Charge exchange reaction at high energies

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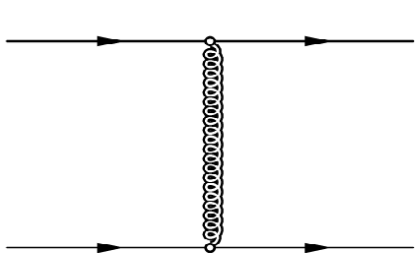
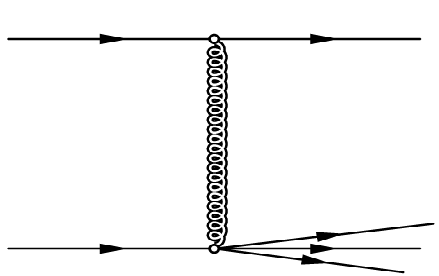
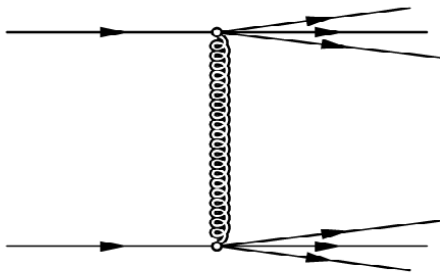
Diffractive event topologies at LHC energies



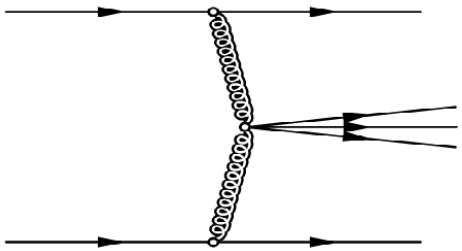
elast. scattering



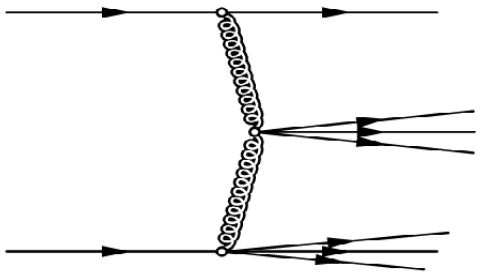
single diff. diss.



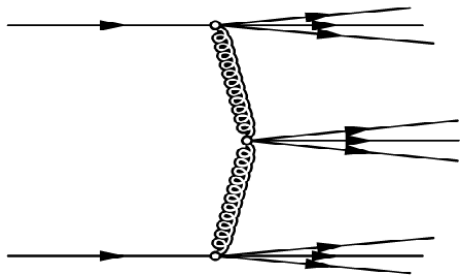
double diff. diss.



central diff.



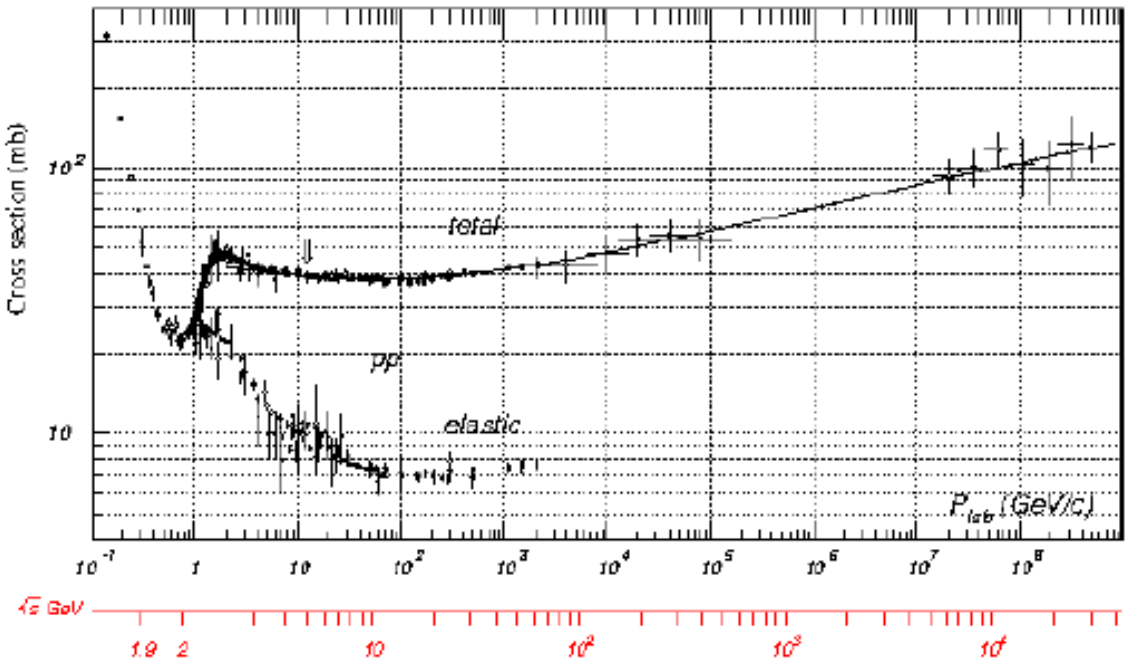
central diff./single diss.



