Track resolution studies with the "LiC Detector Toy" MC Tool

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LiC is a simple but powerful and flexible software tool, written in MatLab, for detector design studies (geometries, material budgets). It is based on a helix track model including multiple scattering, and uses a Kalman filter for track fitting. We use this tool for comparing two variants of the LDC and one of the SiD layout, by studying track resolutions ($\Delta p_T/p_T$, $\Delta p_T/p_T^2$, transverse impact parameter) over a wide range of p_T in the barrel region. Investigation of the forward region so far for LDC only. **All results are still preliminary.**

Program features – a reminder

- The "LiC Detector Toy" is a simple but powerful program tool for detector design studies. It aims at investigating track resolutions for the purpose of optimizing the layout (geometries and material budgets).
- Detector model corresponds to a collider experiment with a solenoid magnet. Geometry is cylinder symmetric w.r.t. beam axis z, but not necessarily symmetric w.r.t. the $z = 0$ plane. Surfaces are either cylinders ("barrel") or planes ("forward/backward region"). The track model is a helix.
- The latest version supports tracking from the barrel into the forward/backward region, and vice versa (i.e. re-entry into the barrel). However, this feature is not yet fully tested.
- Simulation takes into account multiple scattering, detector inefficiencies and measurement errors, but no other degradation. Track reconstruction is performed by a Kalman filter, with the reference surface being the inside of the beam tube. Goodness-of-fit tests are standard.
- Supported detectors are Si pixels, Si strips (single- or double-sided with any stereo angle), and a TPC. Detector description defined by a simple "input sheet". An interactive GUI is available as well.
- The program is written in MatLab. A beta release is available on request. For more information, please, consult the User Guide at

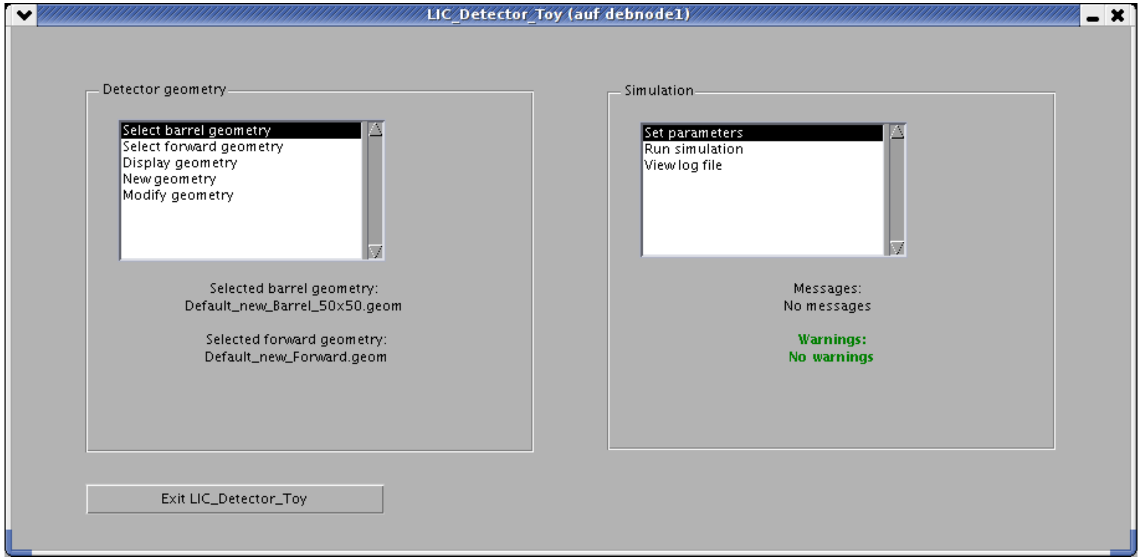
  `http://wwwhephy.oeaw.ac.at/p3w/ilc/reports/LiC_Det_Toy/UserGuide.pdf`

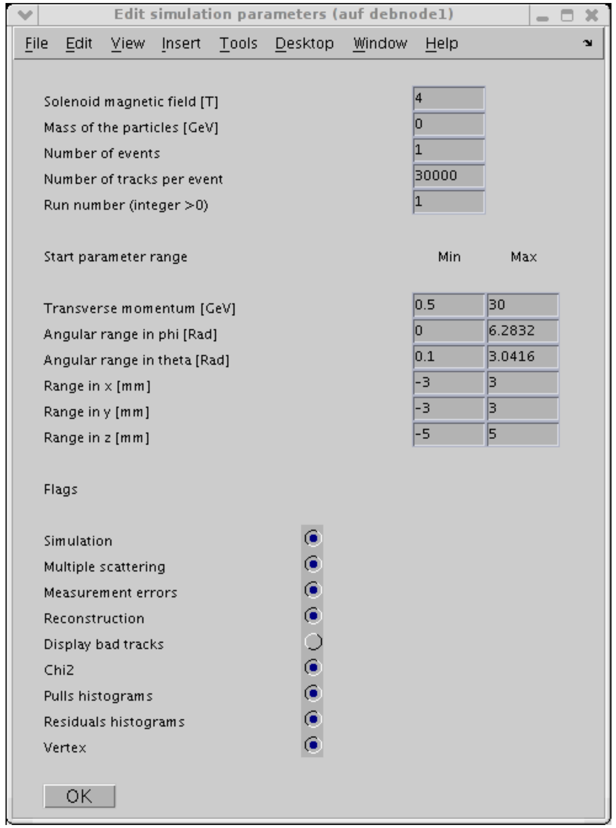
  and the ILC forum at

  `http://forum.linearcollider.org/` → Fast Simulations → LiC Detector Toy.

