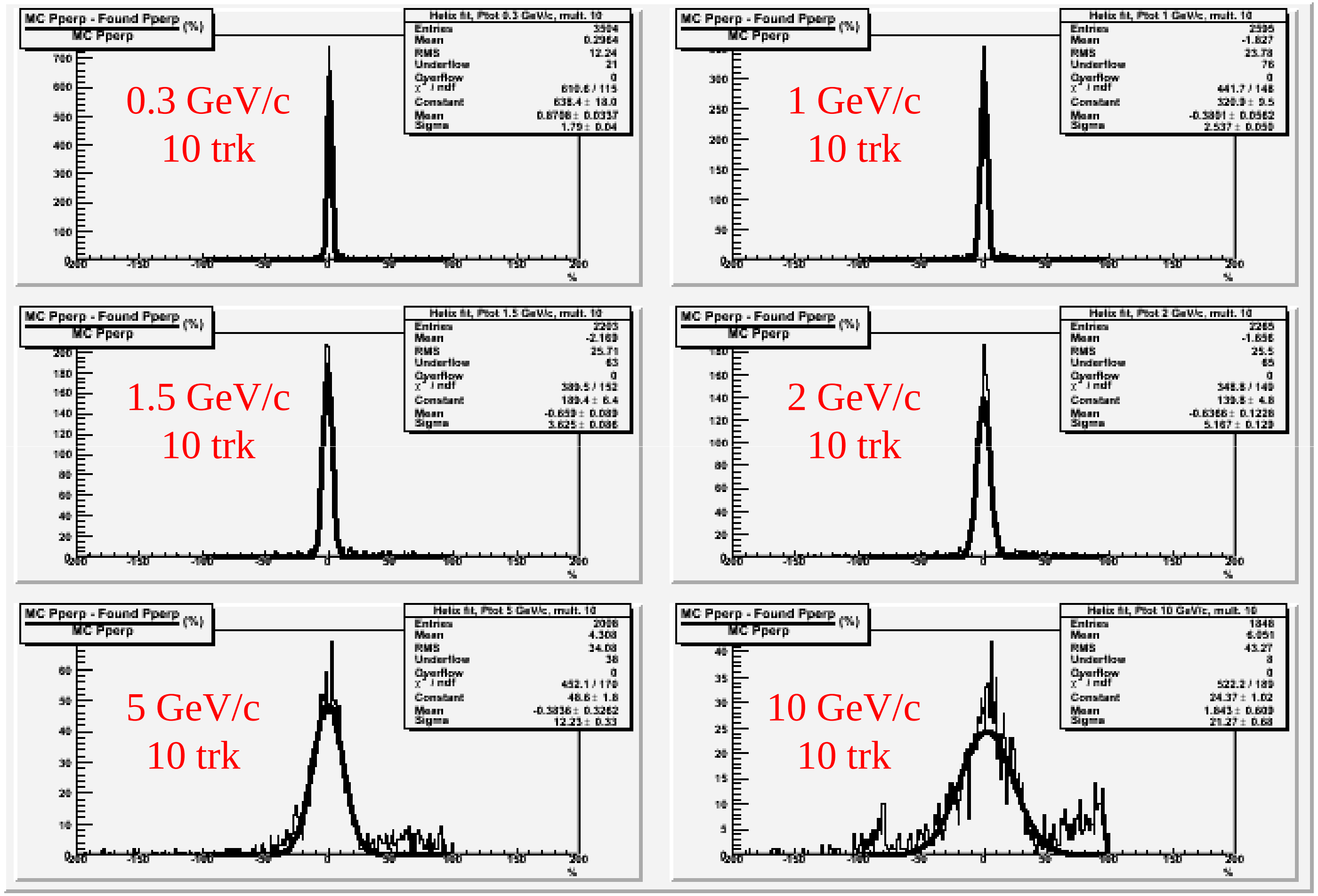
= = same result with PR alone or PR & fit

Track
$P_{\perp}$, P_Z and Φ_0 resolutions
and
comparisons
between
PR alone
and
PR + fit

