Minimum-bias Backgrounds in AFP for Various LHC Optics Settings

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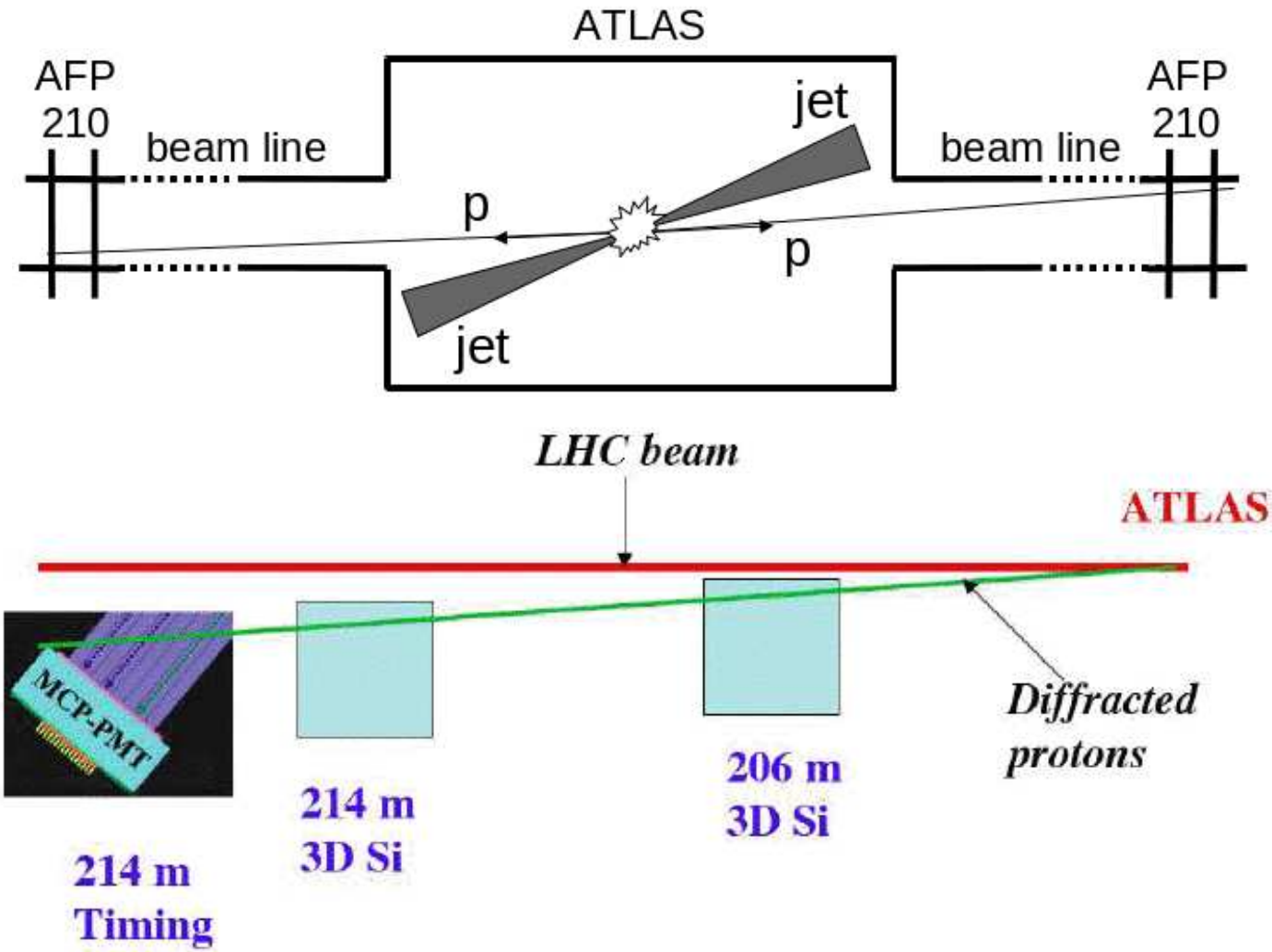
Outlook

1. AFP Detectors.
2. AFP Geometric Acceptance.
3. Soft Production – Generators.
4. Minimum-bias Events in AFP.
5. Summary.

AFP Detectors

AFP Detectors



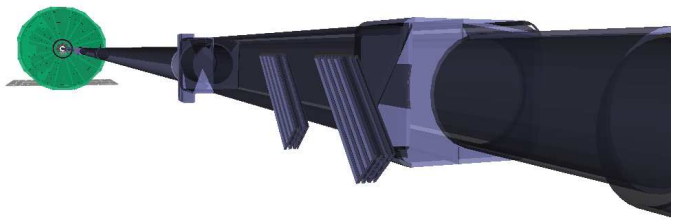
- Detector located close to the beam – Roman Pots.
- Proton position measurement (3-D Pixel detectors, SiD).
- Precise time of flight measurement (QUARTIC timing detector, TD).

See Tuesday talk of M. Bruschi on the AFP status.

ATLAS Simulation

Past:

- generator level studies + proton transport* **or**
- full simulation of ATLAS central detector + proton transport*.

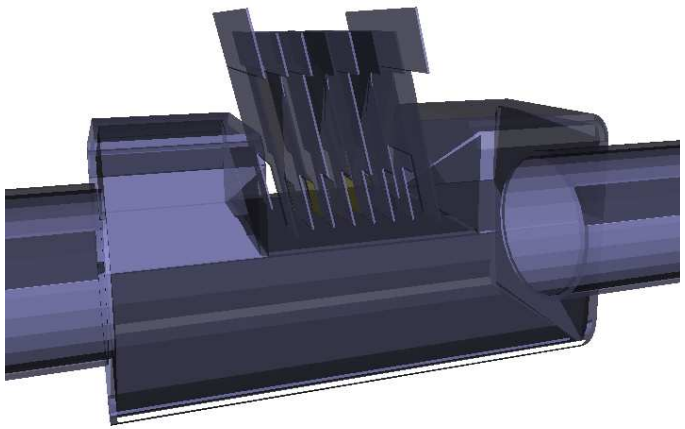


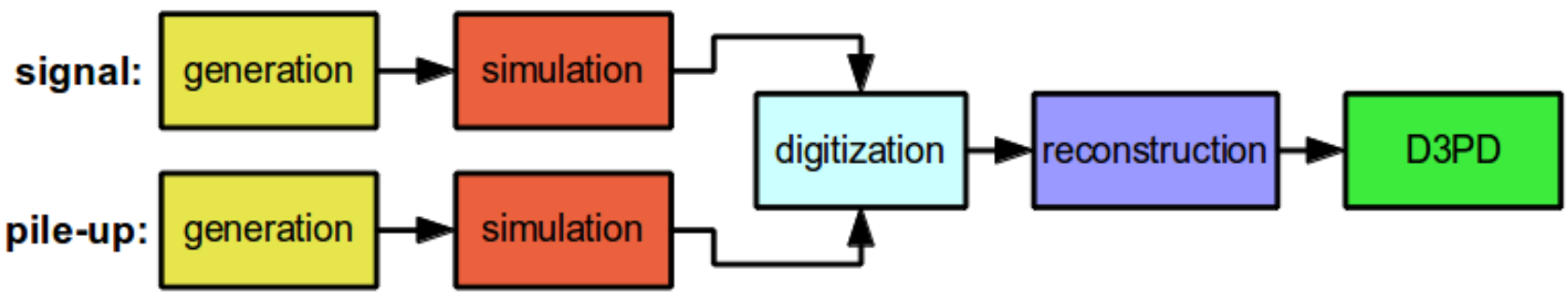
* – protons were transported using MAD-X or FPTracker

Present (in addition):

Geant4 simulation of whole forward region

- Beam elements (beampipe, magnets, collimators) and forward detectors were implemented.
- Full simulation of event: ATLAS central detector AND proton transport.
- Need to write everything from scratch and to include AFP in all steps in simulation chain.





See Friday talk of M. Dyndał on the AFP simulation.

AFP Geometric Acceptance

LHC Beamsize

Table: LHC beam size in x at the AFP stations for different β^* optics modes for nominal and low emittance. Calculations were done for $\sqrt{s} = 14$ TeV.