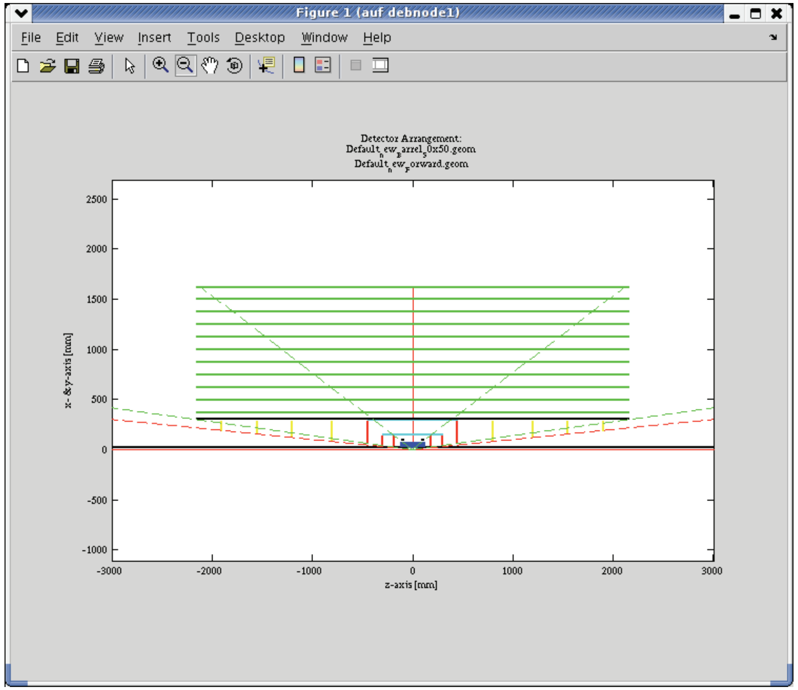
LiC Detector Toy: the GUI

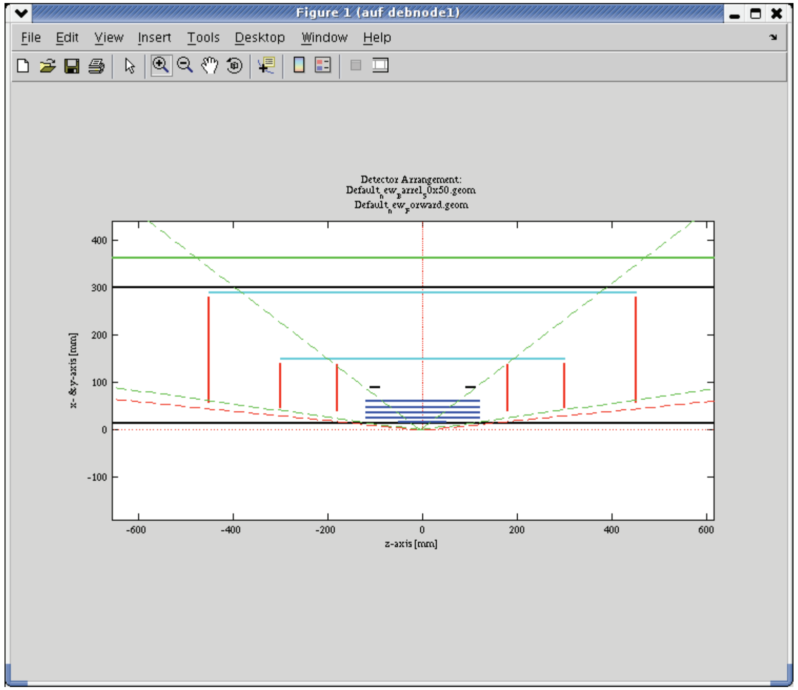
Snapshots





LDC detector layout (barrel & fwd.)





LDC detector description

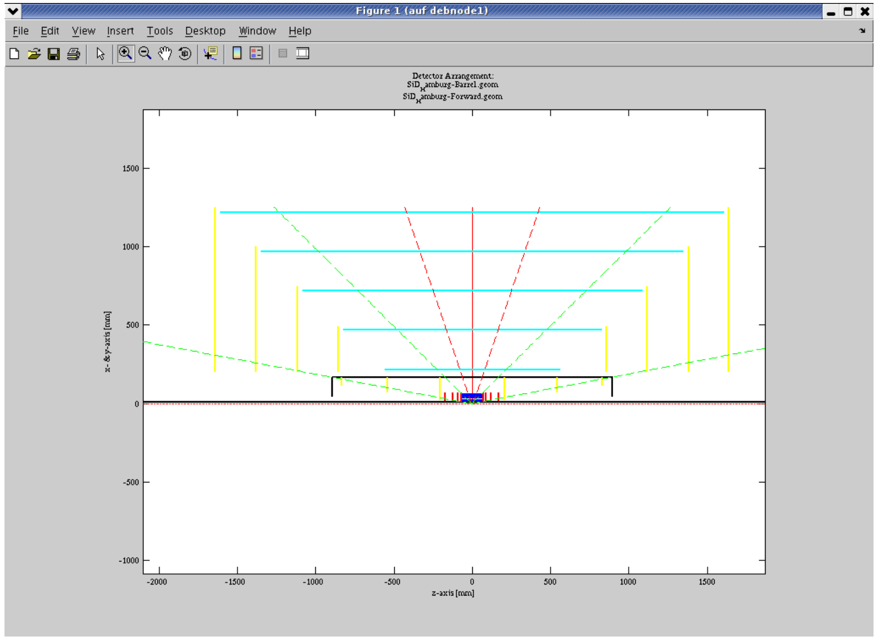
LDC Detector description

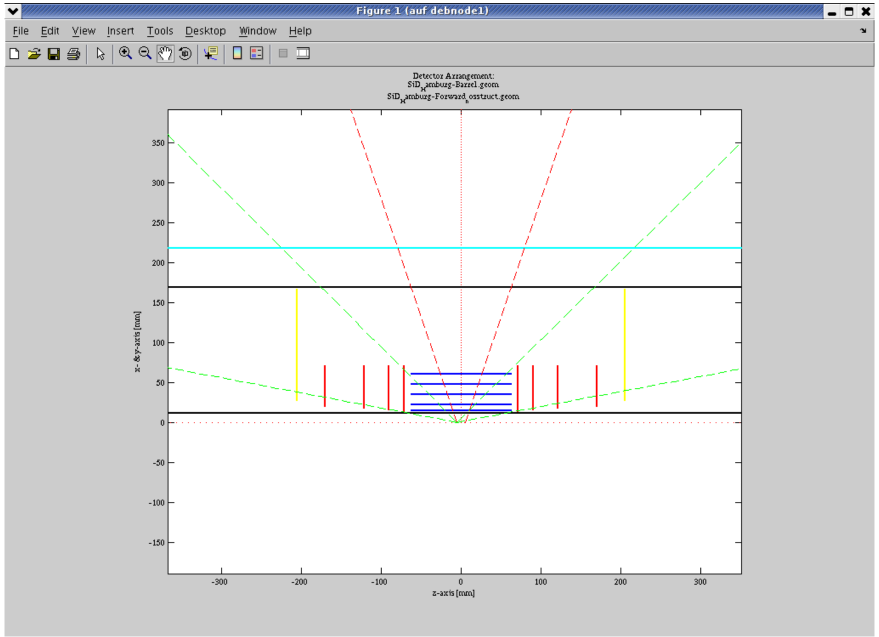
B_z = 4 Tesla; Si efficiency = 95%

BARREL	*R[mm]*	*Z_{min}[mm]*	*Z_{max}[mm]*	*Error distribution*	*d[X_o]*	*Remarks*
Beam pipe	15			passive	.00115	.4 mm Be
VTX 1	16	-50	50	pads 50*50 (25*25) equ. distrib.	.0020	wafer + ladder
VTX 2	26	-120	120	idem	idem	idem
VTX 3	37	idem	idem	idem	idem	idem
VTX 4	48	idem	idem	idem	idem	idem
VTX 5	60	idem	idem	idem	idem	idem
Support structures	90	-110	-90	passive	.0250	arbitrary
idem	idem	90	110	passive	idem	idem
SIT 1	150	-150	150	strips 2*50	.0175	0^o, 10^o
SIT 2	290	-360	360	idem	idem	idem
TPC inn. wall	300	-2160	2160	passive	.0150	
100 pad rings	<1580	idem	idem	$\sqrt{(\sigma_1^2 + \sigma_2^2 \Delta z)}$	$5*10^{-5}$	