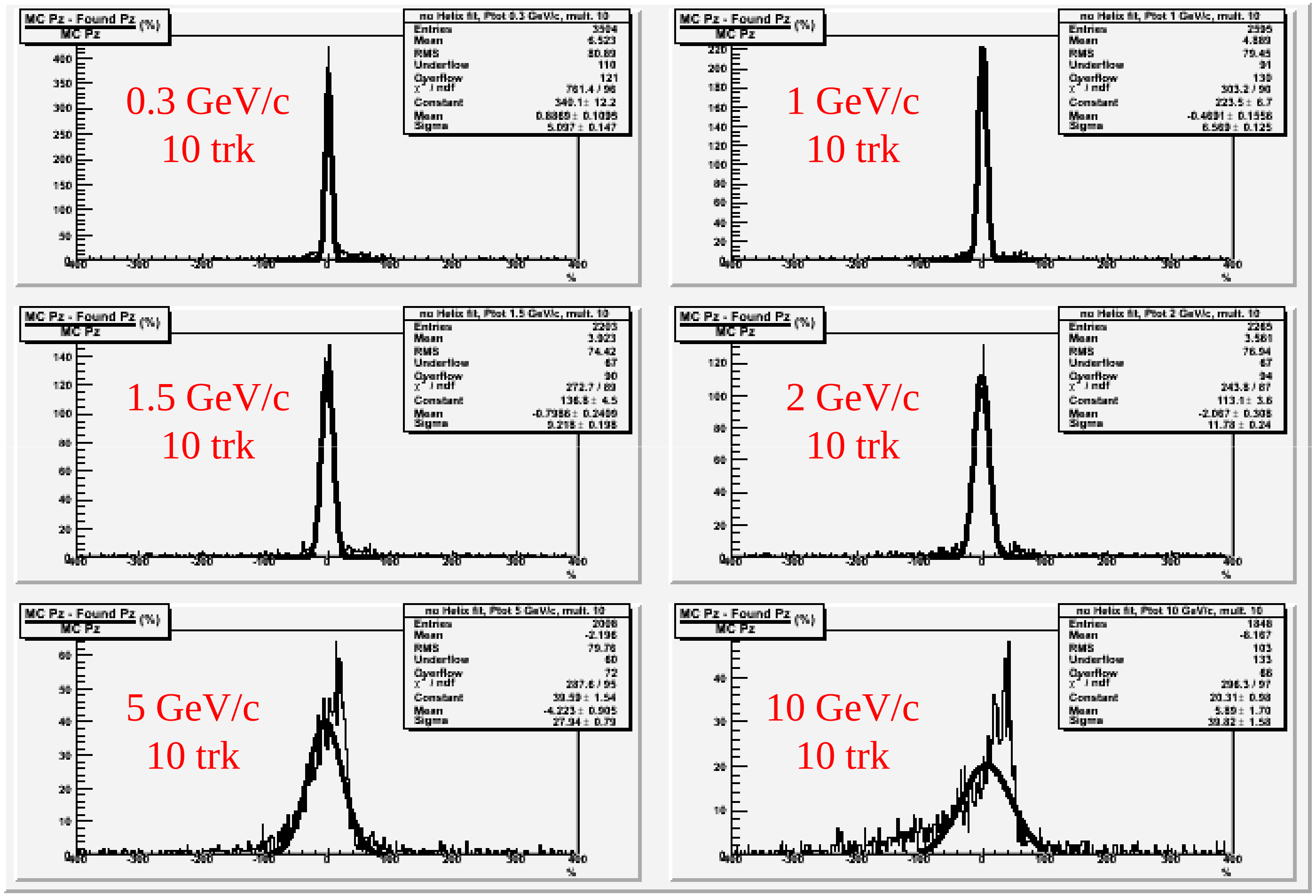
$P_{\perp}$, only Pattern Recognition (%)



