Backgrounds at FP420

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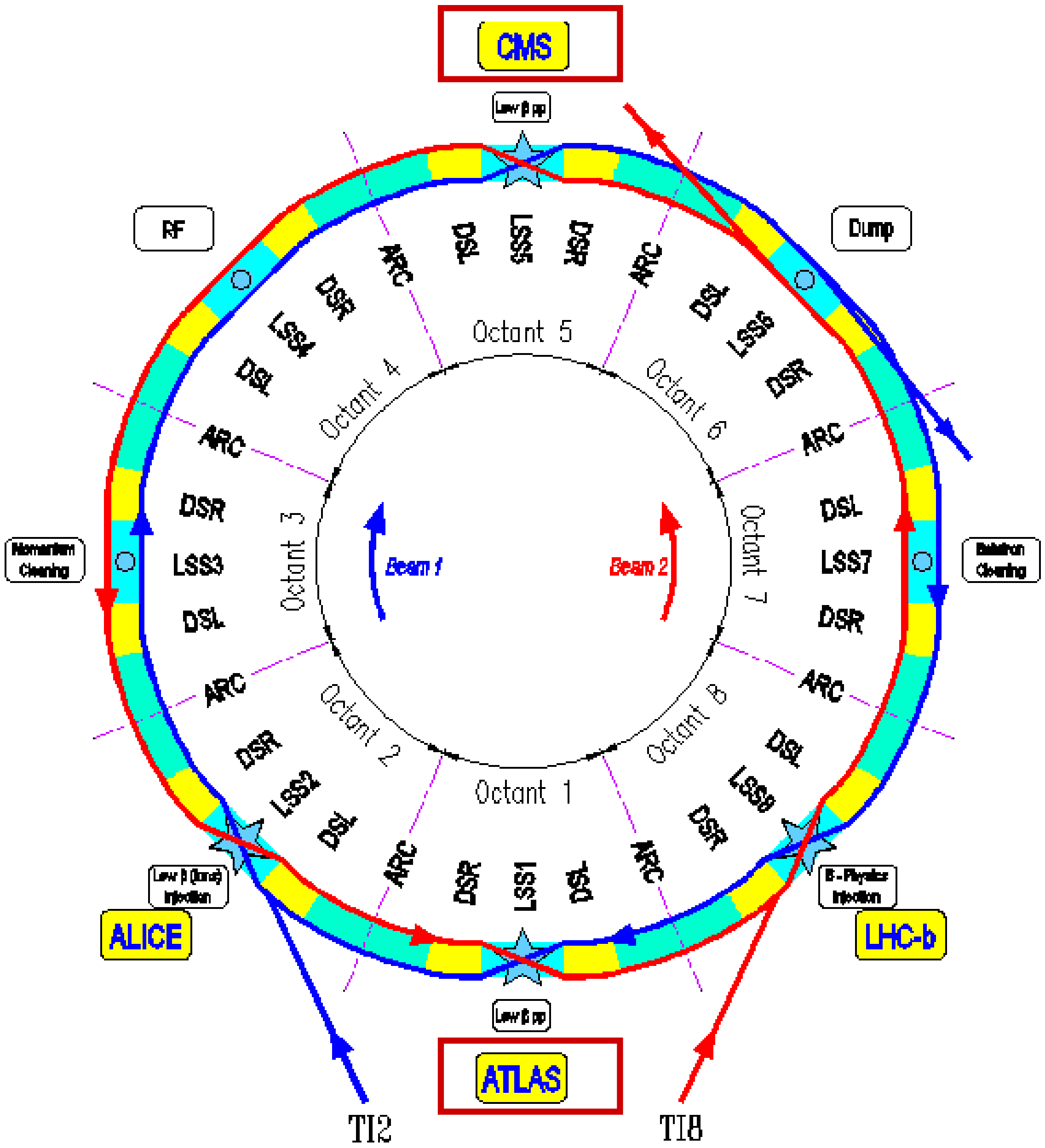
DESY