central diff./double diss.

- Reggeon-Pomeron exchanges contribute to these topologies
- Regge exchanges at LHC ? $\rightarrow$ *Study charge exchange react*.

Hadron-hadron cross section



pp total and elastic cross section

Donnachie-Landshoff fits: $\sigma_{tot} = X \cdot s^{0.08} + Y \cdot s^{-0.45}$

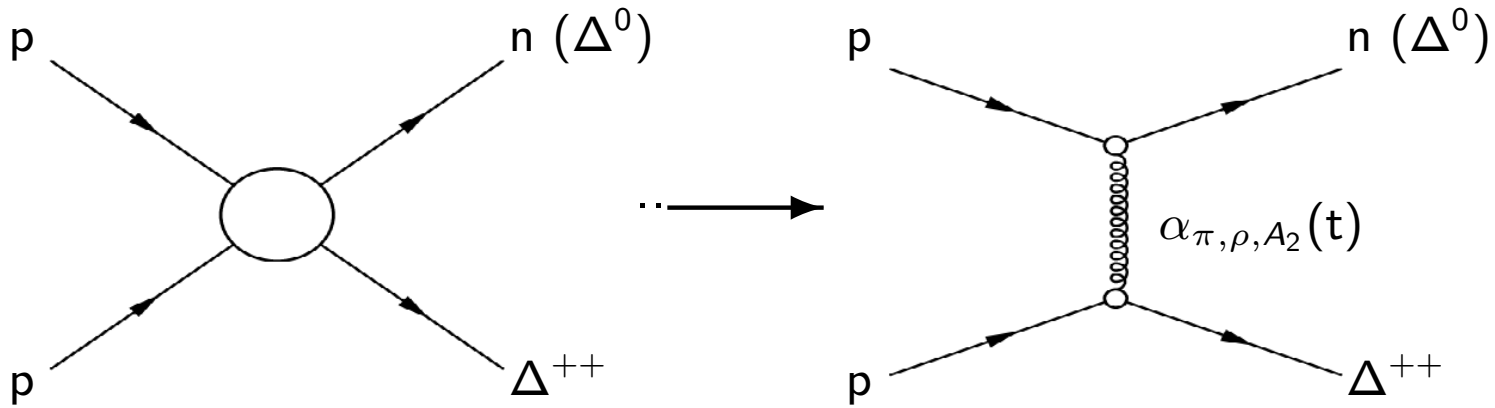
Charge exchange reaction by Reggeon exchange

charge exchange reaction in proton-proton collisions:

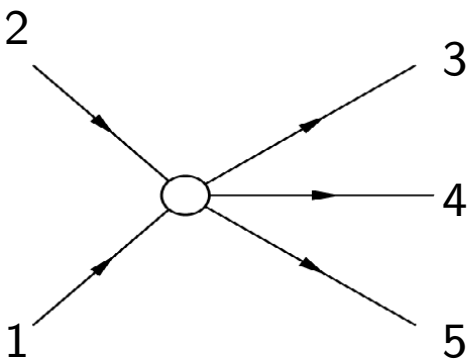
- $p\ p \rightarrow n + \Delta^{++} \rightarrow n + p\ \pi^+$
- $p\ p \rightarrow \Delta^0 + \Delta^{++} \rightarrow n\ \pi^0 + p\ \pi^+$
- $p\ p \rightarrow \Delta^0 + \Delta^{++} \rightarrow p\ \pi^- + p\ \pi^+$