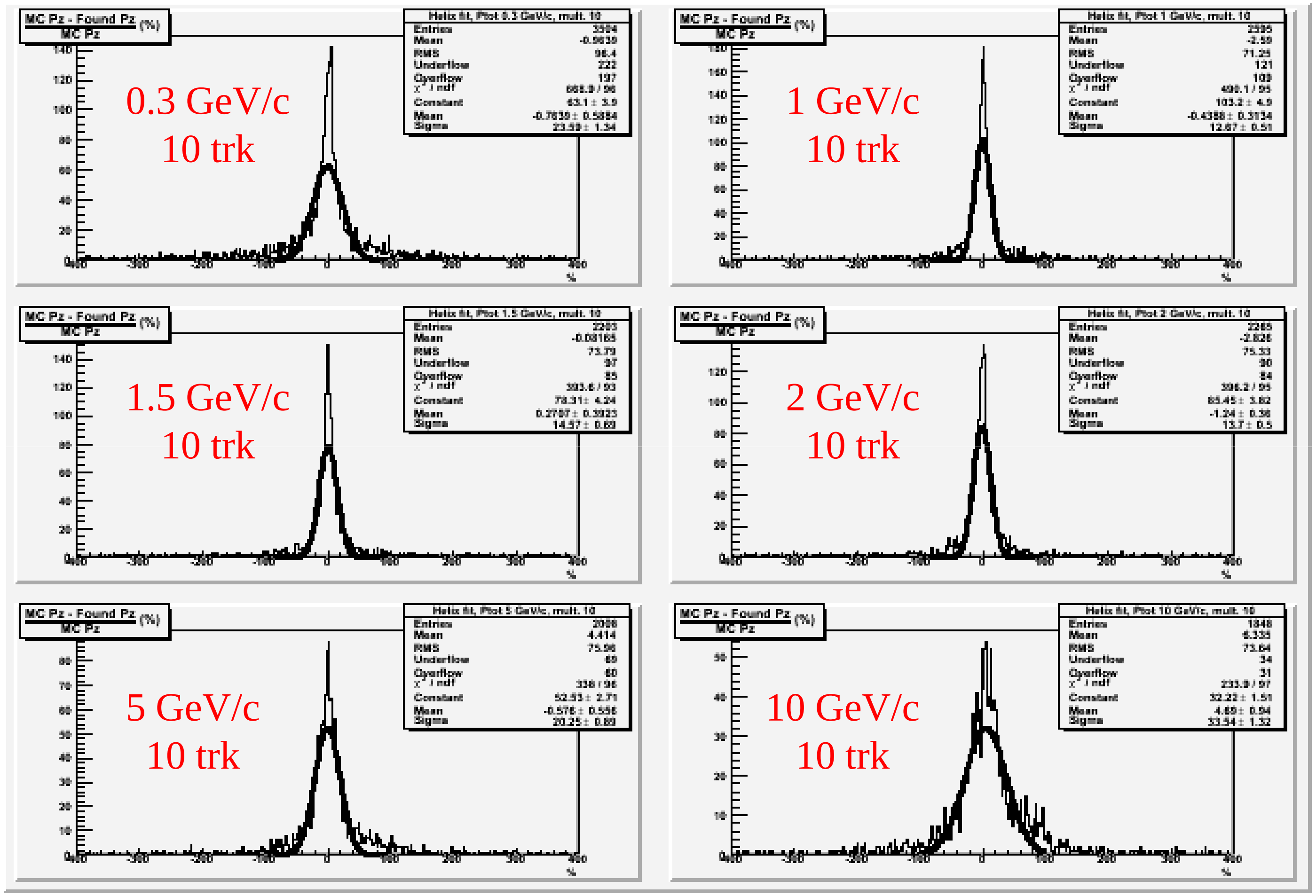
$P_{\perp}$, Pattern Recognition & fit (%)