18th of May 2006



LHC parameters

Length	26.6 km
Nr. of bunches	2808
Nr. of particle/bunch	$1.15\ 10^{11}$
Frequency	40 MHz
Inter-bunch distance	25 nsec

Maximal Luminosity - 10^{34} cm^{-2} s^{-1}

Coasted Beam Optics

x - transverse deviation from the beam position

x' - transverse angular deviation

Transport Matrix

(from text books)

$$\begin{pmatrix} x \\ x' \\ \xi \end{pmatrix} = \begin{pmatrix} \sqrt{\frac{\beta}{\beta_0}}(\cos\Psi + \alpha_0 \sin\Psi) & \sqrt{\beta\beta_0}\sin\Psi & \mathrm{D} \\ \frac{(\alpha_0 - \alpha)\cos\Psi - (1+\alpha_0\alpha)\sin\Psi}{\sqrt{\beta\beta_0}} & \sqrt{\frac{\beta_0}{\beta}}(\cos\Psi - \sin\Psi) & \mathrm{D}' \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} x_0 + 0 \\ x_0' + \theta \\ \xi_0 - x_{IP} \end{pmatrix}$$

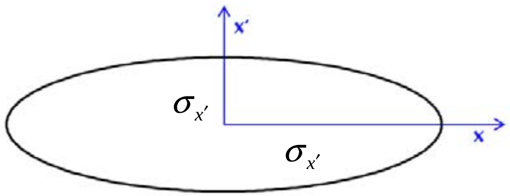
observation point | interaction point

e.g. P.Schmueser in CERN 94-01

β-amplitude function, Ψ-phases, D-dispersion can be obtained from the LHC Optic Webpage

Coasted beam optics is considerably easier to handle than ray tracking in MAD

x, x' are moving on **Phase Ellipse**



$\alpha \neq 0$

$$\sigma_x = \sqrt{\varepsilon\beta_x} \qquad \sigma_{x'} = \sqrt{\frac{\varepsilon(1+\alpha_x^2)}{\beta_x}}$$

LHC High Luminosity Optics

Interaction point

$\beta_x = \beta_y = 0.55\,\mathrm{m}$ $\qquad \varepsilon_N = 3.75\,\mu\mathrm{rad}\cdot\mathrm{m}$

$\sigma_x = \sigma_y = \sqrt{\varepsilon\beta} = 16.6\,\mu\mathrm{m}$ $\qquad \varepsilon = \varepsilon_N / \gamma$

$\sigma_{x'} = \sigma_{y'} = \sqrt{\dfrac{\varepsilon(1+\alpha^2)}{\beta}} = 30.2\,\mu\mathrm{rad}$ $\qquad$ => $p_T \sim 200$ MeV