- need zero degree calorimeters
  + tagging of forward proton,pions
- need good pseudorapidity coverage of detectors

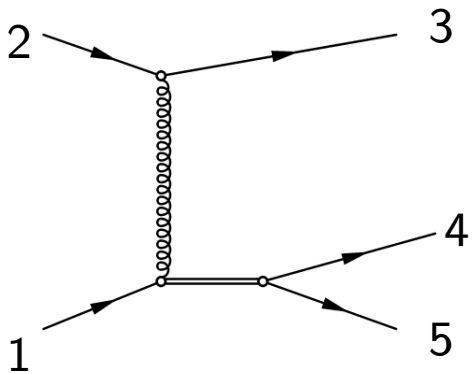
Two-by-two amplitude



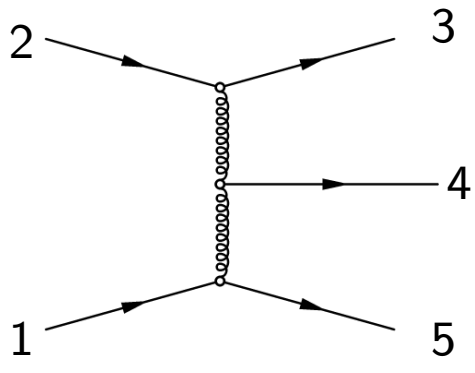
Two-by-three amplitude



two-by-three ampl.