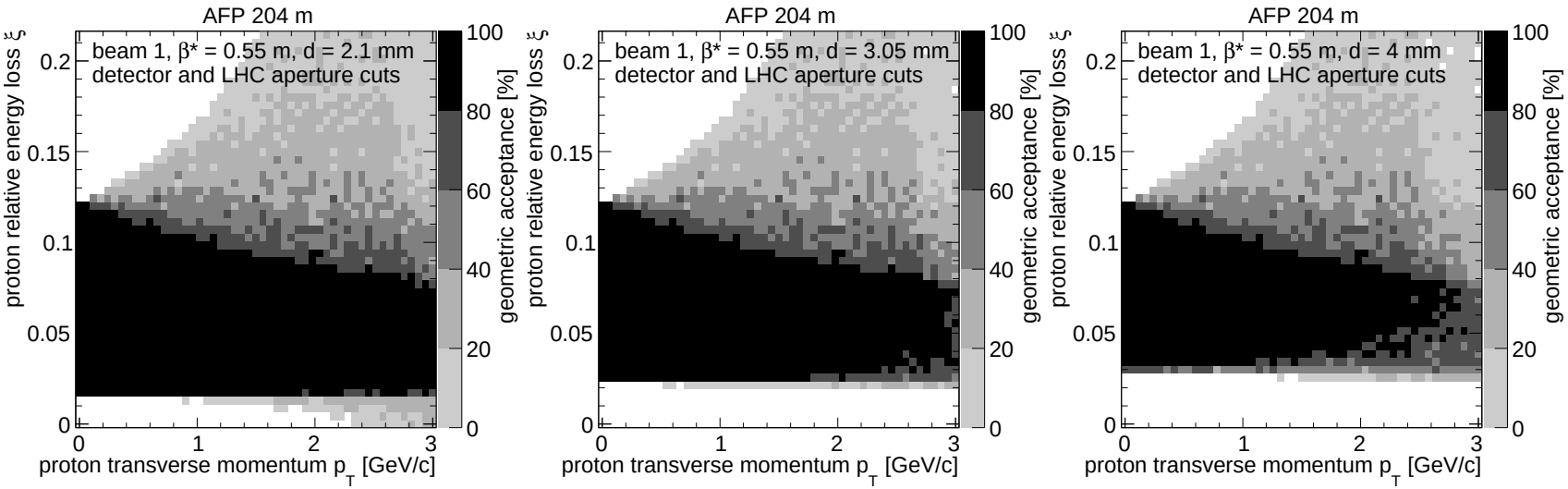
β^* [m]	σ_x^{204} [mm] $\varepsilon = 2$	$\varepsilon = 3.75$	σ_x^{212} [mm] $\varepsilon = 2$	$\varepsilon = 3.75$
0.55	0.14	0.19	0.10	0.14
90	0.43	0.59	0.36	0.49
1000	0.56	0.76	0.48	0.65