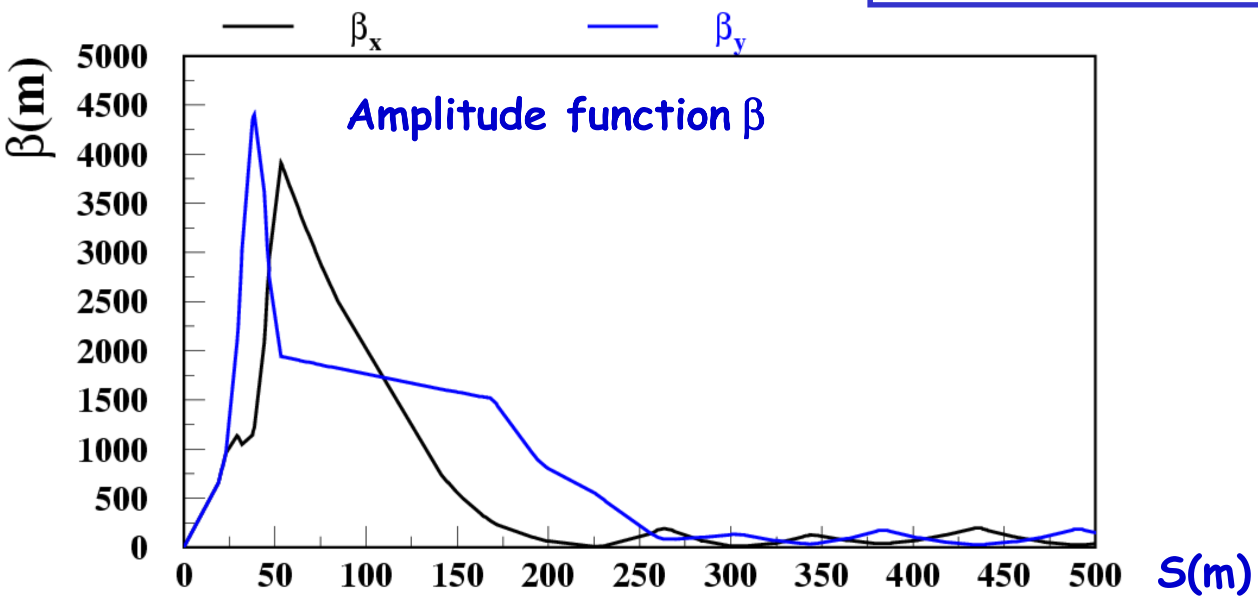
420 m point

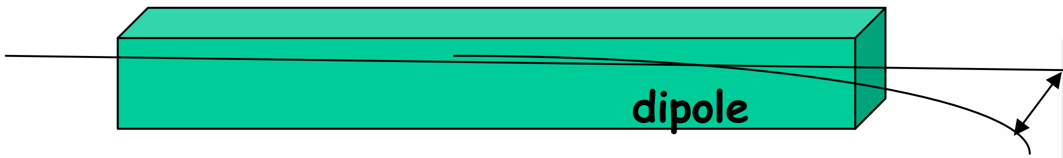
$\beta_x = 130\,\mathrm{m}$ $\qquad \beta_y = 50\,\mathrm{m}$

$\sigma_x = 250\,\mu\mathrm{m}$ $\qquad \sigma_y = 160\,\mu\mathrm{m}$

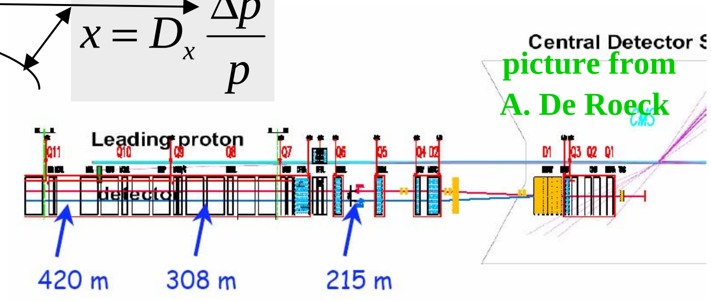
$\sigma_{x'} = 4.5\,\mu\mathrm{rad}$ $\qquad \sigma_{y'} = 4.5\,\mu\mathrm{rad}$

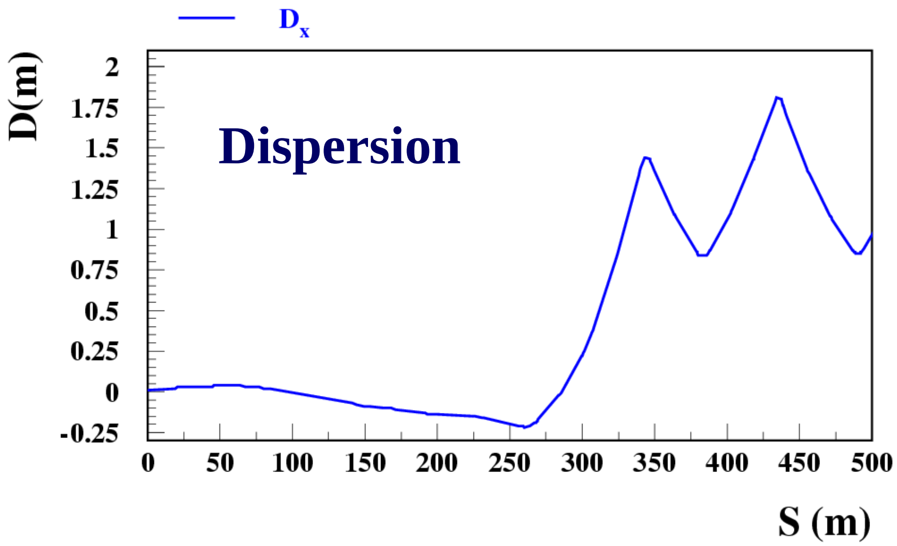
LHC HL Optics: transverse deviations are magnified, angular deviations are diminished





