Transport Simulation and Event Reconstruction at the LHC for High β^* Optics

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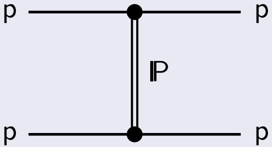
Outline

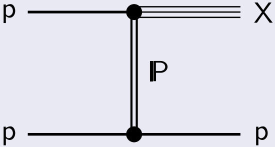
Outline

Physics

Elastic scattering

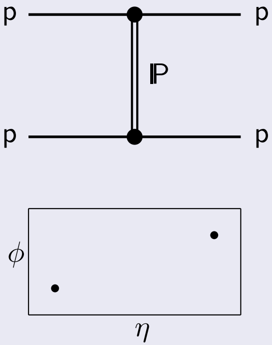


Single diffraction

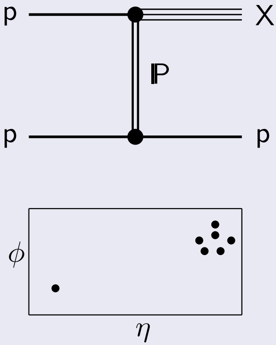


Physics

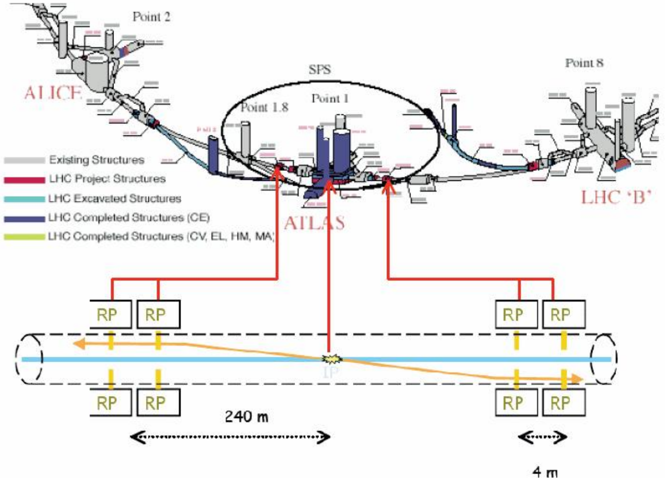
Elastic scattering



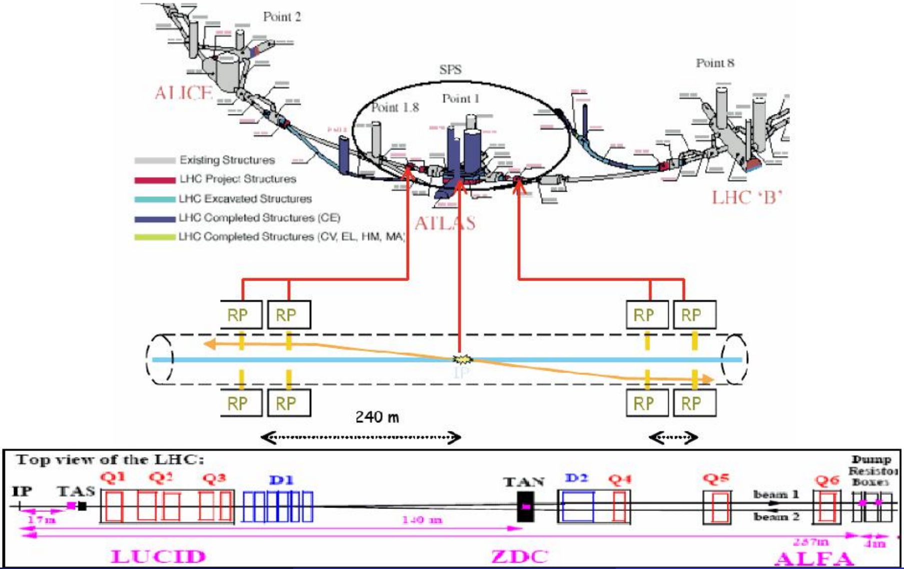
Single diffraction



Particle transport



Particle transport



Measurement tools – standard approach

Use transport programs: MAD-X, FPTrack.