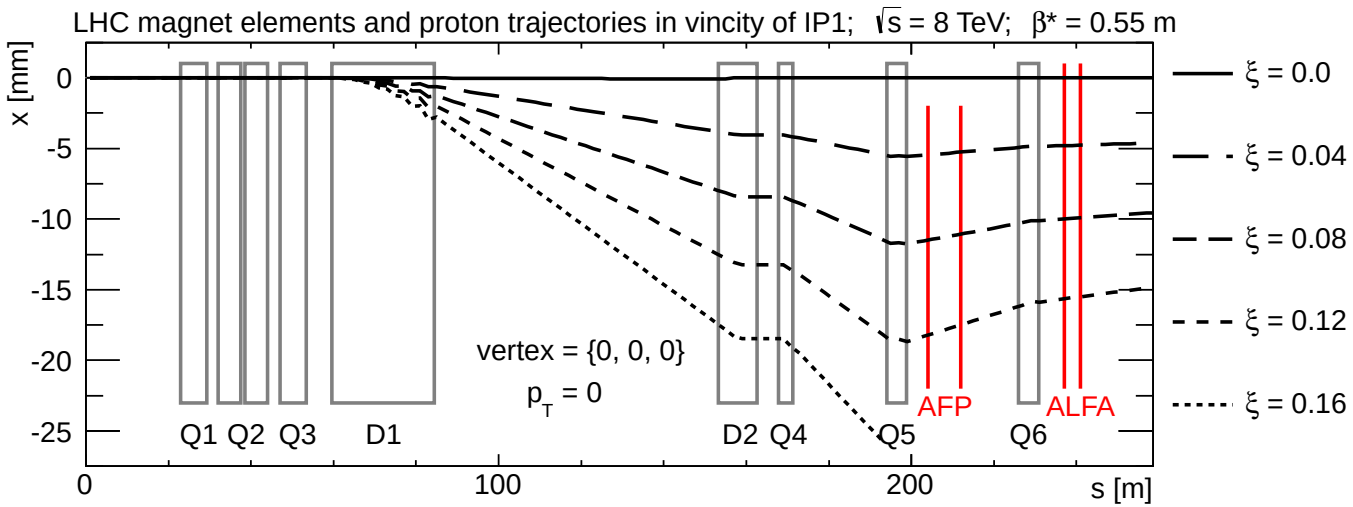
Acceptance for $\beta^* = 0.55$ m

$10\ \sigma$
$0.015 < \xi < 0.12$

$15\ \sigma$
$0.02 < \xi < 0.12$

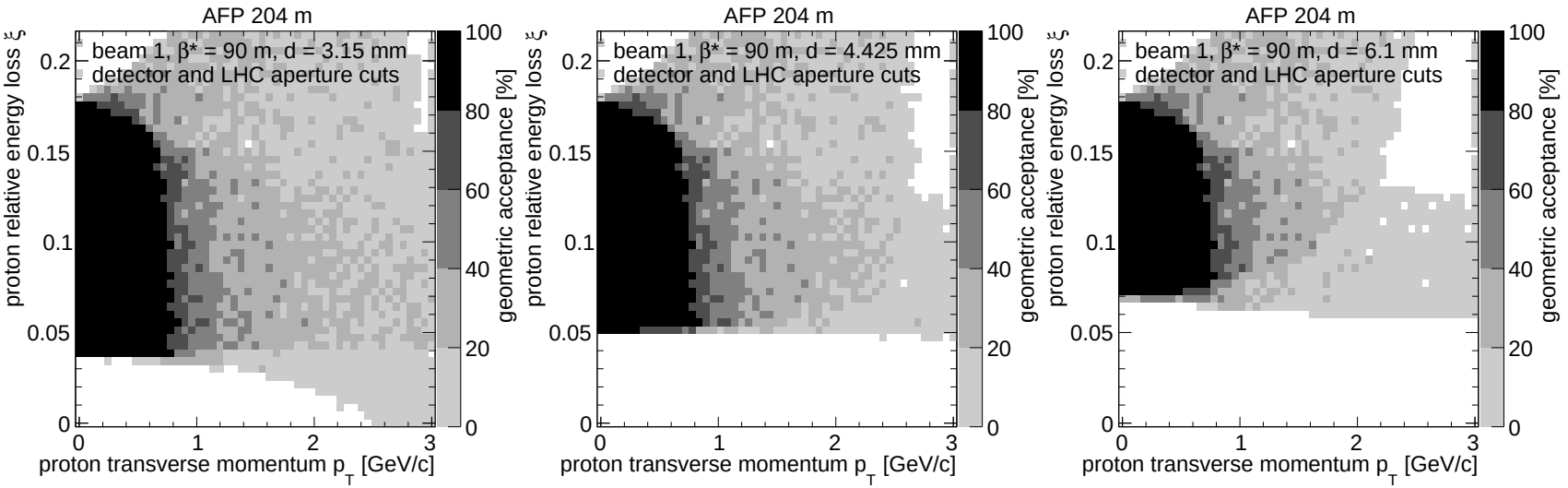
$20\ \sigma$
$0.025 < \xi < 0.12$

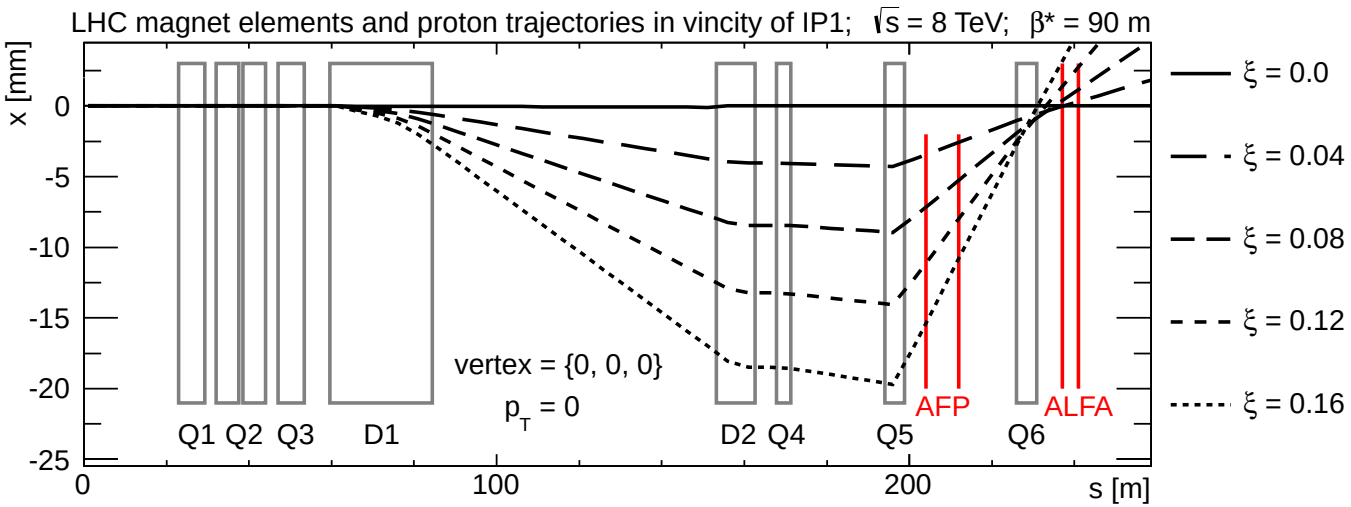




Acceptance for $\beta^* = 90$ m

5 σ	7.5 σ	10 σ
$0.035 < \xi < 0.18$	$0.05 < \xi < 0.18$	$0.07 < \xi < 0.18$



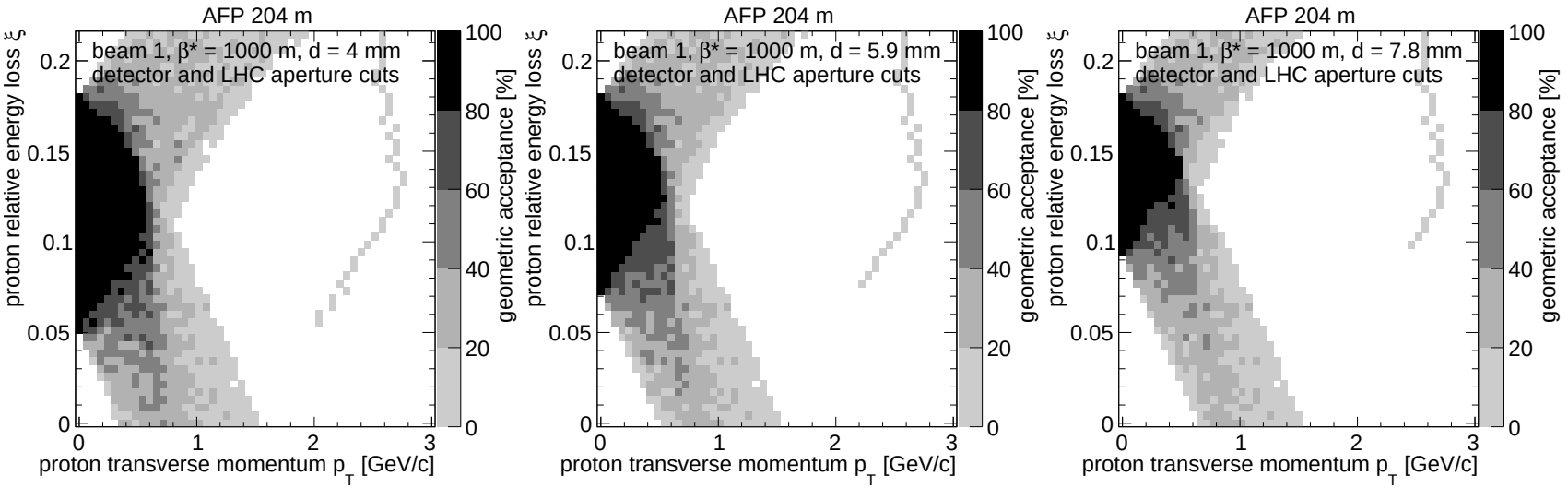


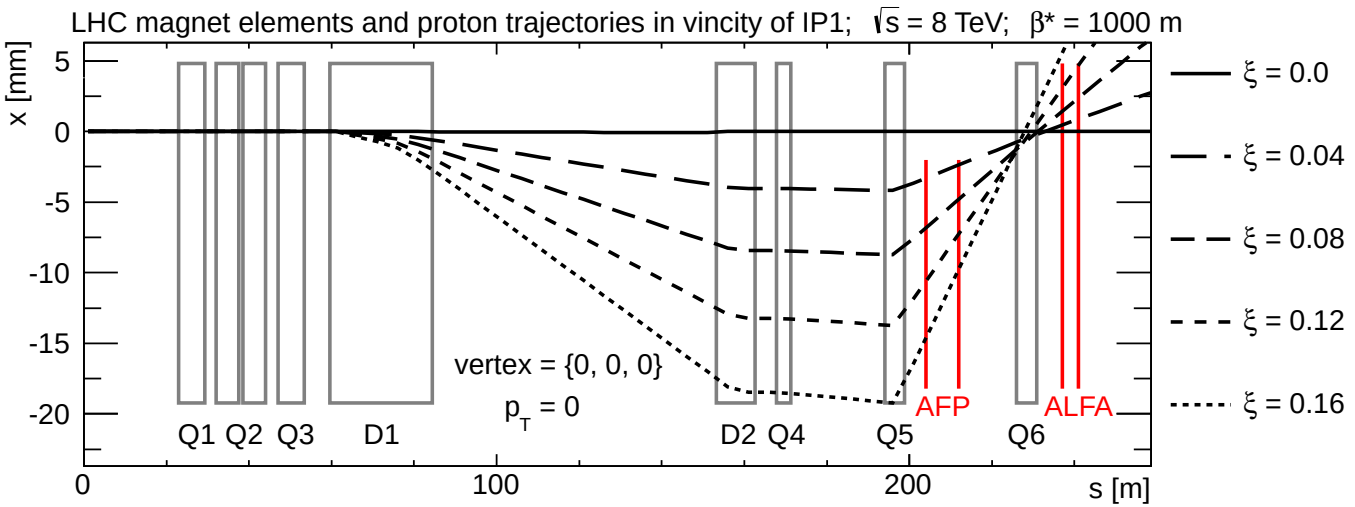
Acceptance for $\beta^* = 1000$ m

$5\ \sigma$