$$x = D_x \frac{\Delta p}{p}$$

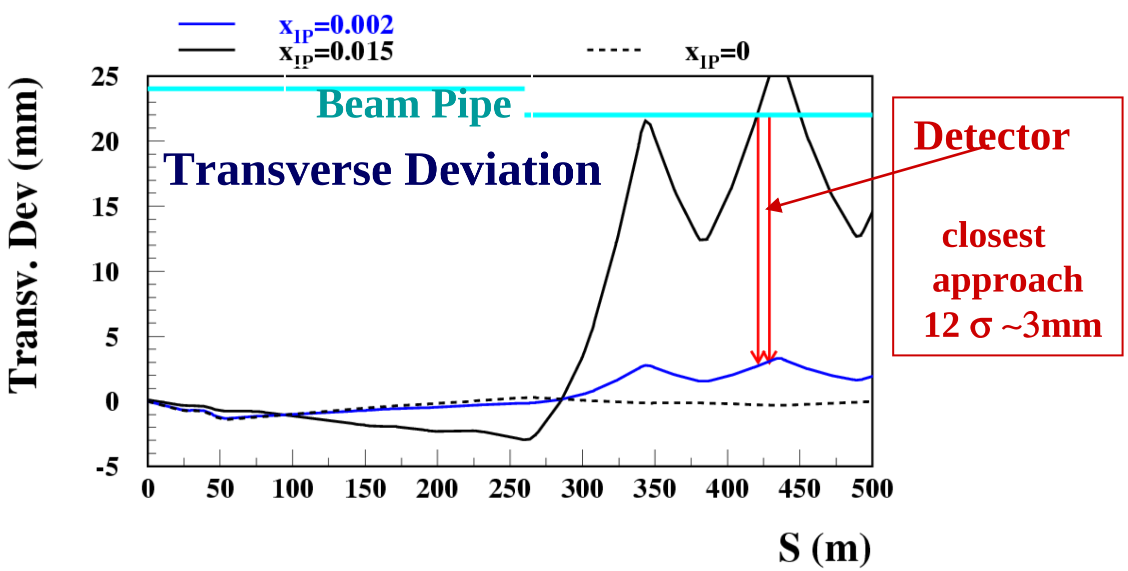




At 420 m

$$\frac{\Delta p}{p} = 0.01 \quad \Rightarrow \quad x = 1.5\,\text{cm}$$

$$\frac{\Delta p}{p} = 0.001 \quad \Rightarrow \quad x = 1.5\,\text{mm}$$



acceptance

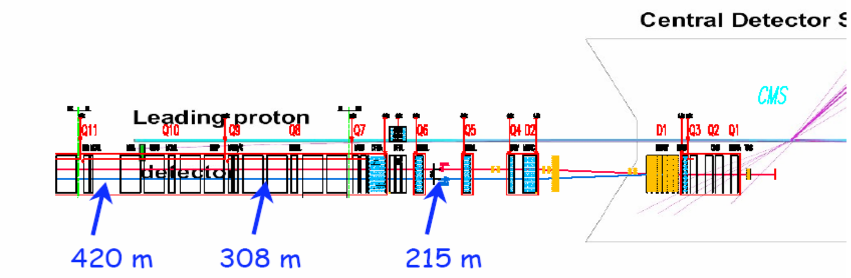
$x_{IP} \sim 0.2 - 1.5$ %

t from 0 to ~10 GeV²

deflection of protons due to main magnets

→ stability against beam tuning effects

420 m Detectors



Missing dipole in the lattice – 14 m space. With a bypass ~10 m space remains for warm detectors sitting in Roman Pots