single Regge limit



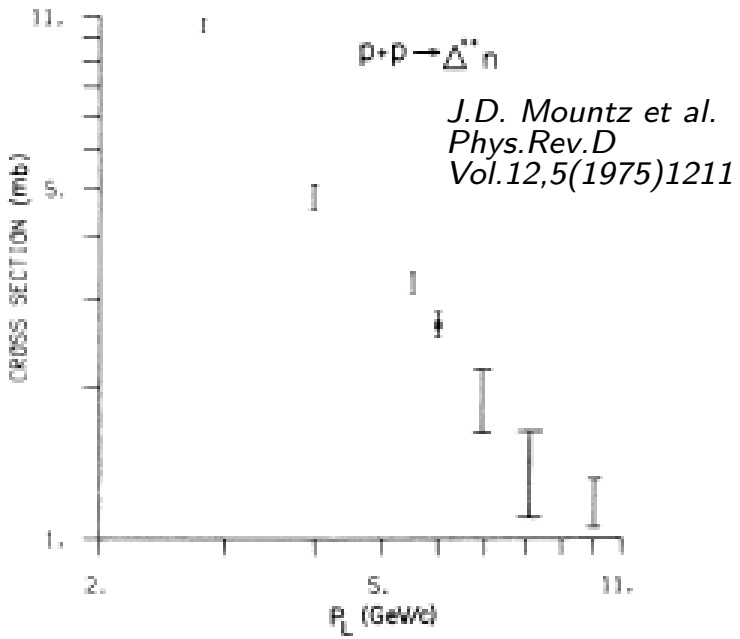
double Regge limit

can be calculated
by dual amplitude

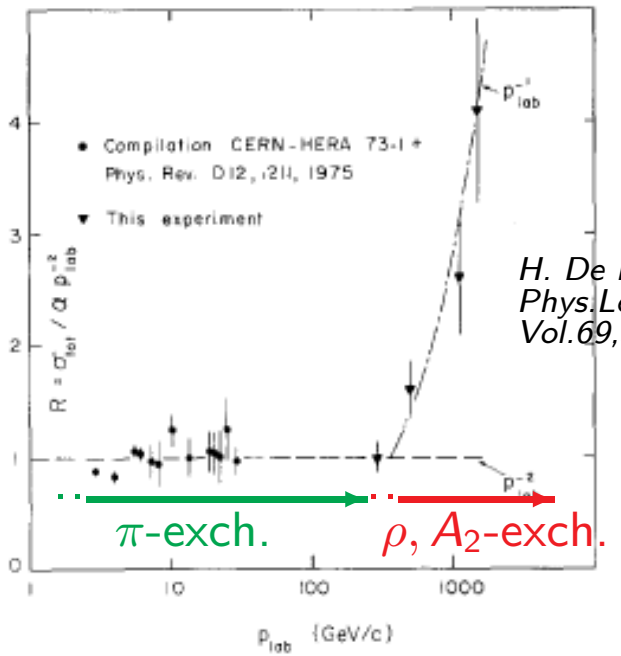
Data charge exchange reaction at low energies

The charge exchange reaction pp $\rightarrow$ n + $\Delta^{++}(1232)$ measured at

- Argonne Nat. Zero Gradient Synchrotron (p_{Lab} = 6 GeV/c)
- Intersecting Storage Ring (ISR) ($\sqrt{s}$ = 23, 31, 45, 53 GeV)



J.D. Mountz et al.
Phys.Rev.D
Vol.12,5(1975)1211



H. De Kerret et al.
Phys.Lett.B
Vol.69,3(1977)372

if Regge exchange due to pion: $\sigma \sim s^{-2}$, due to ρ, A_2: $\sigma \sim s^{-1}$

Prospects charge exchange at high energies

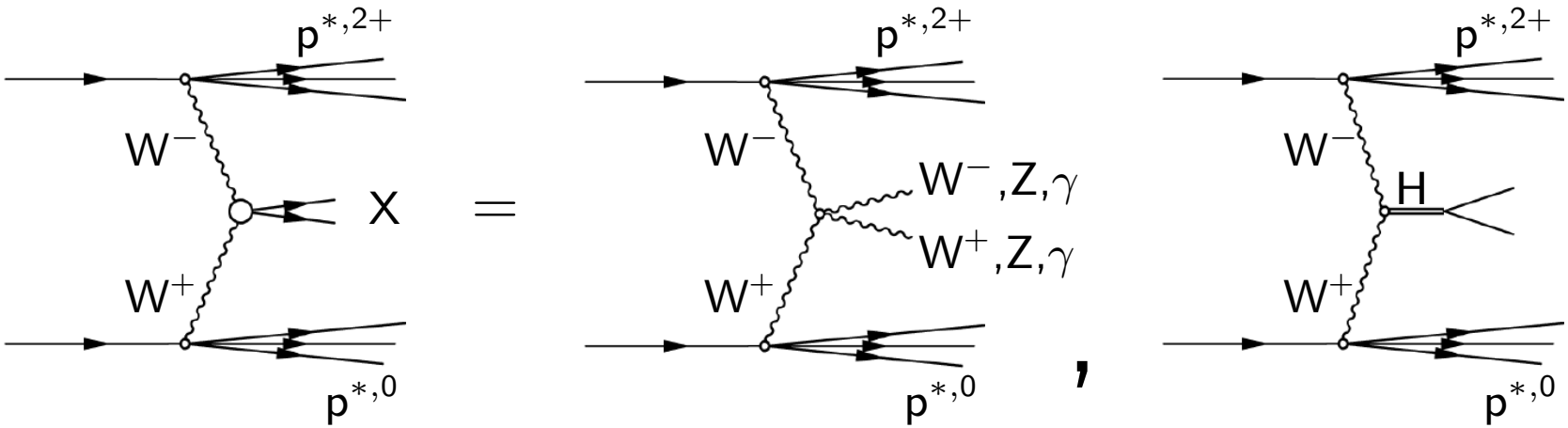
- RHIC Brookhaven: $\sqrt{s} = 100$-200 GeV
- LHC CERN: $\sqrt{s} = 13$-14 TeV

Table: Cross section $pp \to n\Delta^{++}$

	$\sqrt{s}$ (GeV)	σ (nb)
ISR	31	580 $\pm$90
	45	210$\pm$40
	53	170$\pm$40
RHIC	100	48.5$\pm$5.5
	200	12.2$\pm$1.3
LHC	7×10^3	(10.0$\pm$1.1) $\times10^{-3}$
	14×10^3	(2.4$\pm$0.3) $\times10^{-3}$