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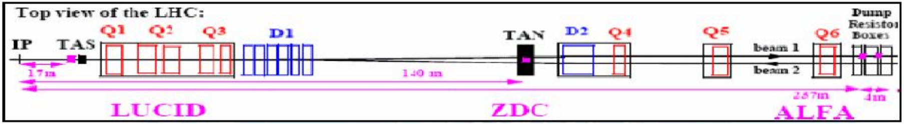

Measurement tools – proposed approach

$$\mathcal{N} = A_{\mathcal{N}}(E) + B_{\mathcal{N}}(E)\cdot x_{\mathrm{IP}} + C_{\mathcal{N}}(E)\cdot y_{\mathrm{IP}} + D_{\mathcal{N}}(E)\cdot z_{\mathrm{IP}} + E_{\mathcal{N}}(E)\cdot x'_{\mathrm{IP}} + \\ + F_{\mathcal{N}}(E)\cdot y'_{\mathrm{IP}} + G_{\mathcal{N}}(E)\cdot z_{\mathrm{IP}}\cdot x'_{\mathrm{IP}} + H_{\mathcal{N}}(E)\cdot z_{\mathrm{IP}}\cdot y'_{\mathrm{IP}},$$

where:

$$A_{\mathcal{N}} = \sum_{i=0}^{k_{A_{\mathcal{N}}}} a_{\mathcal{N},i}\cdot E^i,$$

$$\vdots$$

$$H_{\mathcal{N}} = \sum_{i=0}^{k_{H_{\mathcal{N}}}} h_{\mathcal{N},i}\cdot E^i,$$

where $A_{\mathcal{N}},\ldots,H_{\mathcal{N}}$ are the polynomials of degree $k_{A_{\mathcal{N}}}$, ..., $k_{H_{\mathcal{N}}}$ dependent of the beam energy. The $\mathcal{N}$ coefficient means one of the x, y, x' $(=\frac{p_x}{p_z}), y'$ $(=\frac{p_y}{p_z})$ parameters.

Measurement tools – proposed approach

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where:

$$A_{\mathcal{N}} = \sum_{i=0}^{k_{A_{\mathcal{N}}}} a_{\mathcal{N},i} \cdot E^{i},$$

$$\vdots$$

$$H_{\mathcal{N}} = \sum_{i=0}^{k_{H_{\mathcal{N}}}} h_{\mathcal{N},i} \cdot E^{i},$$

where $A_{\mathcal{N}}, \ldots, H_{\mathcal{N}}$ are the polynomials of degree $k_{A_{\mathcal{N}}}, \ \ldots, \ k_{H_{\mathcal{N}}}$ dependent of the beam energy. The $\mathcal{N}$ coefficient means one of the $x, y, x' \ (= \frac{p_x}{p_z}), y' \ (= \frac{p_y}{p_z})$ parameters.

How to find $k_{A_{\mathcal{N}}}, \ \ldots, \ k_{H_{\mathcal{N}}}$ coefficients?

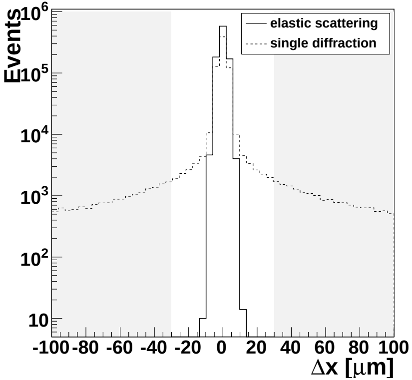
Use ParFind tool.