detector resolution should be better than the beam spread at 420 m

$$\sigma_x \approx 250\ \mu\mathrm{m} \qquad \sigma_y \approx 160\ \mu\mathrm{m}$$

$$\sigma_{x',y'} \approx 4.5\ \mu\mathrm{rad}$$

angular measurement can be performed with silicon detectors spaced 8 m apart, with ~10 μm resolution. Size of the detectors: ~30 mm * 20 mm

alignment with physics reactions (much easier than at HERA, high statistics)

simple estimate of the proton momentum resolution:

$$\Delta x_{IP} / x_{IP} \sim 8\% \quad \text{for} \ \ x_{IP} \approx 0.002 \qquad \sigma_x / 3mm$$

$$\Delta x_{IP} / x_{IP} \sim 1.5\% \quad \text{for} \ \ x_{IP} \approx 0.01 \qquad \sigma_x / 15mm$$

$$\Delta p_T \sim 200\ \mathrm{MeV}$$

Reconstruction of Kinematic Variables

similar to H1-VFPS

Transport Matrix
(from text books)

$$\begin{pmatrix} x \\ x' \\ \xi \end{pmatrix} = \begin{pmatrix} \sqrt{\frac{\beta}{\beta_0}}(\cos\Psi + \alpha_0 \sin\Psi) & \sqrt{\beta\beta_0}\sin\Psi & D \\ \frac{(\alpha_0 - \alpha)\cos\Psi - (1+\alpha_0\alpha)\sin\Psi}{\sqrt{\beta\beta_0}} & \sqrt{\frac{\beta_0}{\beta}}(\cos\Psi - \sin\Psi) & D' \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} x_0 + 0 \\ x'_0 + \theta \\ \xi_0 - x_{IP} \end{pmatrix}$$

observation point ***3-measured***

Real mapping should be computed with MAD

interaction point ***2-unknown***

Calibration using events with reconstructed x_{IP1} and x_{IP2} in CD, e.g EDD with σ ~ O(1) μb

$$x_{IP1} = \frac{M}{\sqrt{s}} e^{y} \qquad x_{IP2} = \frac{M}{\sqrt{s}} e^{-y}$$

Exploit $t = 0$ peak for alignment

$$\chi^2_{calib} = \frac{\theta_x^2}{\sigma_{\theta_x}^2} + \frac{(x_{IP} - x_{IP}^{CD})^2}{\sigma^2_{x_{IP} - x_{IP}^{CD}}}$$

Minimize χ^2

$$\chi^2 = (x_i - x_i(\theta_x, x_{IP}) \cdot c_{ij}^{-1} \cdot (x_j - x_j(\theta_x, x_{IP}))$$

H1 experience with VFPS - Real evaluation should take into account nonlinearities and correlations between the vertical and horizontal planes due to sextupoles and higher order magnets (Pierre van Mechelen)

Background Reactions

Main limits on the beam lifetime at LHC is due to strong interactions $\sigma_{tot} \sim O(100)$ mb

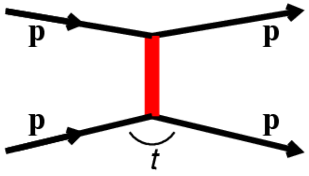
$$(L = 10^{34}\ \mathrm{cm}^{-2}\,\mathrm{sec}^{-1}) \cdot (\sigma = 100 \cdot 10^{-3} \cdot 10^{-24}\ \mathrm{cm}^2) = 10^9\ \mathrm{events/sec}$$

Beam lifetime $2808 \cdot 1.15 \cdot 10^{11} / (2 \cdot 10^9 \cdot 3600) \sim$ **O(40) hours**