FORWARD	*Z[mm]*	*R_{min}[mm]*	*R_{max}[mm]*	*Error distribution*	*d[X_o]*	*Remarks*
FTD 1	180	40	138	pads 50*300	.01	
FTD 2	300	48	140	idem	idem	
FTD 3	450	58	280	idem	idem	
FTD 4	800	88	idem	strips 2*90	idem	$\pm 6^o$
FTD 5	1200	123	idem	idem	idem	idem
FTD 6	1550	158	idem	idem	idem	idem
FTD 7	1900	188	idem	idem	idem	idem

SiD detector layout (barrel only)





SiD detector description

SiD Detector description

B_z = 5 Tesla; Si efficiency = 95%

BARREL	*R[mm]*	*Z_{min}[mm]*	*Z_{max}[mm]*	*Error distribution*	*d[X_o]*	*Remarks*
Beam pipe	12	-62.5 + conus	62.5 + conus	passive	.00253	.4 mm Be + Ti
VXD 1	14.6	-62.5	62.5	pads 20*20 equ. distrib.	.00202	wafer + ladder
VXD 2	22.6	idem	idem	idem	idem	idem
VXD 3	35.4	idem	idem	idem	idem	idem
VXD 4	48.0	idem	idem	idem	idem	idem
VXD 5	60.4	idem	idem	idem	idem	idem
Support cylinder	168.7	-868.8 -894.3	868.8 894.3	passive	.00304	dbl. wall C fibre
TRK 1	218.0	-558.0	558.0	strips 50	.00800	single
TRK 2	468.0	-825.0	825.0	idem	idem	idem
TRK 3	718.0	-1083.0	1083.0	idem	idem	idem
TRK 4	968.0	-1347.0	1347.0	idem	idem	idem
TRK 5	1218.0	-1606.0	1606.0	idem	idem	idem

FORWARD	*Z[mm]*	*R_{min}[mm]*	*R_{max}[mm]*	*Error distribution*	*d[X_o]*	*Remarks*
not implemented so far						

Barrel region defined by $|\lambda| < 20^o$, in order to avoid the "supporting membranes" of the VXD.

Parametrization of track resolution

- Relative error of transverse momentum caused by the magnet spectrometer (cf. Gluckstern):
  $\sigma(p_T)/p_T = A \cdot p_T$

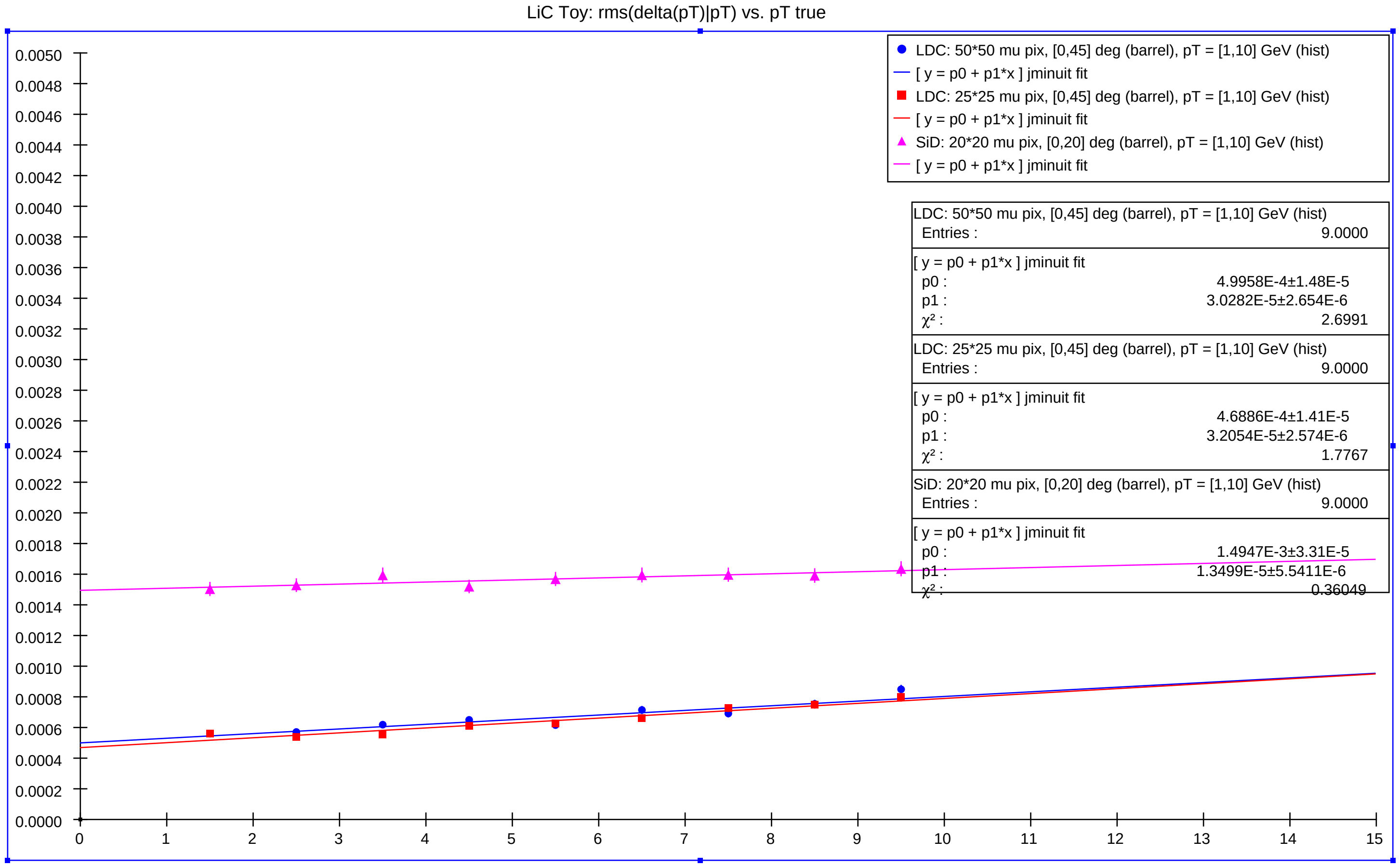
- Relative error of transverse momentum caused by multiple scattering (cf. Rossi-Greisen):
  $\sigma(p_T)/p_T = B \cdot \sqrt{1 + (m/P)^2} \approx B$
  (approximation is good, except for slow protons)