Charge exchange reaction by W^+,W^- exchange

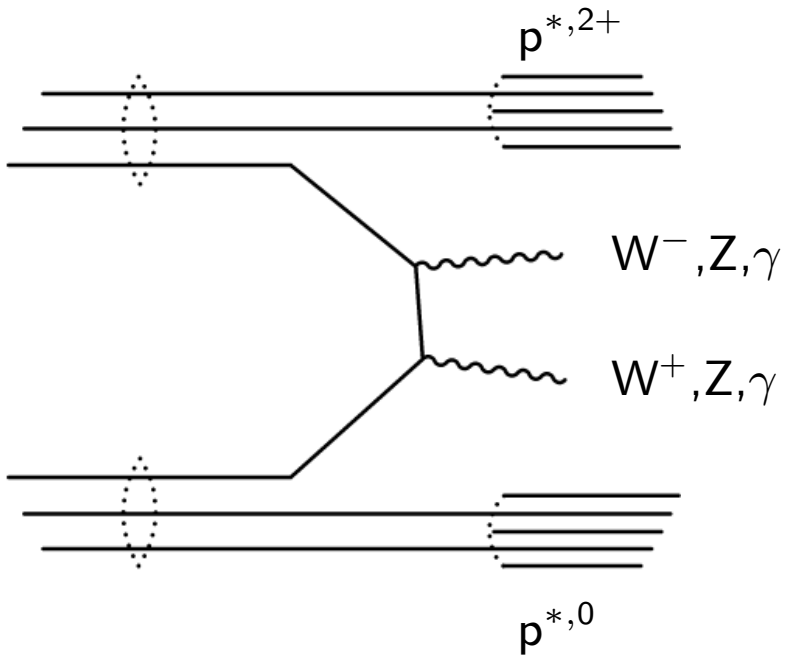
- $pp \to p + X + p,\ p^* + X + p^* \qquad X = W^+W^-,\ ZZ,\ \gamma\gamma,\ H$



- select these events by tagging Z_{tot}=0 system on one side, Z_{tot}=2 system on the other side
- need to identify forward protons, charged pions and kaons (and neutrons)
- Ongoing discussions with R. Pasechnik on cross section of these channels, QCD background

QCD background single quark exchange

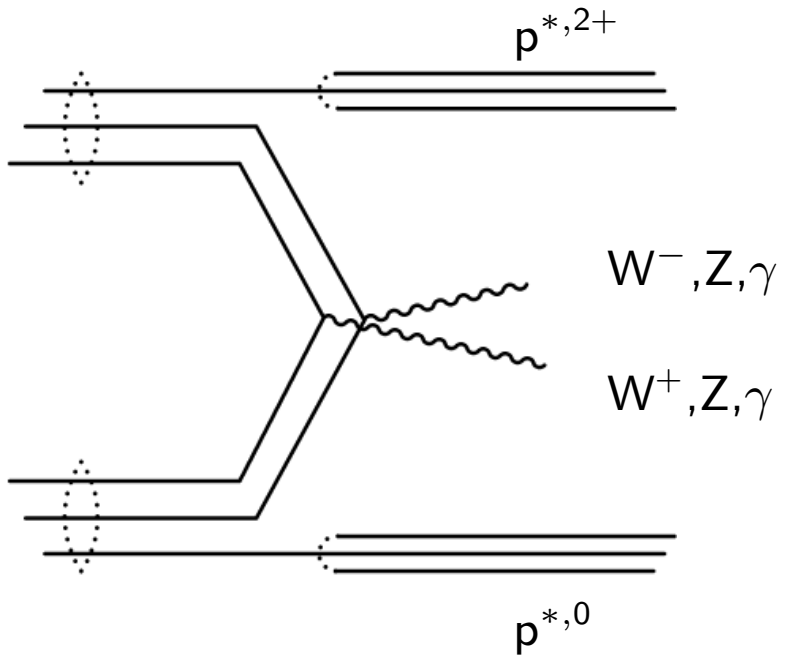
- $q\overline{q} \rightarrow W^+W^-$, ZZ, $\gamma\gamma$, (plus additional parton exchange)



- cross section as function of mass of $p^{*,2+}$, $p^{*,0}$?
- phase space distribution of the proton fragments ?