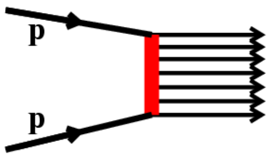
Number of interactions per bunch crossing

$$N_{interactions} = 10^9\ \mathrm{events/sec/40MHz} = 25$$

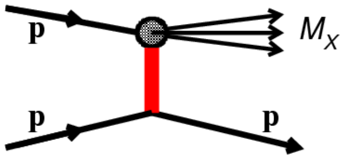
$$N_{vertex} = 0.7 \cdot 25 = 19$$



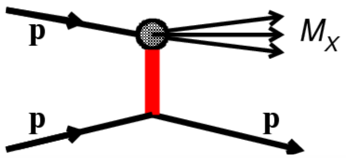
Elastic scattering – $\sigma_{el} \sim O(30)$ mb



Inclusive scattering – $\sigma_{inc} \sim O(50)$ mb

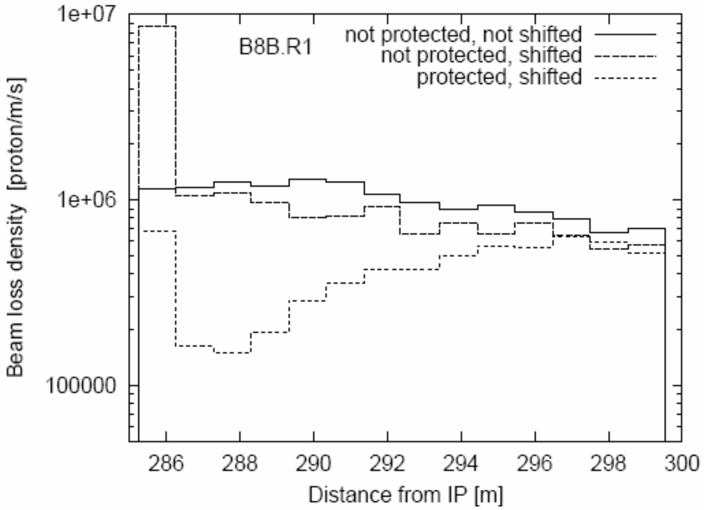


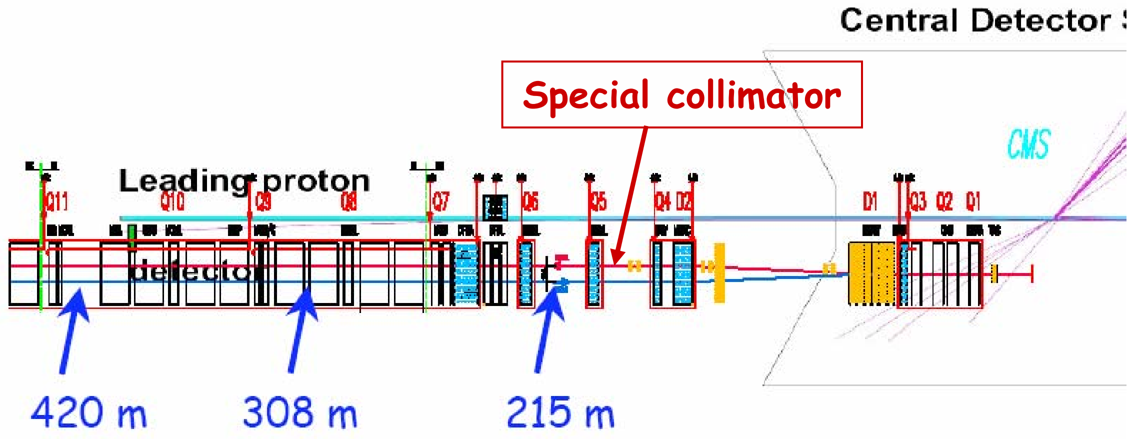
Proton dissociation – $\sigma_{el} \sim 2\ O(10)$ mb for $x_{IP} \sim 1 - 30$ %
Main source of the machine background. Leads to a rate of $O(10^8)$ forward protons/sec. Attention!!! It is above the magnet quench limit of 8 10^6 protons/m/sec