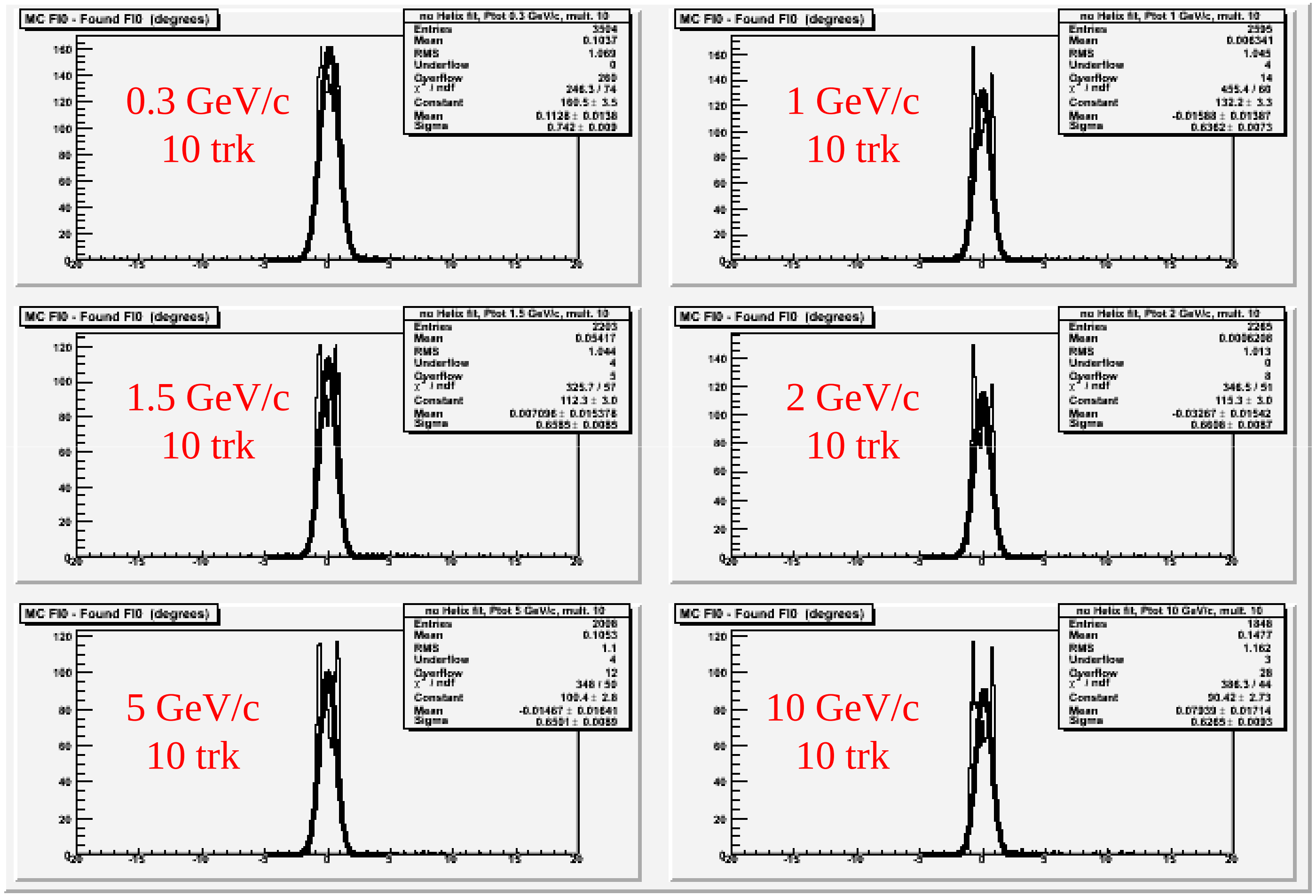
P_Z , only Pattern Recognition (%)