- Above terms are expected to add quadratically. However, a simple parametrizatrion fits the data:
  $\sigma(p_T)/p_T = A \cdot p_T + B$
  $\sigma(p_T)/p_T^2 = A + B/p_T$

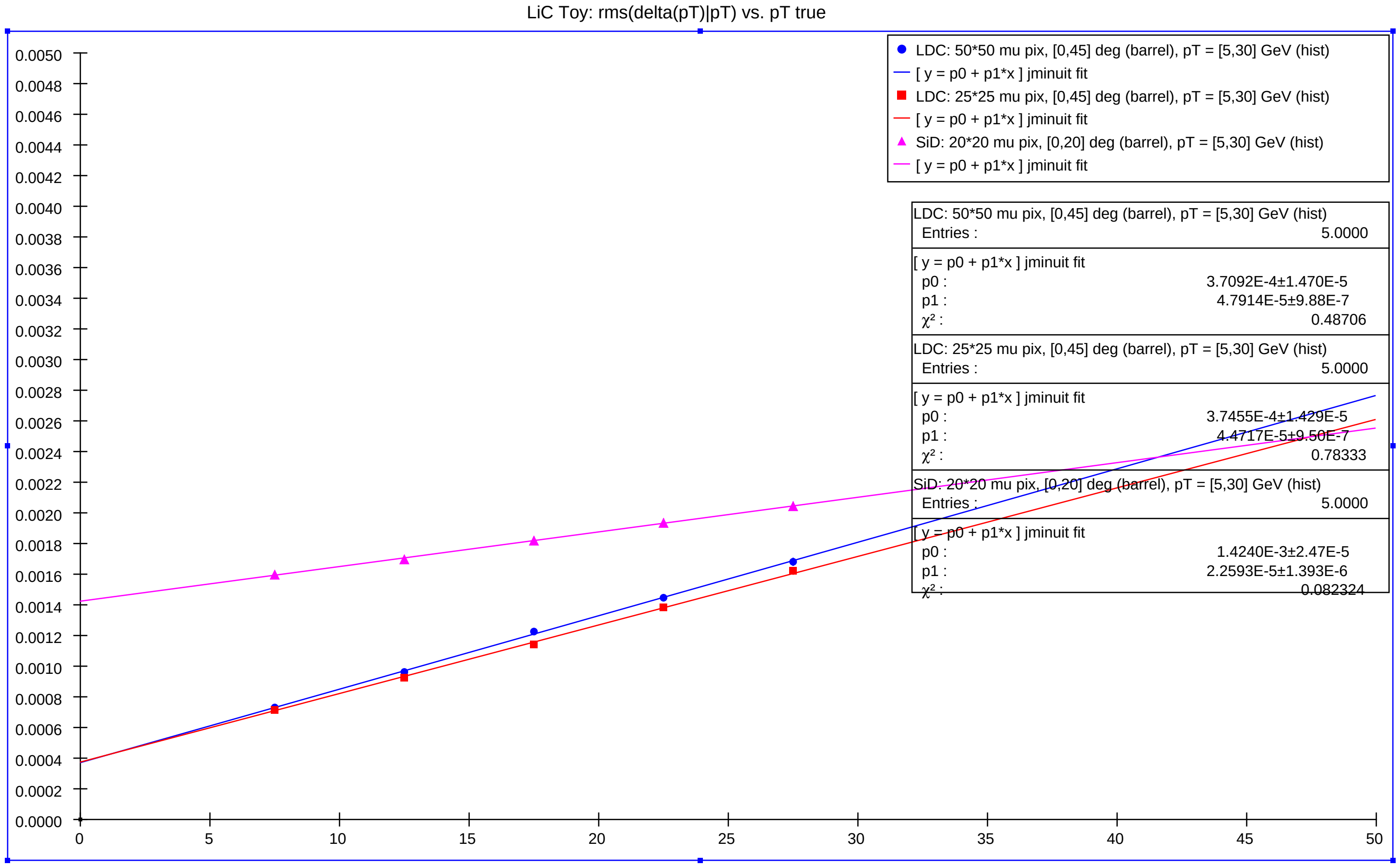
- The transverse impact parameter w.r.t. the true vertex was heuristically parametrized as:
  $\delta_o = a + b \cdot e^{-p_T/c}$

- Just for completeness: the relative error of the absolute momentum is given by
  $\sigma(P)/P = \sqrt{[\sigma(p_T)/p_T]^2 + [\sigma(\vartheta) \cdot \cot\vartheta]^2}$
  with $p_T = P \cdot \sin\vartheta$

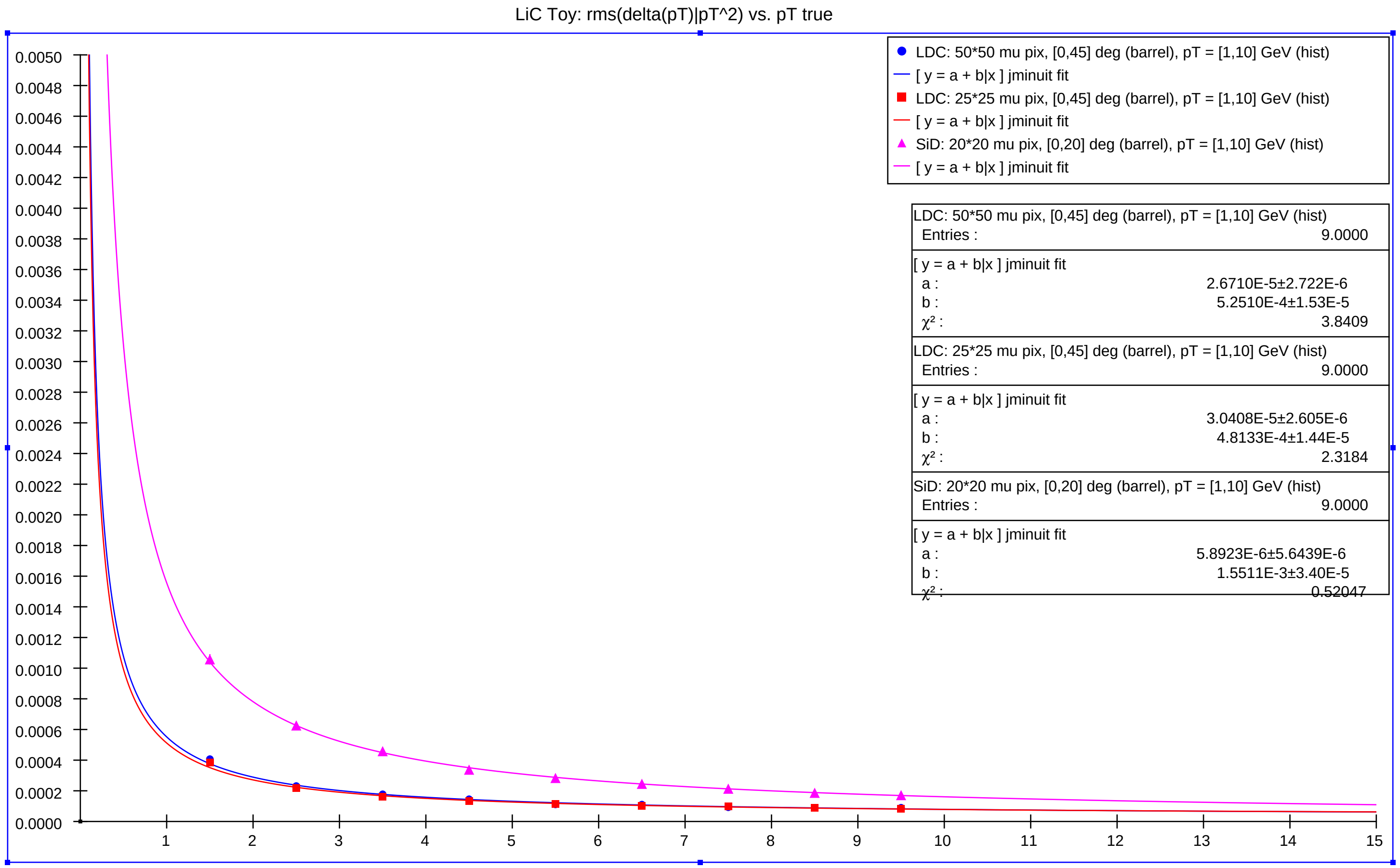
LDC and SiD track resolutions: $\Delta p_T / p_T$