$0.05 < \xi < 0.18$

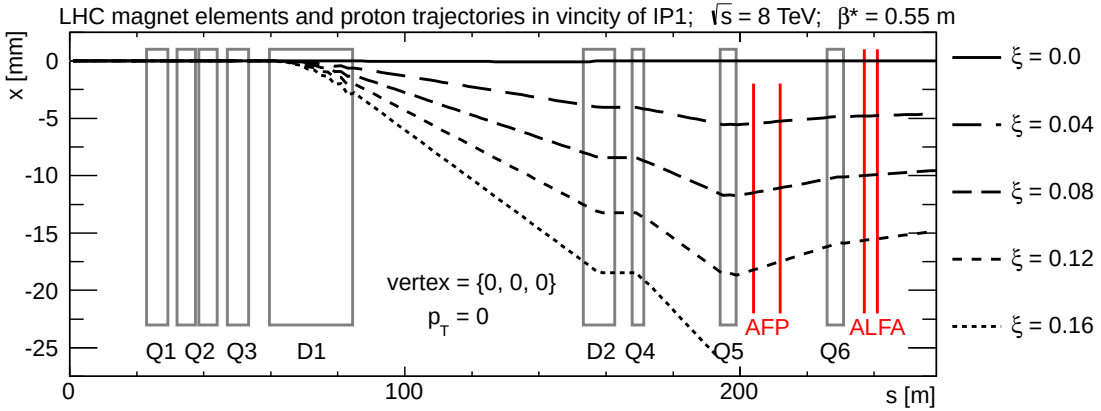
$7.5\ \sigma$
$0.07 < \xi < 0.18$

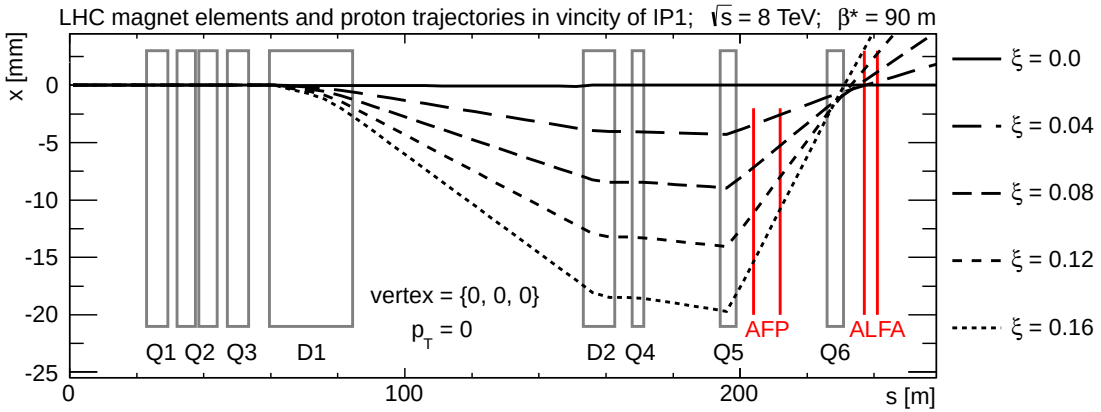
$10\ \sigma$
$0.095 < \xi < 0.18$

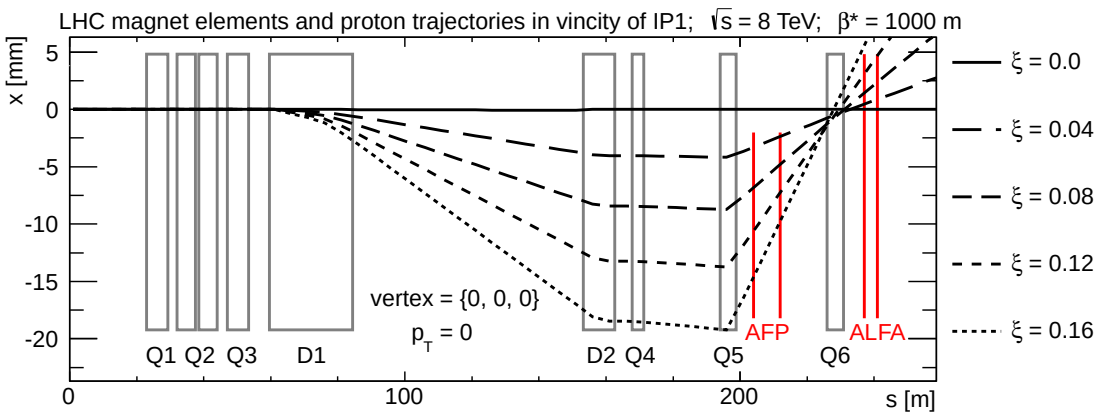




Proton Trajectories – ξ Dependence







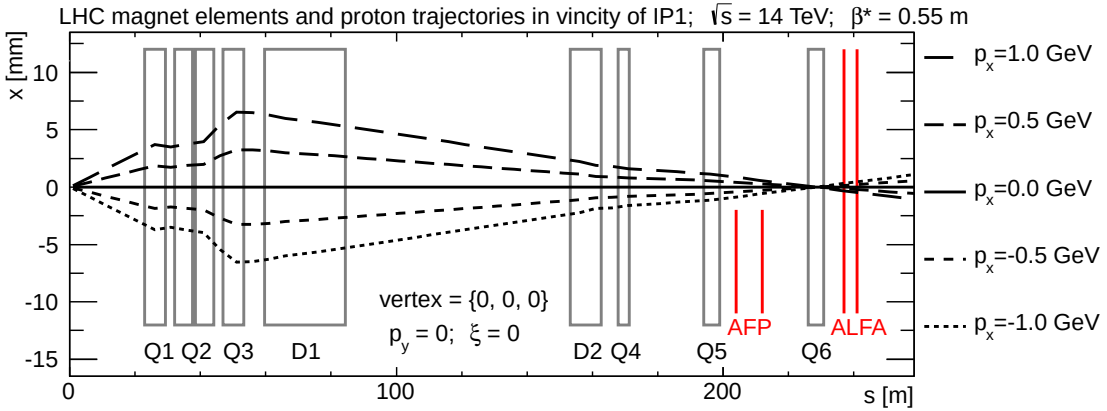
Top: $\beta^* = 0.55$ m

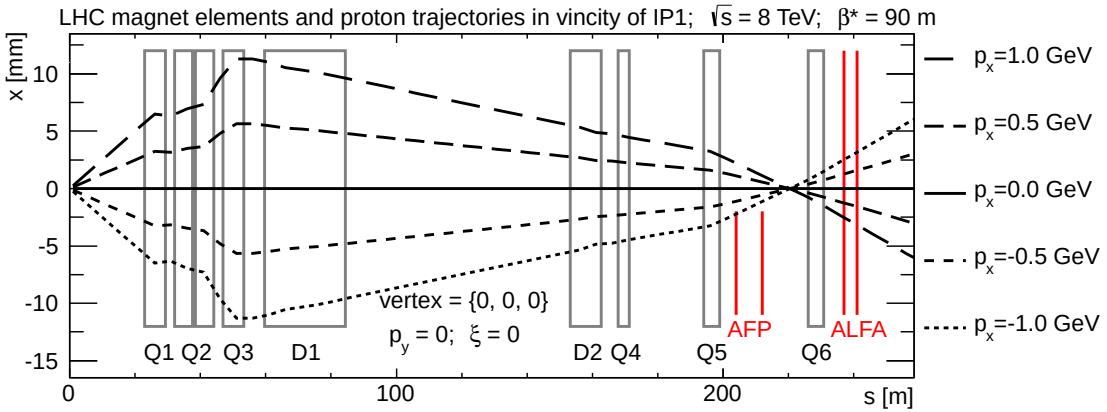
Middle: $\beta^* = 90$ m

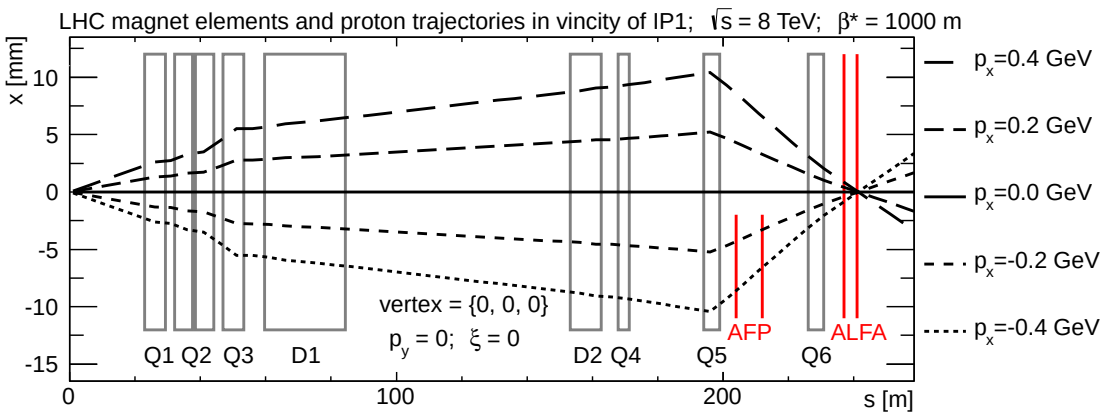
Bottom: $\beta^* = 1000$ m

Collimators are wide open:
- TCL4 @ 150 m,
- TCL5 @ 185 m.