QCD background double quark exchange

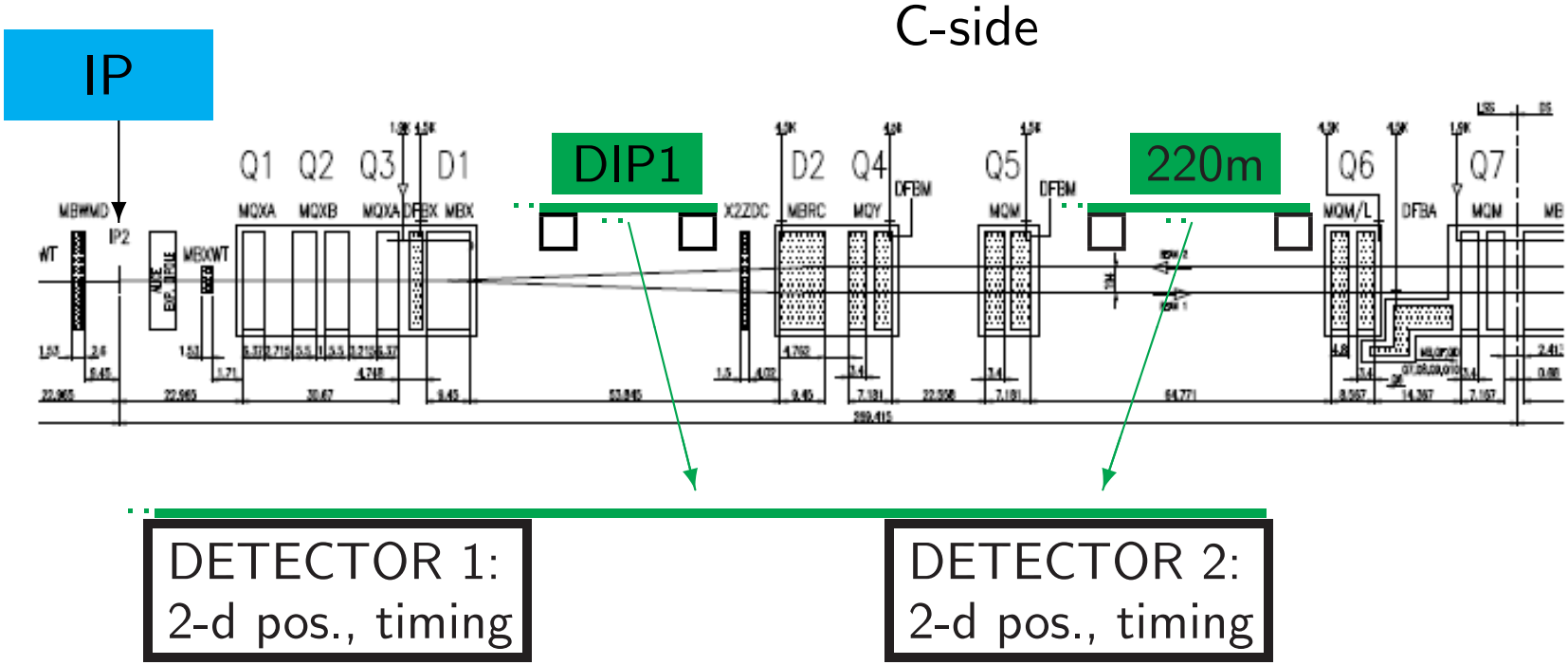
- double parton interaction $q\bar{q}q\bar{q} \rightarrow W^+W^-$, ZZ, $\gamma\gamma$



- cross section as function of mass of $p^{*,2+}$, $p^{*,0}$?
- phase space distribution of the proton fragments ?