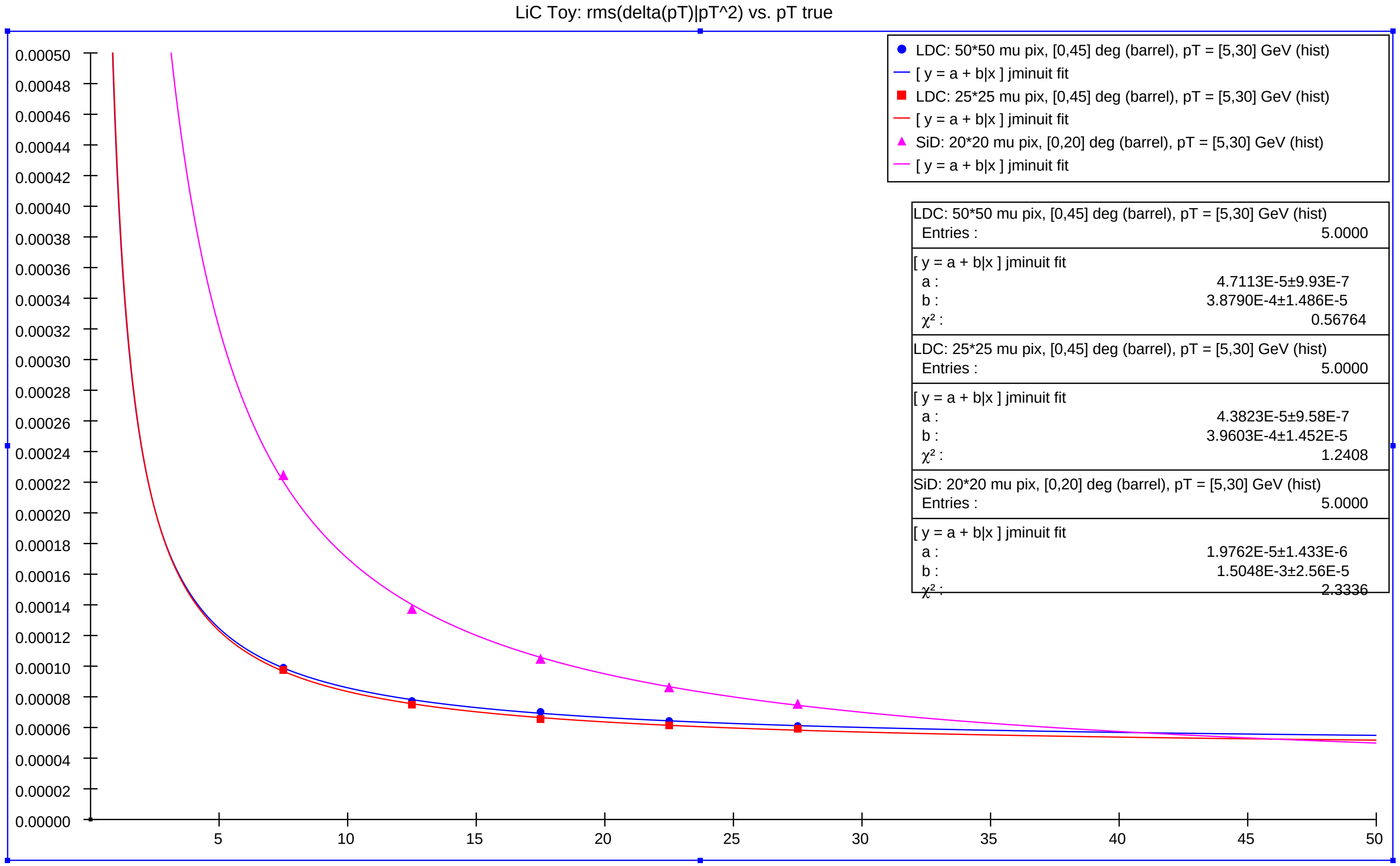
LDC and SiD track resolutions: $\Delta p_T / p_T$