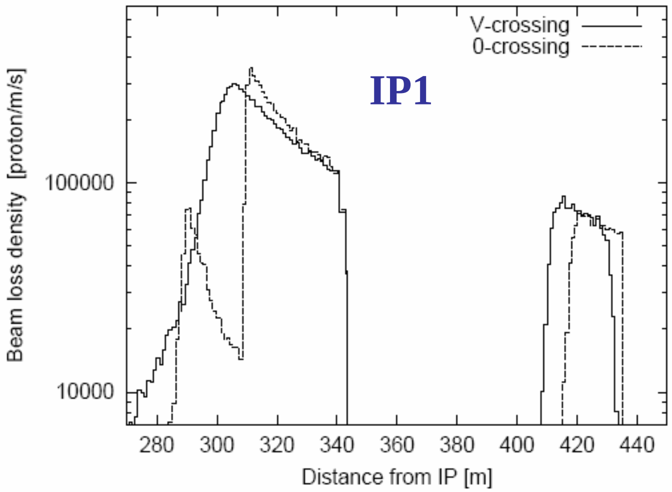


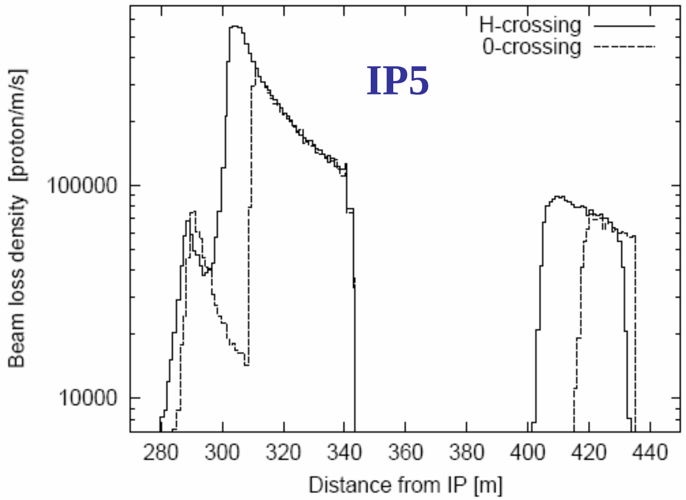
Machine background from proton dissociation reactions

LHC Project Note 240, 208
I. Baishev, J.B. Jeanneret, G.R. Stevenson

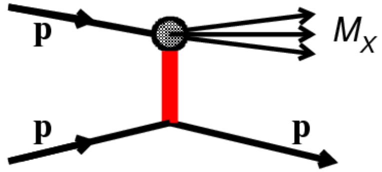








Physics background from proton dissociation reactions



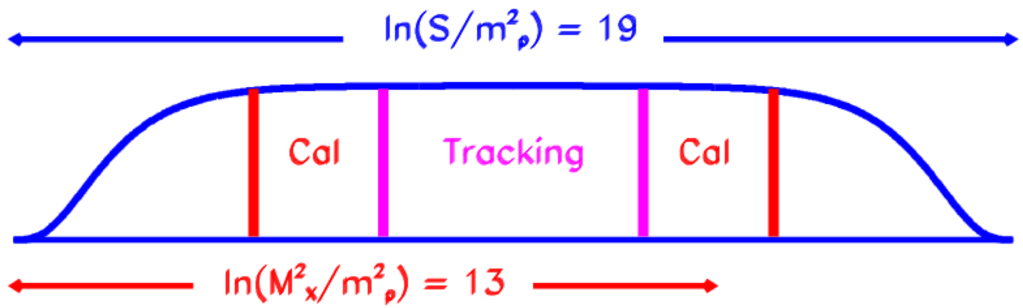
$$\sigma_{p-dis} = c \cdot \int_{x_{IP}^{\min}}^{x_{IP}^{\max}} 1/x_{IP} = \ln(x_{IP}^{\max}) - \ln(x_{IP}^{\min}) \approx c \cdot 16 = 8mb$$

$$\Rightarrow c = 0.5mb$$

$$x_{IP}^{\min} = M_{\min}^2 / 4 \cdot p^2 = 1.5/4 \cdot 7000^2 = 7.7 \cdot 10^{-9} \qquad x_{IP}^{\max} \approx 0.1$$