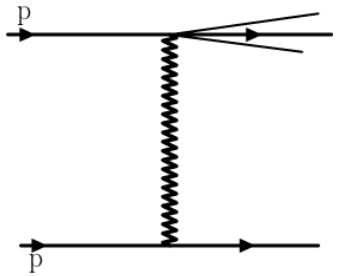
Location of detectors

- Feasibility study @LHC interaction point
- Measure straight sections of tracks



Diffractive excitations of the proton

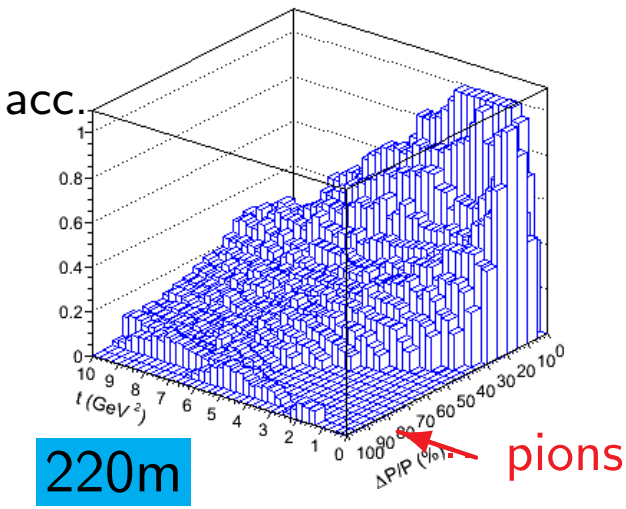
diffractive excitation of the proton p p $\rightarrow$ p N* $\rightarrow$ p p $\pi^+\pi^-$

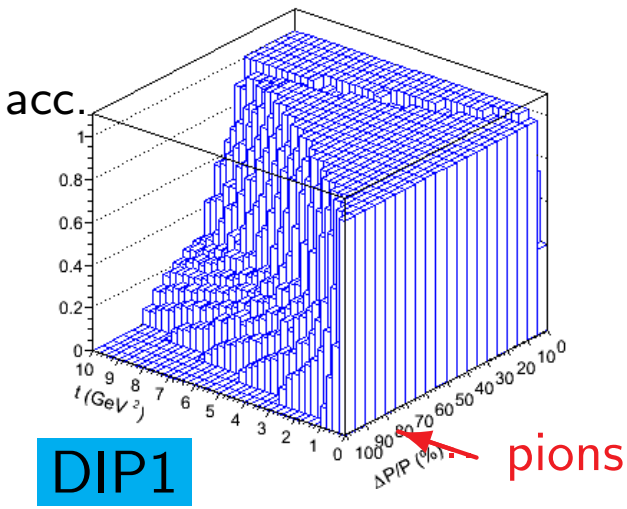


Where do the pions go ?

Instrumentation in both beam lines

in N*-system at threshold:
proton = (m_p,0,0,0), pion = (m_π,0,0,0)
Lorentz boost: N*-system to lab-system:
proton(lab) = (γm_p,0,0,$\gamma\beta m_p$), pion(lab) = (γm_π,0,0,$\gamma\beta m_\pi$)
$\rightarrow$ pion momentum reduced by factor $m_\pi/m_p \sim 0.15$, $\rightarrow \xi \sim 0.85$





Summary theoretical issues

- What are the theoretical uncertainties in signal (W-fusion) at the hadron level ?
- What are the theoretical uncertainties in the background ? (Reggeon-fusion, single parton, double parton exchange ?)
- What are gap survival effects in charge exchange reactions ? (both in W- and Reggeon exchange)
- Both signal and background are expected to be suppressed at high energies. Which suppression is stronger, a naive 1/s-like suppression for Reggeon induced background, or a gap survival suppression for the WW-fusion signal ?
- What are the signal and the background differentially in the invariant mass of the proton fragments ? What is the phase space distribution of these fragments ?

Summary experimental issues

- selection of Z_{tot}=0 and Z_{tot}=2 systems with good acceptance requires large acceptance forward spectrometer
- major investment in magnet configuration, detector systems, beam optics development
- presently not foreseen at the LHC
- a project for the FCC ?
- evaluation of signal and background with event generators