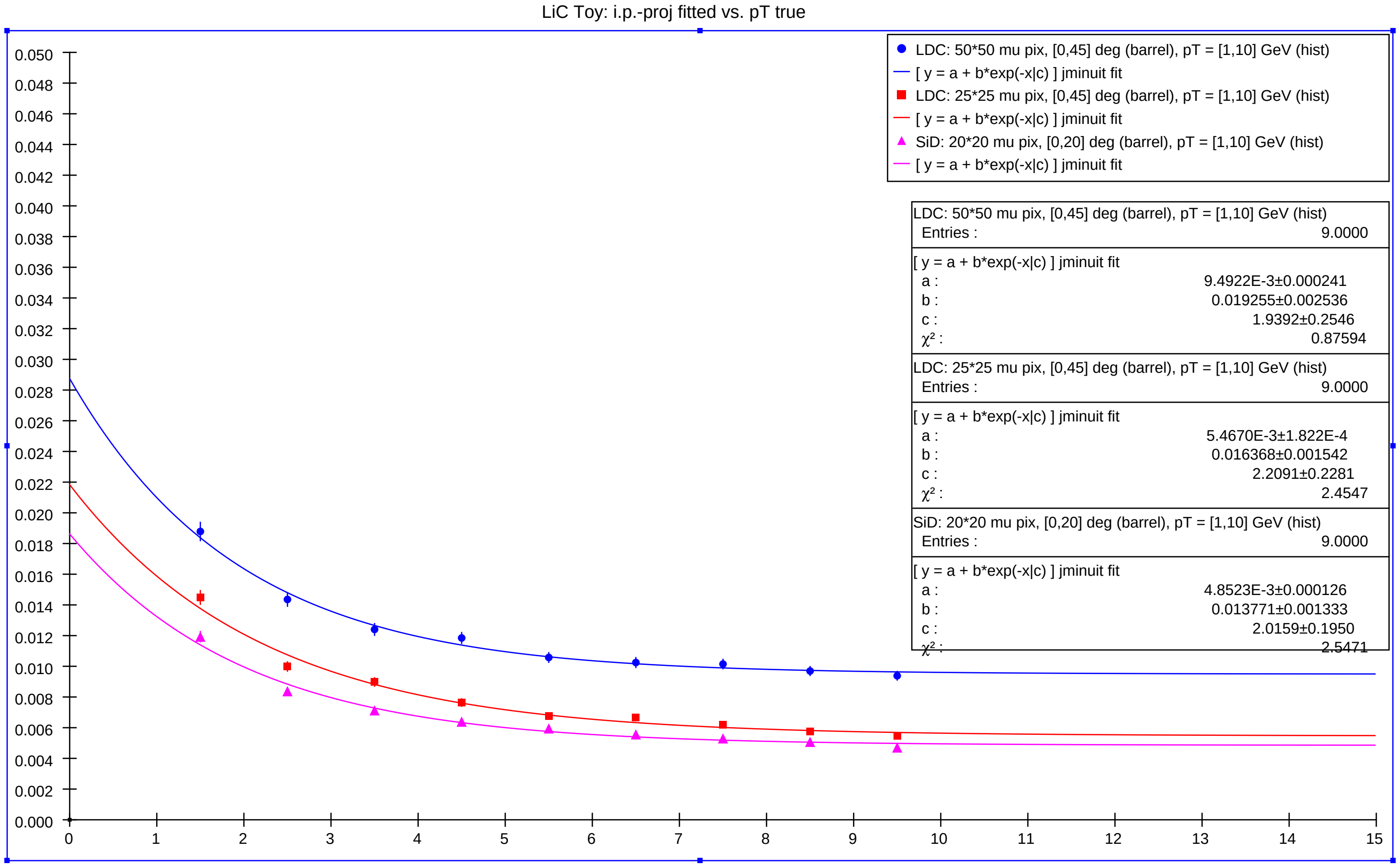
LDC and SiD track resolutions: $\Delta p_T/p_T^2$



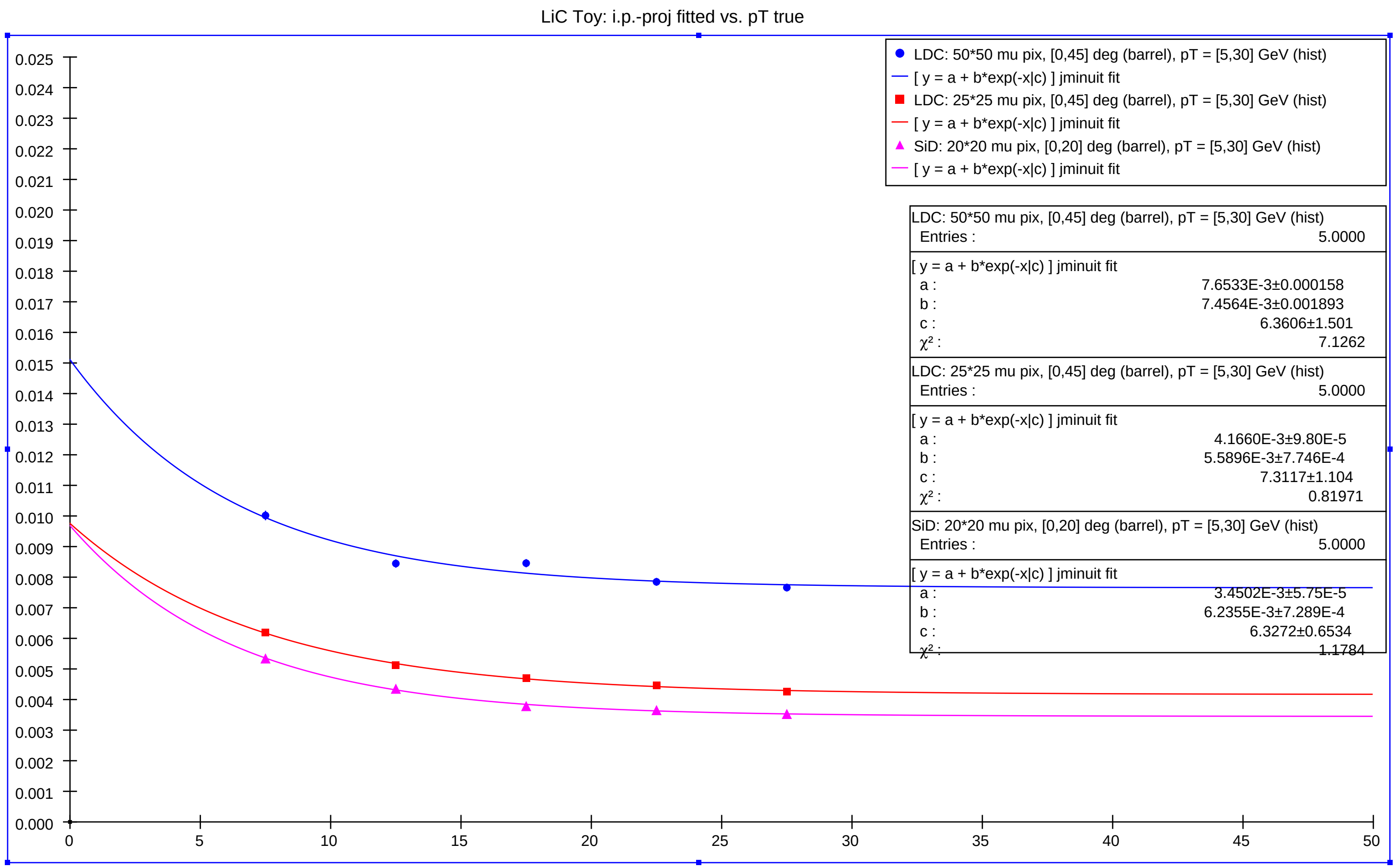
LDC and SiD track resolutions: $\Delta p_T/p_T^2$