Proton Trajectories – p_x Dependence







Top: $\beta^* = 0.55$ m

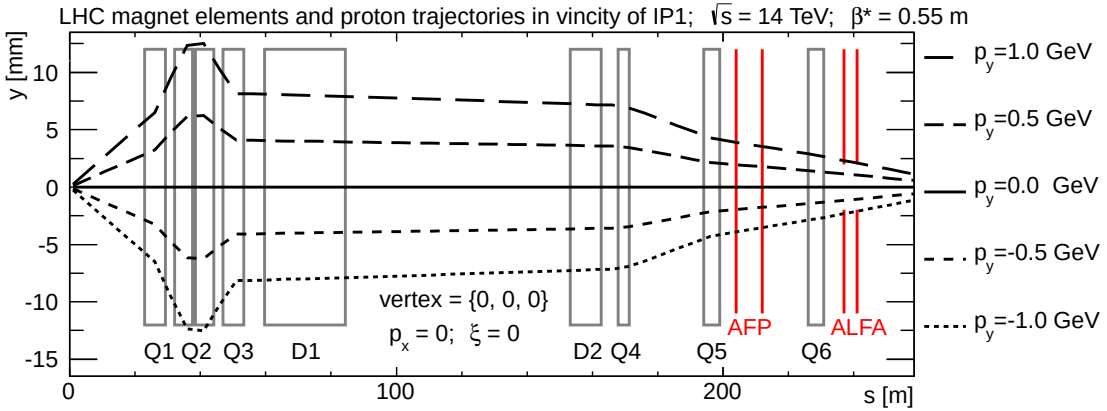
Middle: $\beta^* = 90$ m

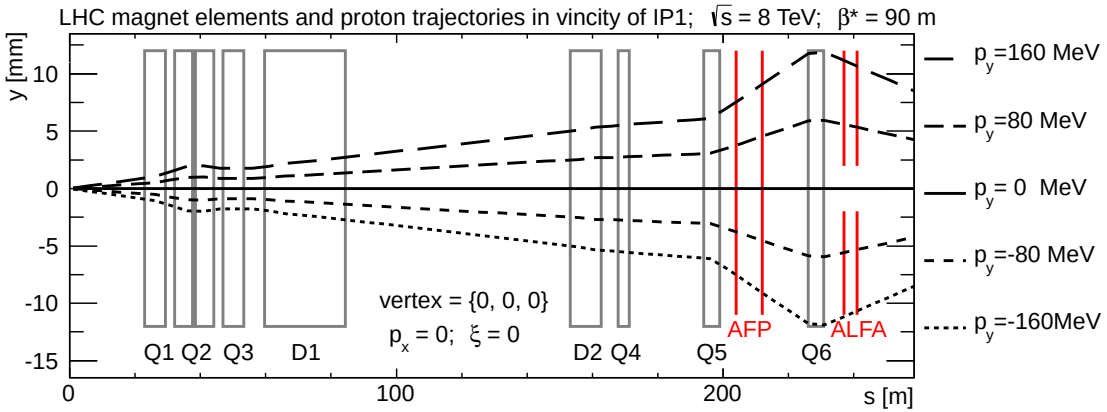
Bottom: $\beta^* = 1000$ m

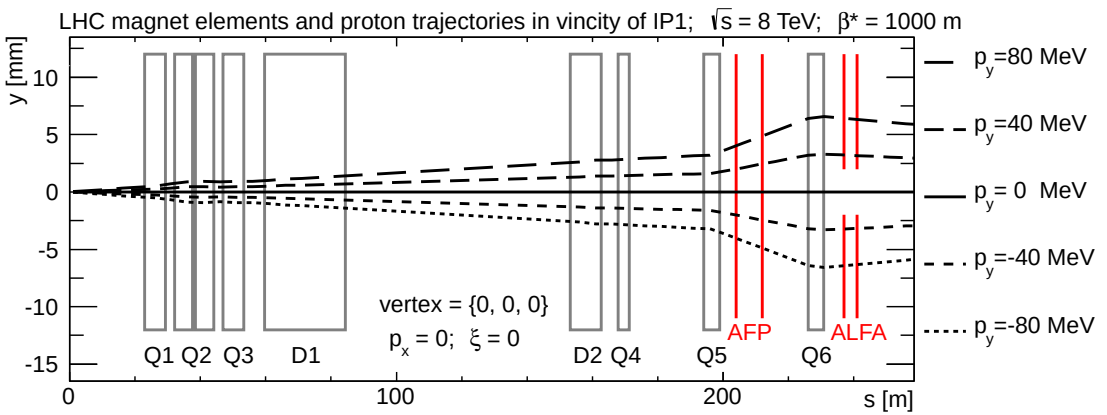
Collimators are wide open:
– TCL4 @ 150 m,
– TCL5 @ 185 m.

Protons with a given p_x are visible further in AFP (at lower x position) with the increase of β^*.

Proton Trajectories – p_y Dependence







Top: $\beta^* = 0.55$ m

Middle: $\beta^* = 90$ m

Bottom: $\beta^* = 1000$ m

Collimators are wide open:
– TCL4 @ 150 m,
– TCL5 @ 185 m.

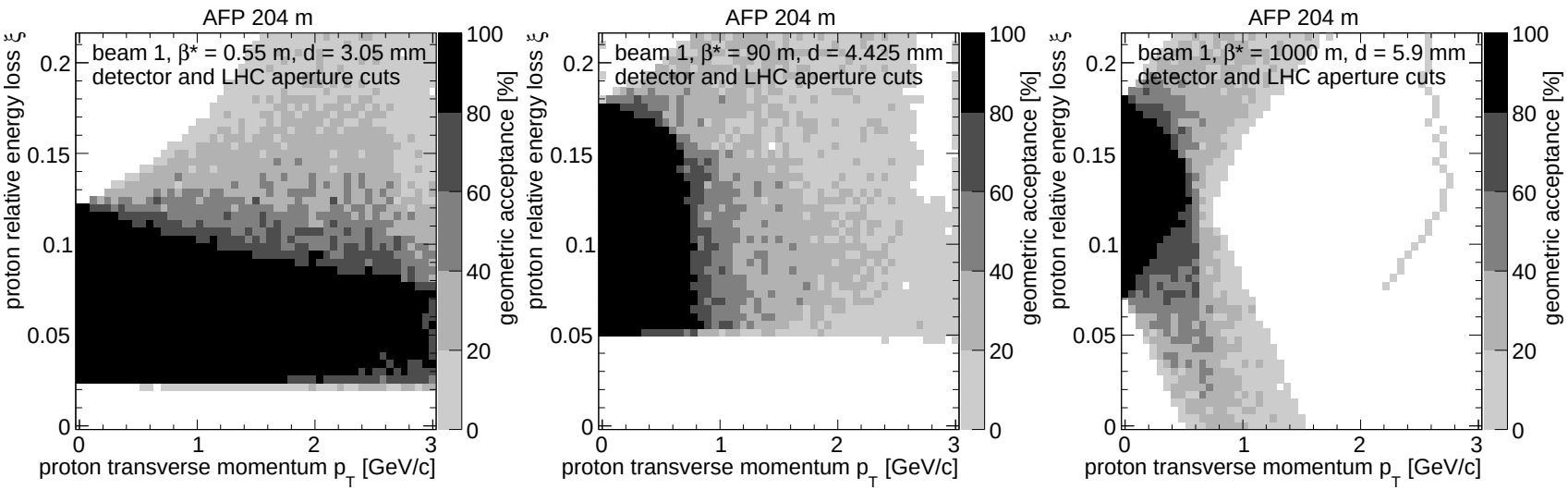
Proton spread in y for a given p_y is growing with β^*.