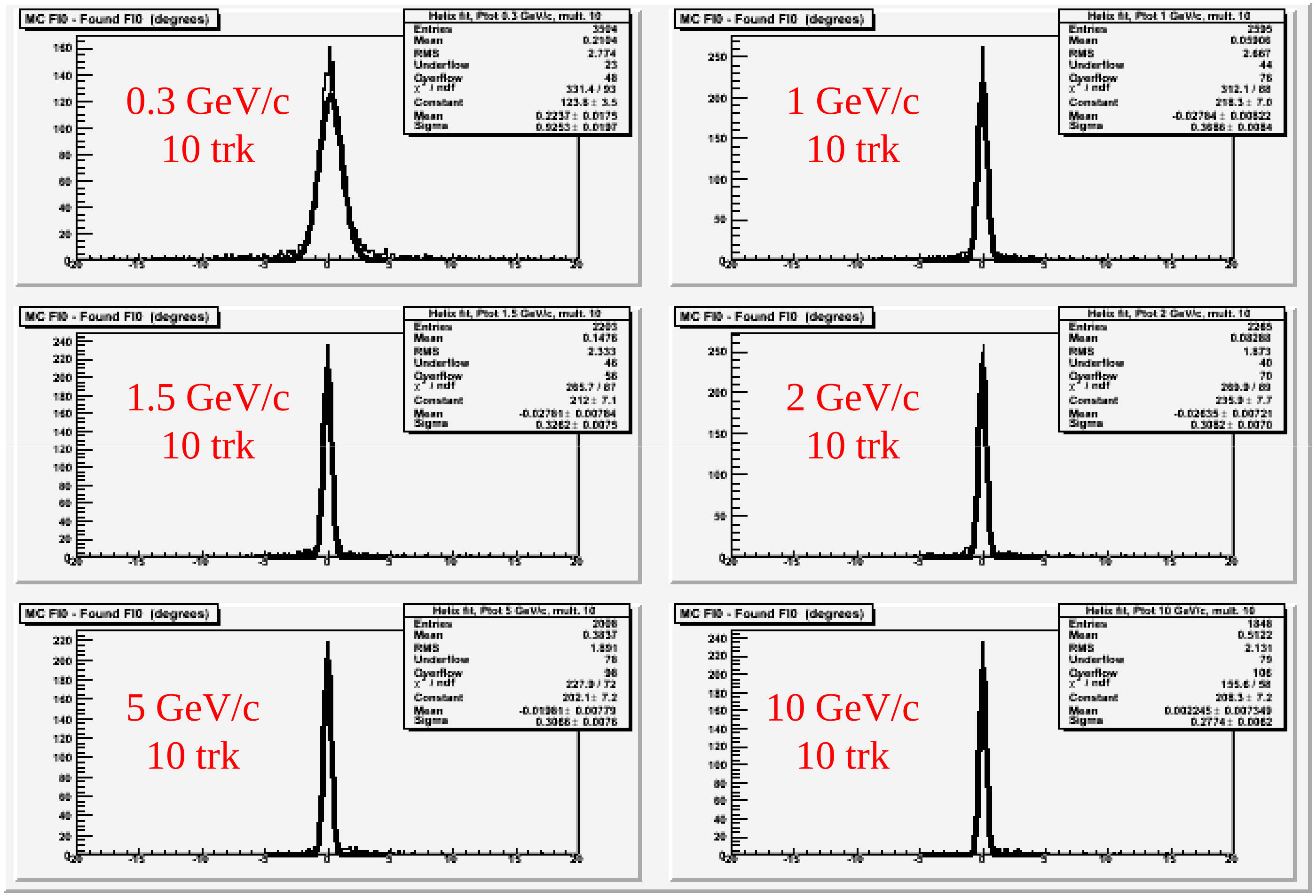
P_Z , Pattern Recognition & fit (%)



Φ_0 only Pattern Recognition (degrees)



Φ_0 Pattern Recognition & fit (degrees)



Track $P_\perp$, P_Z and Φ_0 resolutions

Comparison pure Pattern Recognition & Pattern Recognition+fit with Helix

	(MC Pz -Pz)/ MC Pz (%) Pure PR	(MC Pz -Pz)/ MC Pz (%) PR & Fit	(MC $P_\perp$ -$P_\perp$) / MC $P_\perp$ (%) Pure PR	(MC $P_\perp$ -$P_\perp$) / MC $P_\perp$ (%) PR & Fit	MC φ_0 - φ_0 (degrees) Pure PR	MC φ_0 - φ_0 (degrees) PR & Fit
0.3 GeV/c 1 track	5.0	15.7	2.6	1.5	0.72	0.70
0.3 GeV/c 6 track	5.5	18.7	2.5	1.7	0.71	0.82
0.3 GeV/c 10 track	5.1	23.6	2.6	1.8	0.74	0.93
1 GeV/c 1 track	6.0	12.0	5.6	2.4	0.66	0.33
1 GeV/c 6 track	6.8	11.7	5.5	2.4	0.64	0.36
1 GeV/c 10 track	6.6	12.7	5.7	2.5	0.64	0.37