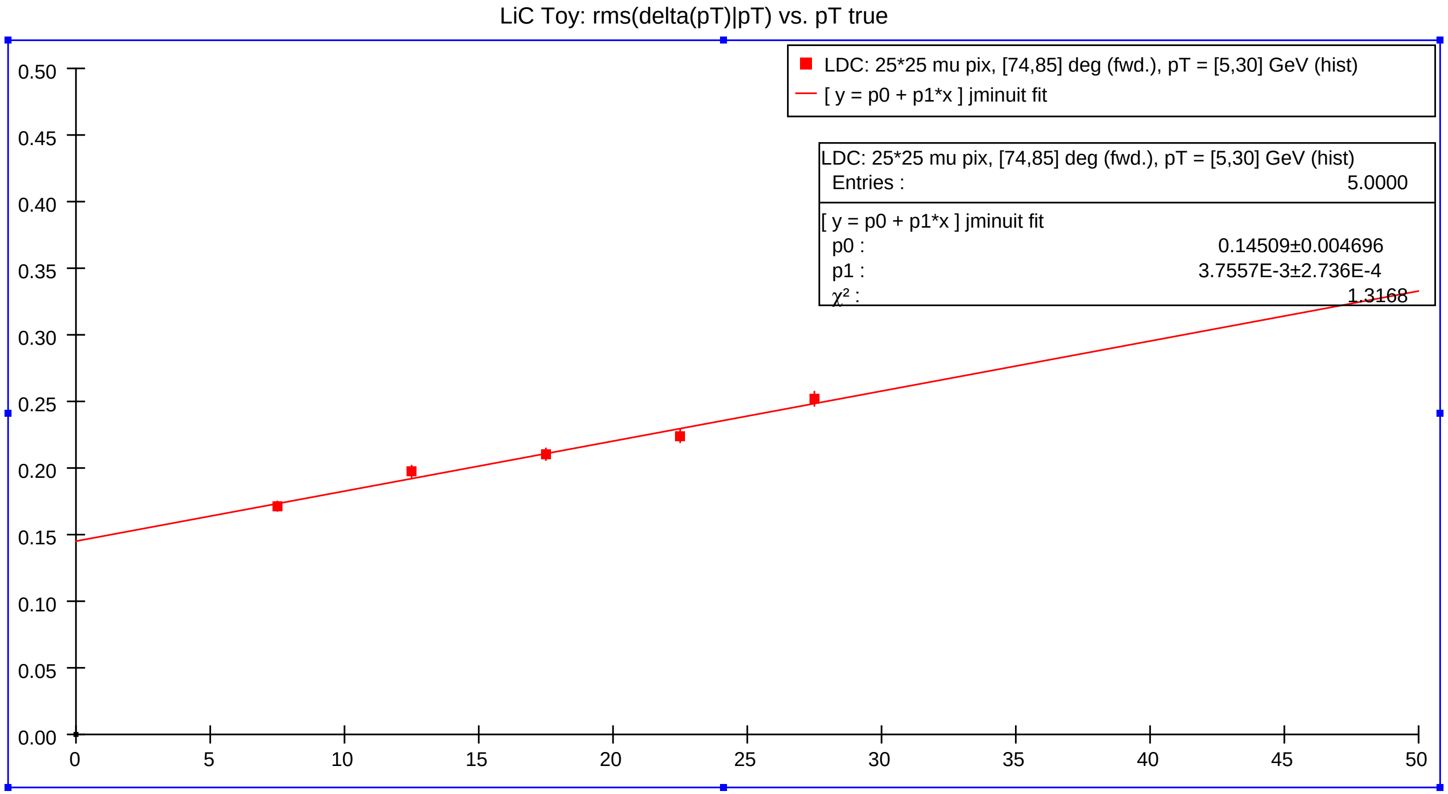
LDC and SiD track resolutions: transverse i.p.



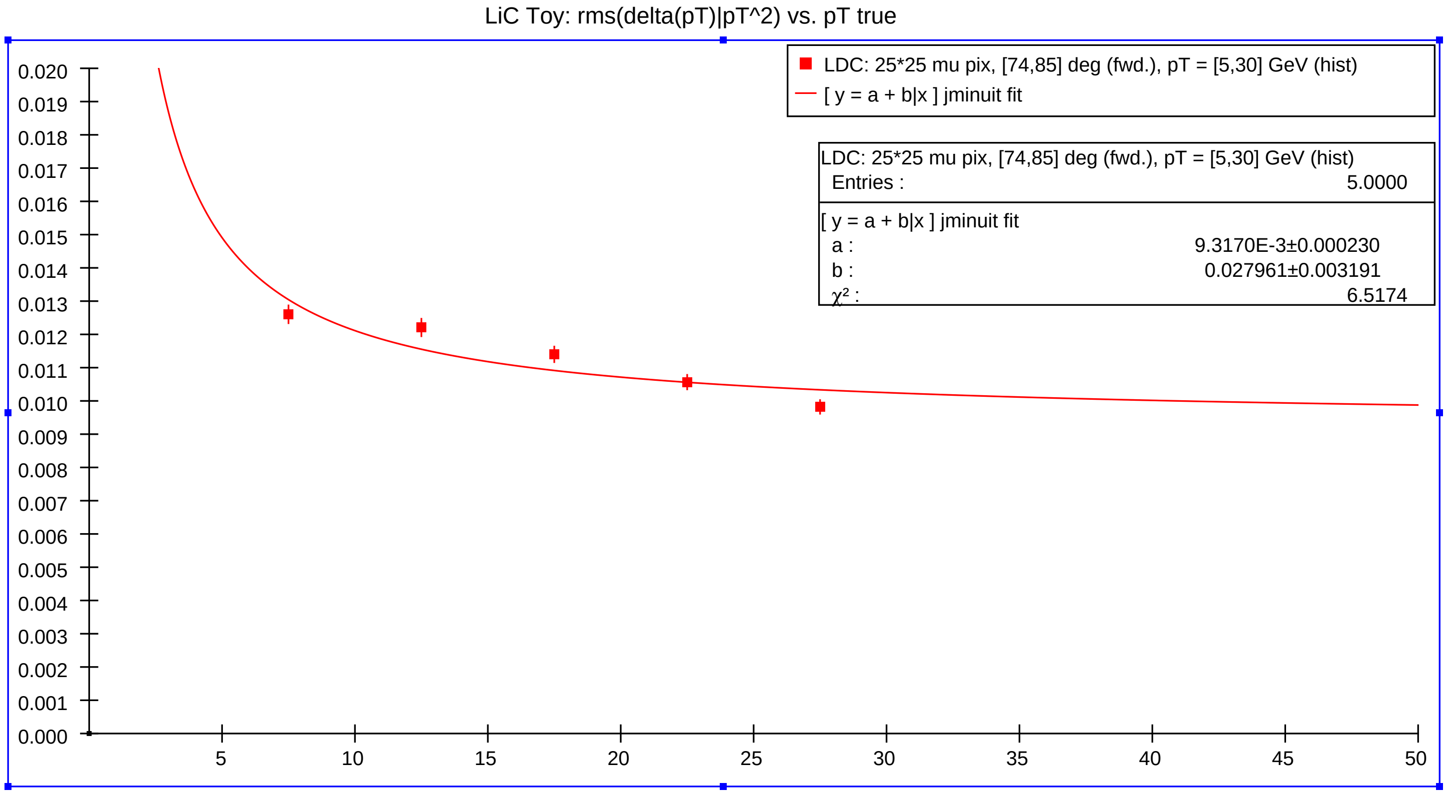
LDC and SiD track resolutions: transverse i.p.