FP420 detector sees protons with x_{IP} *~ 0.2 - 1.5 %* and $\sigma_{p\text{-}dis}$ ~ 1 mb
At luminosity of 10^{34} s^{-1} cm^2 there will be ~ 10^7 protons/sec
~ 0.25 protons per bunch crossing

However, these protons are produced in a *soft interaction* together with a particle cloud of a mass M_X *~ 700 - 1700 GeV*. Such a large mass cannot escape undetected in the central detector.



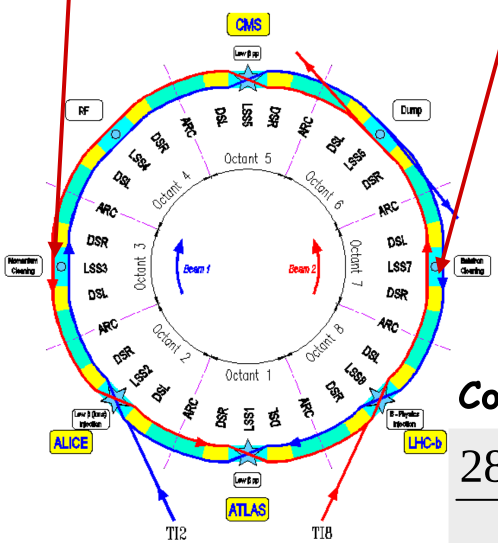
Beam Halo background from beam-beam tune shift

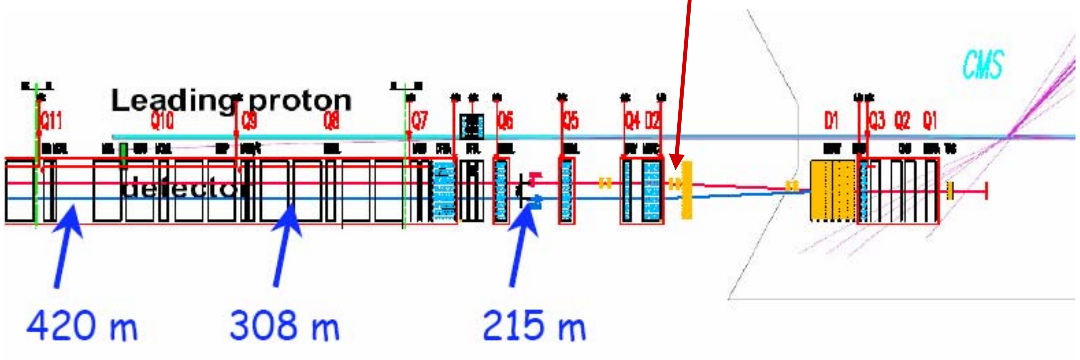
In bunch-bunch collision the particle of one bunch see the other bunch as a nonlinear lens.
Focusing properties are changing => protons of large amplitude
are getting out of tune after many crossings

Estimate of the proton loss: # protons / beam lifetime (40h)

Primary and secondary collimators
beam scratched to 6 and 7 σ

New tertiary collimators





Collimator cleaning inefficiency after 10 σ ~ 4 10^{-4}

$$\frac{2808\cdot 1.15\cdot 10^{11}\cdot 0.63\cdot 4\cdot 10^{-4}}{40\cdot 3600} = 0.5\cdot 10^{6}\ \text{protons/sec}$$

1 beam halo proton per ~80 bunches at the top luminosity

Presumably even considerably smaller in the 420m region,
in the shadow of the incoming collimator, after D2 (R. Assmann)