Track $P_\perp$, P_Z and Φ_0 resolutions
Comparison pure Pattern Recognition & Pattern Recognition+fit with Helix

	(MC Pz -Pz)/ MC Pz (%) Pure PR	(MC Pz -Pz)/ MC Pz (%) PR & Fit	(MC $P_\perp$ -$P_\perp$) / MC $P_\perp$ (%) Pure PR	(MC $P_\perp$ -$P_\perp$) / MC $P_\perp$ (%) PR & Fit	MC φ_0 - φ_0 (degrees) Pure PR	MC φ_0 - φ_0 (degrees) PR & Fit
1.5 GeV/c 1 track	8.8	11.6	8.4	3.3	0.71	0.29
1.5 GeV/c 6 track	9.5	13.1	8.5	3.5	0.64	0.31
1.5 GeV/c 10 track	9.2	14.6	8.4	3.6	0.66	0.33
2 GeV/c 1 track	12.6	11.0	11.3	4.0	0.72	0.28
2 GeV/c 6 track	11.5	14.1	10.4	4.6	0.66	0.30
2 GeV/c 10 track	11.8	13.7	11.0	5.2	0.66	0.31

Track $P_\perp$, P_Z and Φ_0 resolutions
Comparison pure Pattern Recognition & Pattern Recognition+fit with Helix

	(MC Pz -Pz)/ MC Pz (%) Pure PR	(MC Pz -Pz)/ MC Pz (%) PR & Fit	(MC $P_\perp$ -$P_\perp$) / MC $P_\perp$ (%) Pure PR	(MC $P_\perp$ -$P_\perp$) / MC $P_\perp$ (%) PR & Fit	MC φ_0 - φ_0 (degrees) Pure PR	MC φ_0 - φ_0 (degrees) PR & Fit
5 GeV/c 1 track	34.6	14.9	39.7	10.0	0.74	0.25
5 GeV/c 6 track	26.8	18.1	24.9	12.0	0.69	0.30
5 GeV/c 10 track	27.9	20.2	25.2	12.2	0.65	0.31
10 GeV/c 1 track	32.3	29.5	36.1	20.2	0.67	0.26
10 GeV/c 6 track	41.2	31.2	36.3	21.4	0.62	0.26
10 GeV/c 10 track	39.8	33.5	34.1	21.3	0.63	0.28

Track $P_\perp$, P_Z and Φ_0 resolutions
Comparison pure Pattern Recognition & Pattern Recognition+fit with Helix

	(MC Pz -Pz)/ MC Pz (%)	(MC $P_\perp$ -$P_\perp$) / MC $P_\perp$ (%)	MC φ_0 - φ_0 (degrees)
0.3 / 1 track	NO	fit	fit
0.3 / 6 track	NO	fit	NO
0.3 / 10 track	NO	fit	NO
1 / 1 track	NO	fit	fit
1 / 6 track	NO	fit	fit
1 / 10 track	NO	fit	fit

	(MC Pz -Pz)/ MC Pz (%)	(MC $P_\perp$ -$P_\perp$) / MC $P_\perp$ (%)	MC φ_0 - φ_0 (degrees)
1.5 / 1 track	NO	fit	fit
1.5 / 6 track	NO	fit	fit
1.5 / 10 track	NO	fit	fit
2 / 1 track	fit	fit	fit
2 / 6 track	NO	fit	fit
2 / 10 track	NO	fit	fit

Track $P_{\perp}$, P_Z and Φ_0 resolutions
Comparison pure Pattern Recognition & Pattern Recognition+fit with Helix

	(MC Pz -Pz)/ MC Pz (%)	(MC $P_{\perp}$ -$P_{\perp}$) / MC $P_{\perp}$ (%)	MC φ_0 - φ_0 (degrees)
5 GeV/c 1 track	fit	fit	fit
5 GeV/c 6 track	fit	fit	fit
5 GeV/c 10 track	fit	fit	fit
10 GeV/c 1 track	fit	fit	fit
10 GeV/c 6 track	fit	fit	fit
10 GeV/c 10 track	fit	fit	fit

three remarks

1) All results are obtained with simulations assuming a constant B field of 2 Tesla. No magnetic maps. I don’t think this hinders since the STT are placed in the very central part of the solenoid.