Acceptances – Summary

$\beta^* = 0.55$ m
15 σ
$0.02 < \xi < 0.12$

$\beta^* = 90$ m
7.5 σ
$0.05 < \xi < 0.18$

$\beta^* = 1000$ m
7.5 σ
$0.07 < \xi < 0.18$

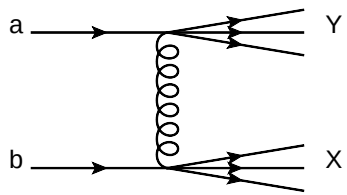


Soft Production Generators

Soft Processes

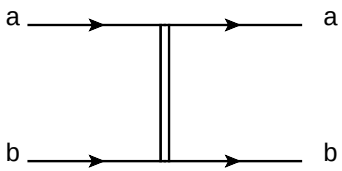
Perturbative approach of calculating is not valid; large cross-sections.

- **non-diffractive**:

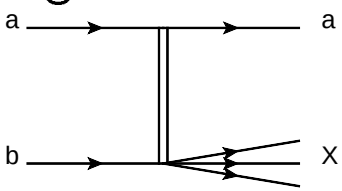


- **diffractive**:

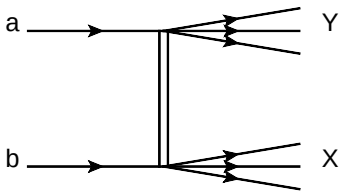
Elastic Scattering



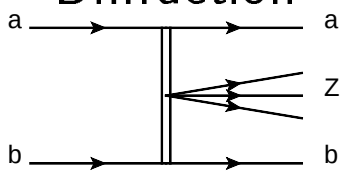
Single Diffraction



Double Diffraction



Central Diffraction



Diffraction:

- vacuum quantum numbers exchanged,
- Pomeron (QCD = two gluons + ...).

Natural ways to seek for diffraction:

- **rapidity gaps**,
- **forward protons**.

Probability of Single and Double Tag

Single Tag (ST) Interactions					
probability					
default	0.18	0.045	–	0.0055	0.038
MBR	0.12	0.040	0.42	0.0054	0.030
cross section [mb]					
default	2.3	0.40	–	0.32	3.0
MBR	1.3	0.38	0.34	0.30	2.3
	SD	DD	CD	ND	MB

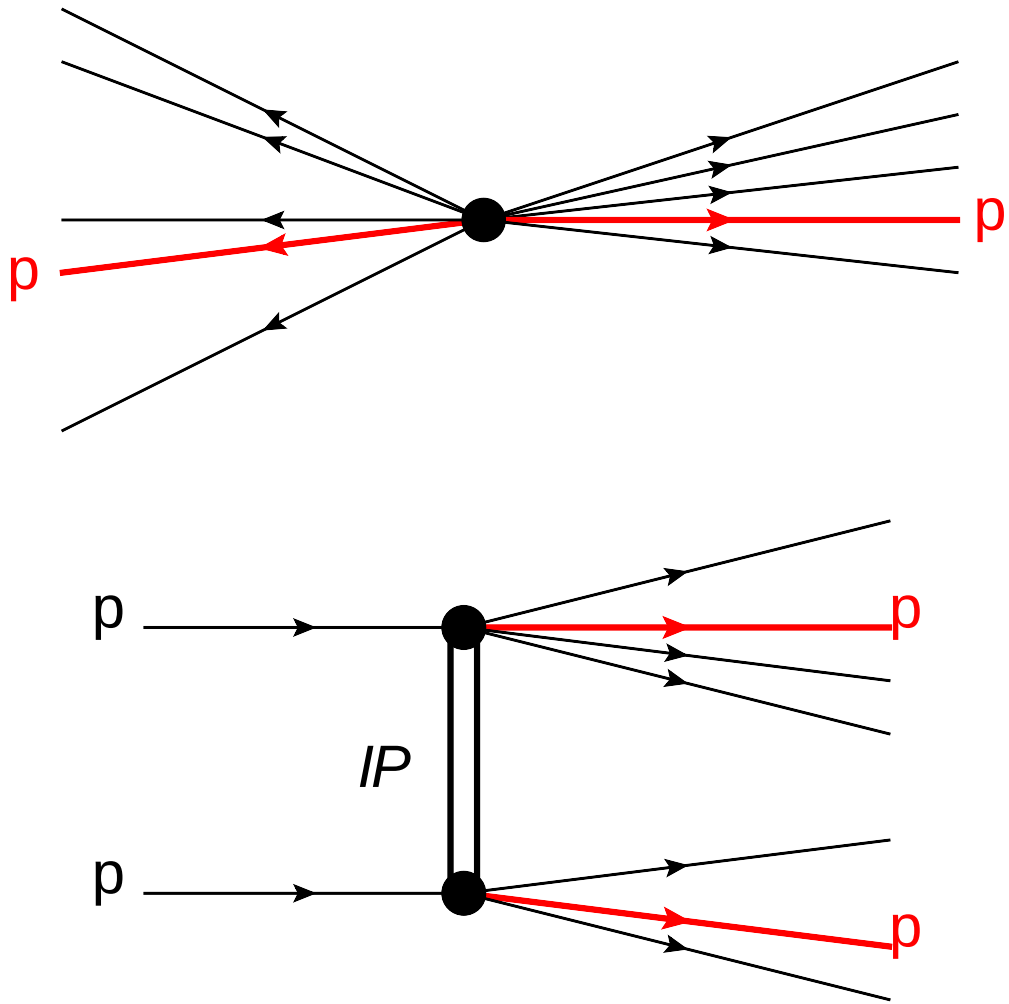
Double Tag (DT) Interactions					
probability $[10^{-3}]$					
default	0.47	0.37	–	0.014	0.13
MBR	0.31	0.36	26.0	0.012	0.37
cross section $[\mu b]$					
default	6.1	3.3	–	0.81	10
MBR	3.5	3.4	21	0.67	28
	SD	DD	CD	ND	MB

default – Schuler and Sjöstrand (PomFlux = 1)

MBR – Minimum Bias Rockefeller (PomFlux = 5)

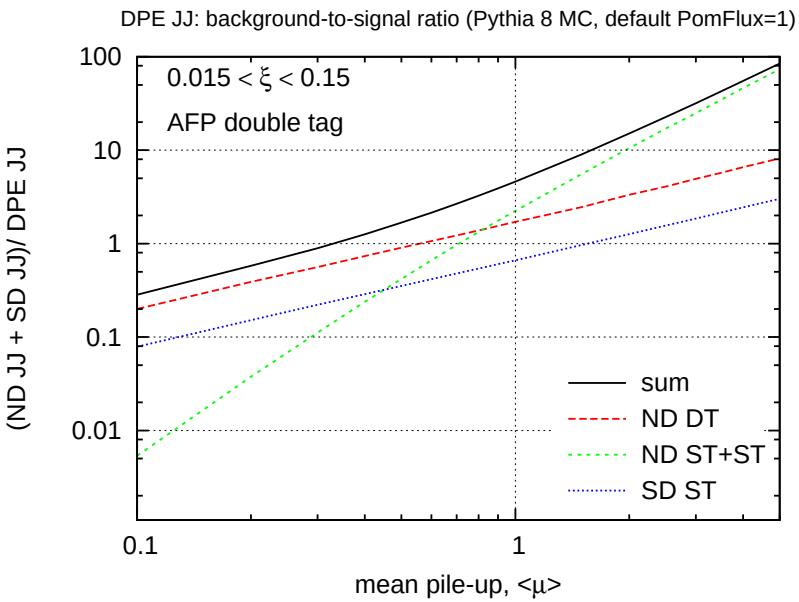
Double Tagged Soft Interaction(DT)

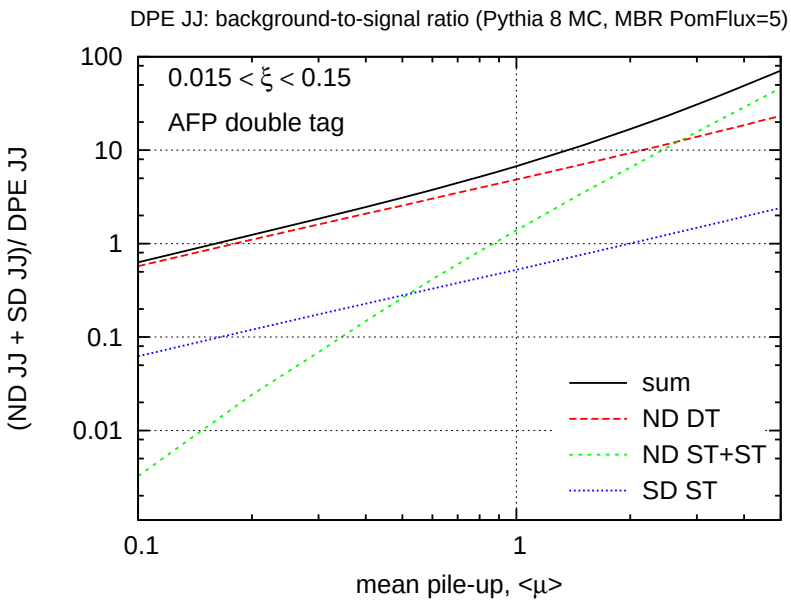
E.g. Double Diffractive Dissociation with protons from hadronisation propagating in forward direction.