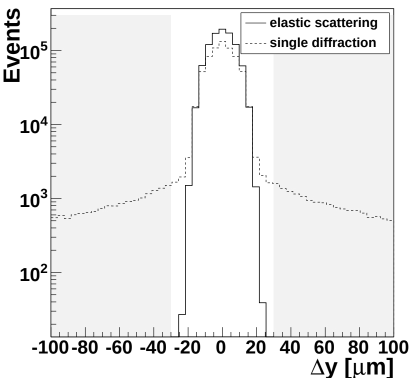
Outline

The transport equations in case of the ALFA detector

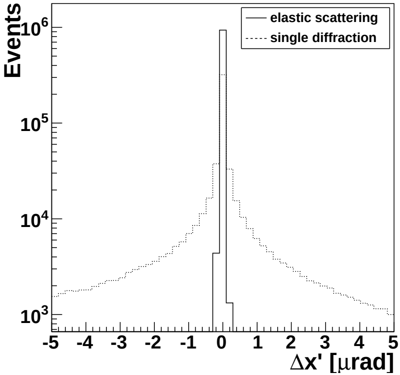
$$
\begin{aligned}
x_1 &= \sum_{i=0}^{8} a_{x_1,i} \cdot \xi^i + \sum_{i=0}^{4} b_{x_1,i} \cdot \xi^i \cdot x_{\mathrm{IP}} + \sum_{i=0}^{4} e_{x_1,i} \cdot \xi^i \cdot x'_{\mathrm{IP}}, \\
y_1 &= \sum_{i=0}^{6} c_{y_1,i} \cdot \xi^i \cdot y_{\mathrm{IP}} + \sum_{i=0}^{4} f_{y_1,i} \cdot \xi^i \cdot y'_{\mathrm{IP}}, \\
x'_1 &= \sum_{i=0}^{8} a_{x'_1,i} \cdot \xi^i + \sum_{i=0}^{4} b_{x'_1,i} \cdot \xi^i \cdot x_{\mathrm{IP}} + \sum_{i=0}^{4} e_{x'_1,i} \cdot \xi^i \cdot x'_{\mathrm{IP}}, \\
y'_1 &= \sum_{i=0}^{6} c_{y'_1,i} \cdot \xi^i \cdot y_{\mathrm{IP}} + \sum_{i=0}^{4} f_{y'_1,i} \cdot \xi^i \cdot y'_{\mathrm{IP}},
\end{aligned}
$$

$$\Delta x = x_{\mathrm{MAD-X}} - x_{\mathrm{parameterization}}$$
$$\Delta y = y_{\mathrm{MAD-X}} - y_{\mathrm{parameterization}}$$





$$\Delta x' = x'_{\mathrm{MAD-X}} - x'_{\mathrm{parameterization}}$$
$$\Delta y' = y'_{\mathrm{MAD-X}} - y'_{\mathrm{parameterization}}$$



Outline

1. Problem identification
2. Transport simulation
3. Event reconstruction

Parameterization

$$(x_{\mathrm{IP}}, y_{\mathrm{IP}}, z_{\mathrm{IP}}, x'_{\mathrm{IP}}, y'_{\mathrm{IP}}, E) \rightarrow (x_1, y_1, x'_1, y'_1)$$

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$$(x_{\rm IP}, y_{\rm IP}, z_{\rm IP}, x'_{\rm IP}, y'_{\rm IP}, E) \rightarrow (x_1, y_1, x'_1, y'_1)$$

Unfolding

$$(x_1, y_1, x'_1, y'_1) \rightarrow (x_{\rm IP}, y_{\rm IP}, z_{\rm IP}, x'_{\rm IP}, y'_{\rm IP}, E)$$

Parameterization

$$(x_{\mathrm{IP}}, y_{\mathrm{IP}}, z_{\mathrm{IP}}, x'_{\mathrm{IP}}, y'_{\mathrm{IP}}, E) \rightarrow (x_1, y_1, x'_1, y'_1)$$

Unfolding

$$(x_1, y_1, x'_1, y'_1) \rightarrow (x_{\mathrm{IP}}, y_{\mathrm{IP}}, z_{\mathrm{IP}}, x'_{\mathrm{IP}}, y'_{\mathrm{IP}}, E)$$