2) The Pattern Recognition algorithm assumes tracks coming from the vertex at (0,0,0). The montecarlo events used for all results presented here have an intentional displacement of the vertex at (0.2 cm; 0.2 cm ; 0) as it may be in the experimental situation.

3) All results are obtained with simulations without the MVD detector in place (for historical reasons). To convince myself that results don’t change dramatically I simulated also event at the lowest momentum (0.3 GeV/c) with 1 track, 6 tracks, 10 tracks and compare these with the analogous results without the MVD.

a check
with also
the MVD

Hit X, Y, Z position resolutions, with and w/o MVD
Comparison pure Pattern Recognition & Pattern Recognition+fit with Helix

	δ X Paral. RMS (cm) Pure PR	δ X Paral. RMS (cm) PR & Fit	δ Y Paral. RMS (cm) Pure PR	δ Y Paral. RMS (cm) PR & Fit	δ Z Paral. RMS (cm) Pure PR	δ Z Paral. RMS (cm) PR & Fit	δ X Skew RMS (cm) Pure PR	δ X Skew RMS (cm) PR & Fit	δ Y Skew RMS (cm) Pure PR	δ Y Skew RMS (cm) PR & Fit	δ Z Skew RMS (cm) Pure PR	δ Z Skew RMS (cm) PR & Fit
0.3 / 1 trk	0.15	0.02	0.16	0.03	0.98	1.25	0.12	0.12	0.11	0.11	1.14	1.19
0.3 / 6 trk	0.16	0.04	0.16	0.04	0.99	1.36	0.12	0.13	0.11	0.12	1.16	1.30
0.3 / 10 trk	0.16	0.05	0.16	0.05	1.01	1.43	0.12	0.13	0.11	0.13	1.20	1.39
0.3 1 trk MVD	0.16	0.03	0.16	0.03	0.99	1.26	0.12	1.25	0.12	0.11	1.14	1.18
0.3 / 6 trk MVD	0.16	0.04	0.16	0.04	1.04	1.35	0.13	1.28	0.12	0.12	1.20	1.28
0.3 / 10 trk MVD	0.16	0.05	0.16	0.05	0.99	1.41	0.12	1.26	0.11	0.13	1.19	1.36

Track $P_\perp$, P_Z and Φ_0 resolutions, with and w/o MVD
Comparison pure Pattern Recognition & Pattern Recognition+fit with Helix

	(MC Pz -Pz)/ MC Pz (%) Pure PR	(MC Pz -Pz)/ MC Pz (%) PR & Fit	(MC $P_\perp$ -$P_\perp$) / MC $P_\perp$ (%) Pure PR	(MC $P_\perp$ -$P_\perp$) / MC $P_\perp$ (%) PR & Fit	MC φ_0 - φ_0 (degrees) Pure PR	MC φ_0 - φ_0 (degrees) PR & Fit
0.3 GeV/c 1 track	5.0	15.7	2.6	1.5	0.72	0.70
0.3 GeV/c 6 track	5.5	18.7	2.5	1.7	0.71	0.82
0.3 GeV/c 10 track	5.1	23.6	2.6	1.8	0.74	0.93
0.3 GeV/c 1 track MVD	5.9	15.3	2.7	1.8	0.92	1.02
0.3 GeV/c 6 track MVD	6.0	16.4	2.8	1.9	0.89	1.10
0.3 GeV/c 10 track MVD	5.8	26.8	2.8	2.0	0.89	1.16

Conclusions

The problem of the spurious hits for some topologies ov event is solved. The PR hit efficiency, track efficiency are satisfactory.

The track parameter determination error can most of the times be improved with the use of Lia's fit after the PR.

The next step for the PR is the integration with the MVD system : STT first, then MVD, then back to STT