Large differences between MC generators and tunes!

Example – Impact on DPE JJ Analysis

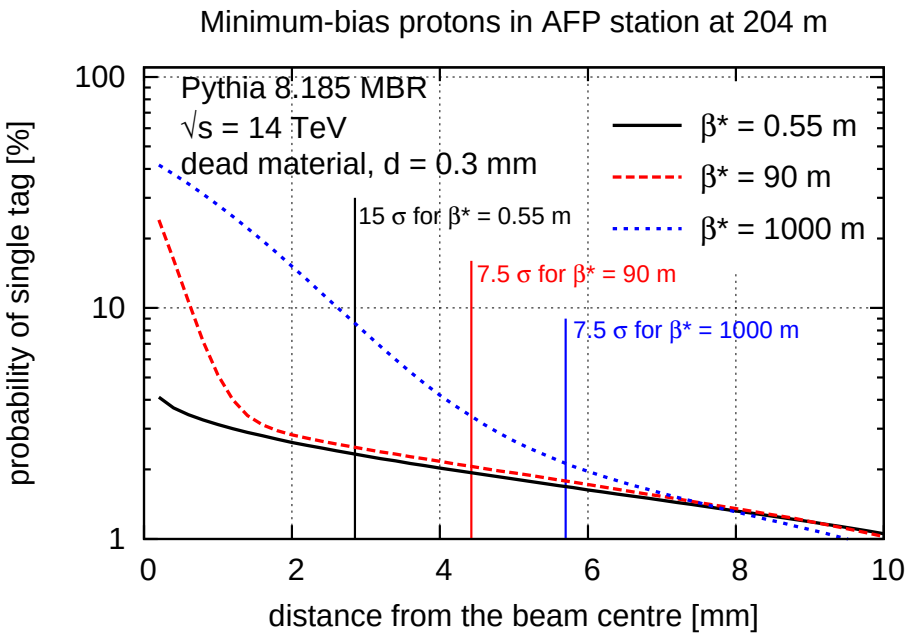


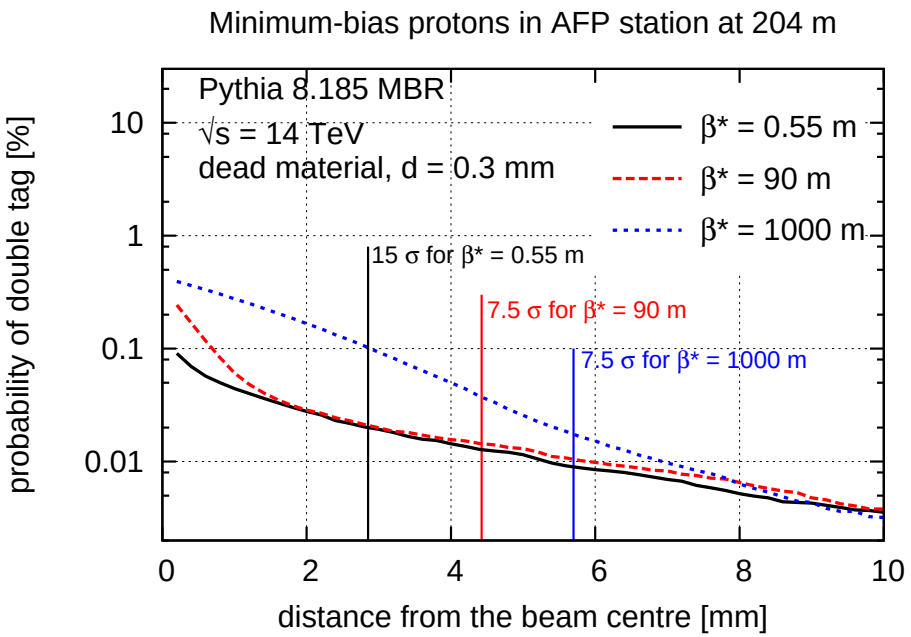


- generator: Pythia 8.165,
- **left**: Schuler and Sjöstrand (PomFlux = 1),
- **right**: MBR (PomFlux = 5),
- differences between tunes,
- differences between generators (not shown here).

Minimum-bias Events in AFP

Minimum-bias Protons in AFP





Top: Single Tag

Bottom: Double Tag

Assuming **realistic** values of 15 / 7.5 / 7.5 σ distance for $\beta^* = 0.55$ / 90 / 1000 m one can conclude that:

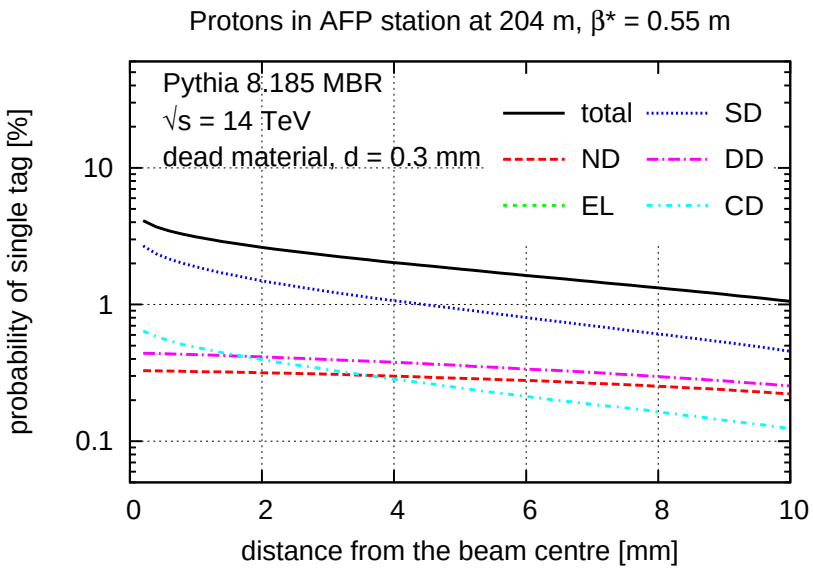
– background is on the same level for all optic settings for both ST and DT events,

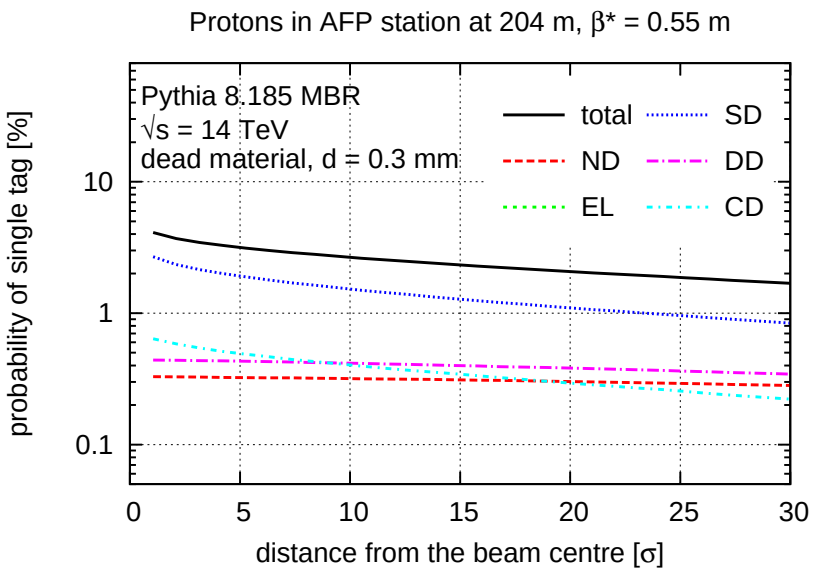
– ST probability is $\sim 2\%$,

– DT probability is $\sim 0.02\%$.