Simplification

$$(x_1, x'_1) \rightarrow (x_{\mathrm{IP}}, x'_{\mathrm{IP}}, E)$$
$$(y_1, y'_1) \rightarrow (y_{\mathrm{IP}}, y'_{\mathrm{IP}}, E)$$

Parameterization

$$(x_{\text{IP}}, y_{\text{IP}}, z_{\text{IP}}, x'_{\text{IP}}, y'_{\text{IP}}, E) \to (x_1, y_1, x'_1, y'_1)$$

Unfolding

$$(x_1, y_1, x'_1, y'_1) \to (x_{\text{IP}}, y_{\text{IP}}, z_{\text{IP}}, x'_{\text{IP}}, y'_{\text{IP}}, E)$$

Simplification

$$(x_1, x'_1) \to (\quad x'_{\text{IP}}, E)$$
$$(y_1, y'_1) \to (\quad y'_{\text{IP}}, E)$$

Parameterization

$$(x_{\mathrm{IP}}, y_{\mathrm{IP}}, z_{\mathrm{IP}}, x'_{\mathrm{IP}}, y'_{\mathrm{IP}}, E) \to (x_1, y_1, x'_1, y'_1)$$

Unfolding

$$(x_1, y_1, x'_1, y'_1) \to (x_{\mathrm{IP}}, y_{\mathrm{IP}}, z_{\mathrm{IP}}, x'_{\mathrm{IP}}, y'_{\mathrm{IP}}, E)$$

Simplification

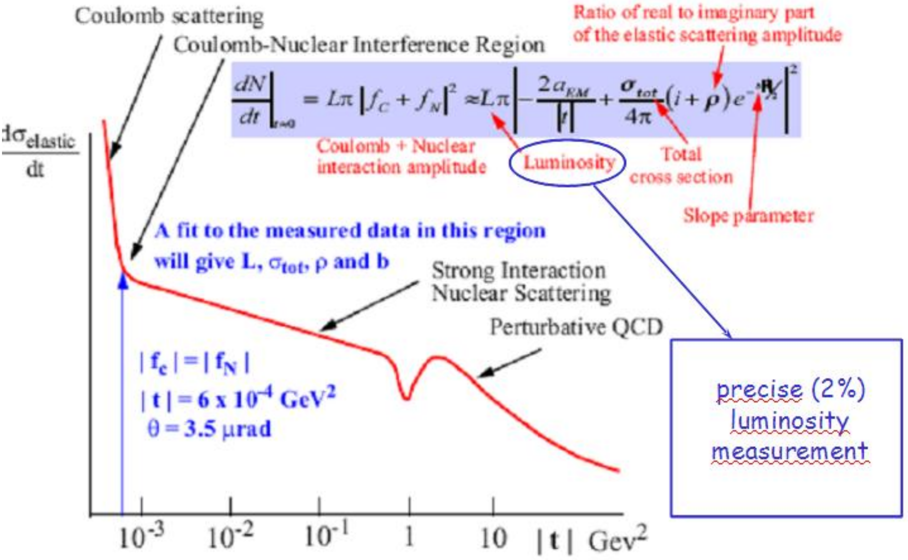
$$(x_1, x'_1) \to (\quad x'_{\mathrm{IP}}, E)$$
$$(y_1, y'_1) \to (\quad y'_{\mathrm{IP}}, E)$$

Systematics

- detector resolution,
- unknown vertex,
- multiple scattering,
- B field variation.

Backup

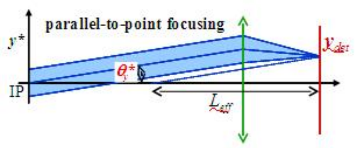
ALFA – Absolute Luminosity For ATLAS



High β^* optics

parameter	optics	
	normal	high β^*
β^*	0.5 m	2625.0 m
σ^*	16.6 μm	0.61 mm
σ'^*	30.2 μrad	0.23 μrad

Parallel-to-point focusing



„Roman pots" technology