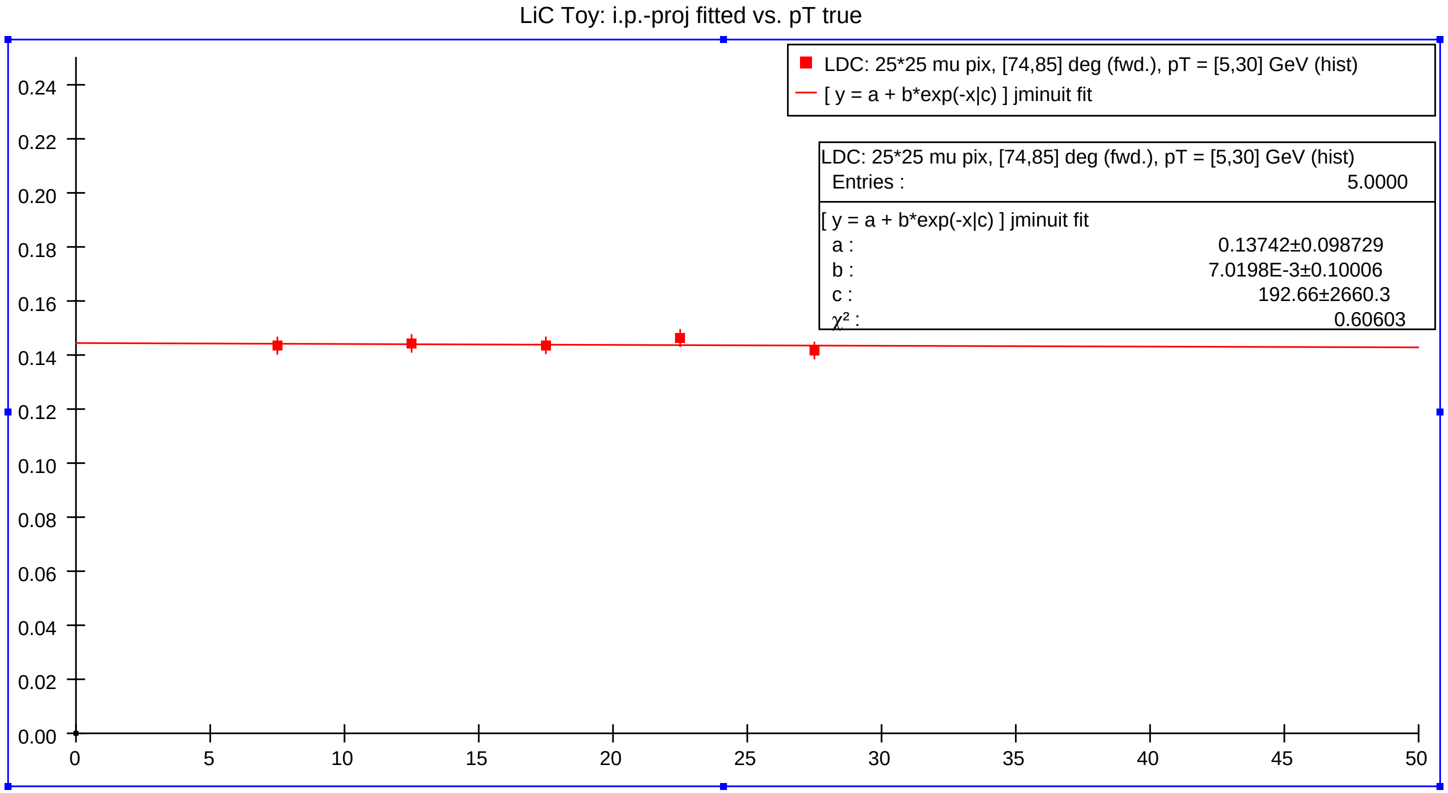
LDC forward track resolutions: $\Delta p_T / p_T$



LDC forward track resolutions: $\Delta p_T/p_T^2$



LDC forward track resolutions: transverse i.p.



Summary of results (very preliminary)

Barrel region (LDC: $|\lambda| < 45^o$, SiD: $|\lambda| < 20^o$), $\mathbf{p_T = 1 \ldots 10}$ **GeV:**

Detector	$\Delta p_T/p_T$	$\Delta p_T/p_T^2$	transv. i.p. (asympt.)
LDC $50 * 50\mu$m	$(3.0 \cdot p_T + 50.0) \cdot 10^{-5}$	$(2.7 + 52.5/p_T) \cdot 10^{-5}$ GeV^{-1}	9.49μm
LDC $25 * 25\mu$m	$(3.2 \cdot p_T + 46.9) \cdot 10^{-5}$	$(3.0 + 48.1/p_T) \cdot 10^{-5}$ GeV^{-1}	5.47μm
SiD $20 * 20\mu$m	$(1.3 \cdot p_T + 149) \cdot 10^{-5}$	$(0.6 + 155/p_T) \cdot 10^{-5}$ GeV^{-1}	4.85μm

Barrel region (LDC: $|\lambda| < 45^o$, SiD: $|\lambda| < 20^o$), $\mathbf{p_T = 5 \ldots 50}$ **GeV:**

Detector	$\Delta p_T/p_T$	$\Delta p_T/p_T^2$	transv. i.p. (asympt.)
LDC $50 * 50\mu$m	$(4.8 \cdot p_T + 37.1) \cdot 10^{-5}$	$(4.7 + 38.8/p_T) \cdot 10^{-5}$ GeV^{-1}	7.65μm
LDC $25 * 25\mu$m	$(4.5 \cdot p_T + 37.5) \cdot 10^{-5}$	$(4.4 + 39.6/p_T) \cdot 10^{-5}$ GeV^{-1}	4.17μm
SiD $20 * 20\mu$m	$(2.3 \cdot p_T + 142) \cdot 10^{-5}$	$(2.0 + 150/p_T) \cdot 10^{-5}$ GeV^{-1}	3.45μm

Forward region (LDC: $74^o < |\lambda| < 85^o$), $\mathbf{p_T = 5 \ldots 50}$ **GeV:**

Detector	$\Delta p_T/p_T$	$\Delta p_T/p_T^2$	transv. i.p. (asympt.)
LDC $25 * 25\mu$m	$(3.8 \cdot p_T + 145) \cdot 10^{-3}$	$(9.3 + 28.0/p_T) \cdot 10^{-3}$ GeV^{-1}	137.4μm
		bad fit	