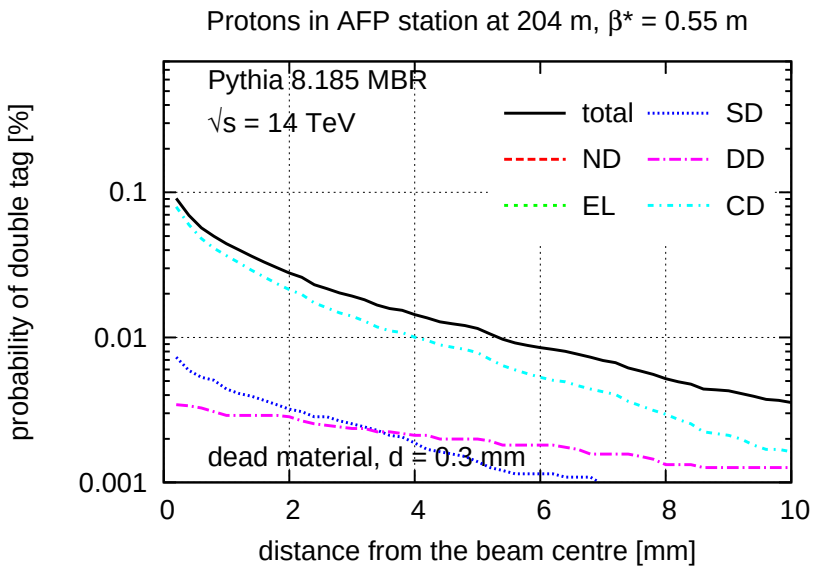
Minimum-bias Protons in AFP – Origin, $\beta^* = 0.55$ m

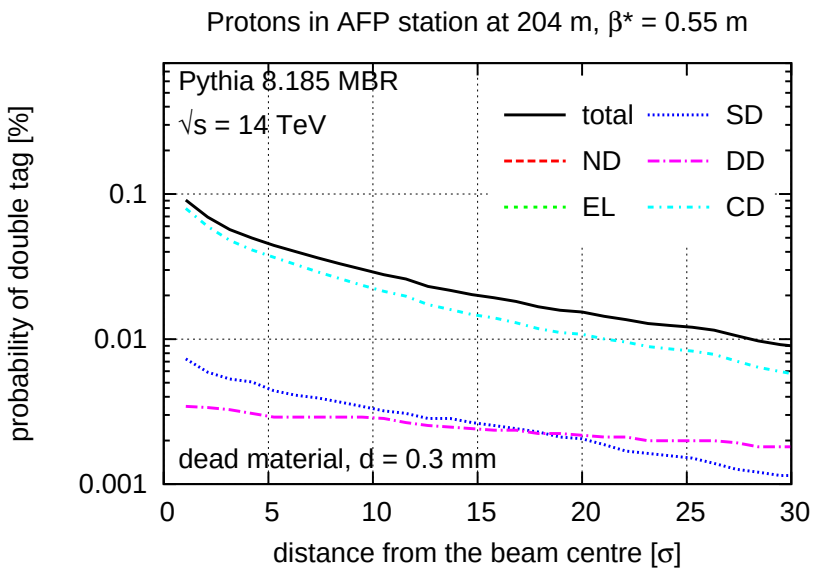
Single Tagged Events





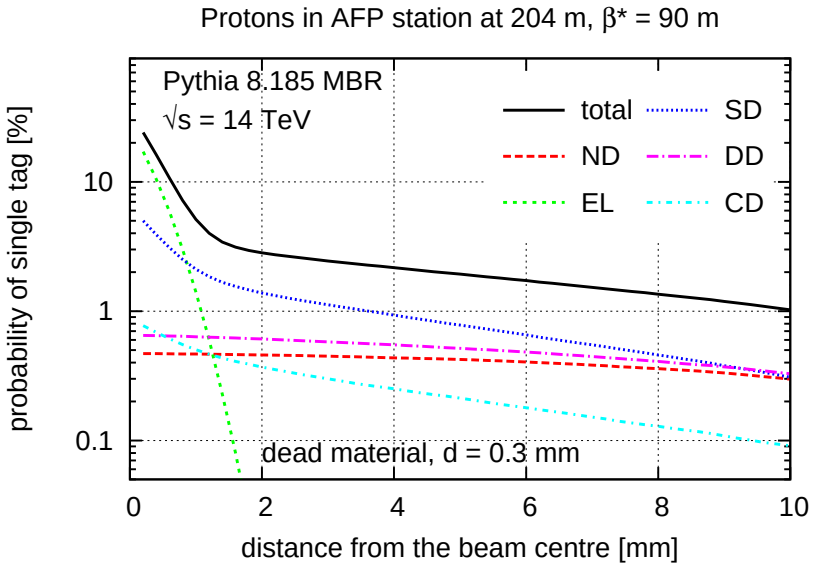
Double Tagged Events



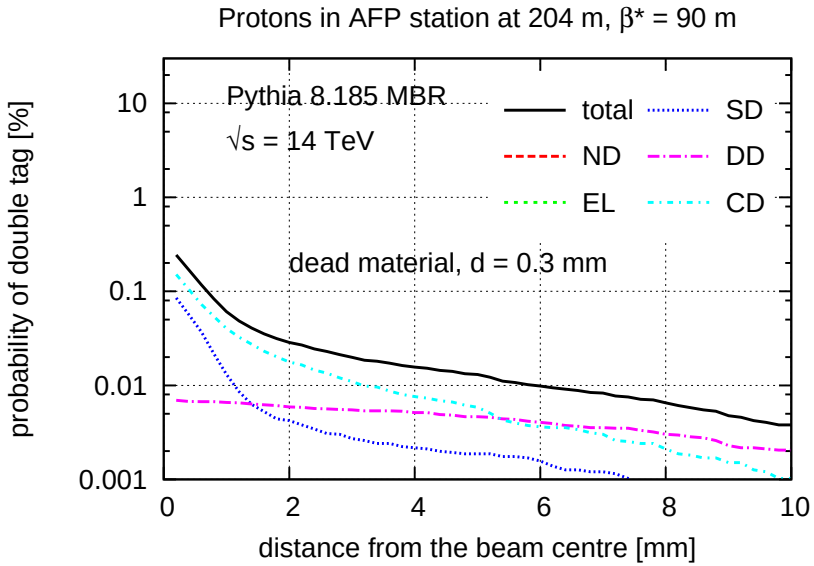


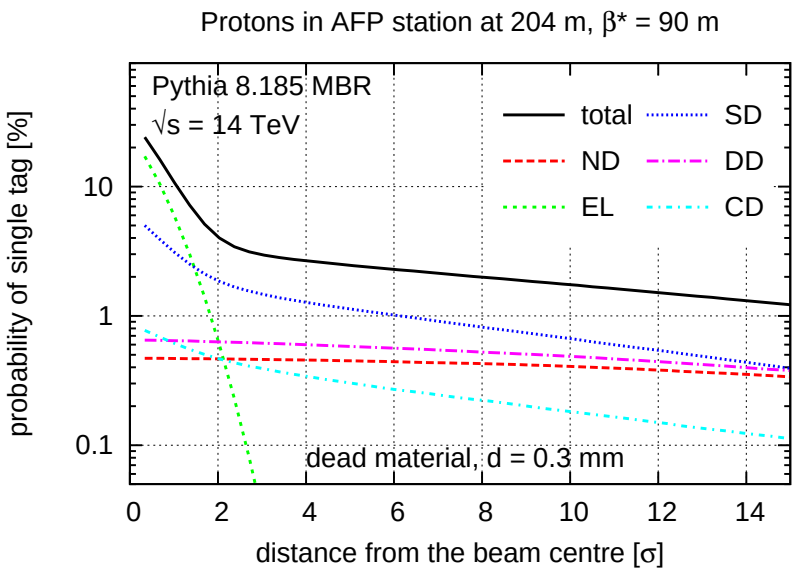
Minimum-bias Protons in AFP – Origin, $\beta^* = 90$ m

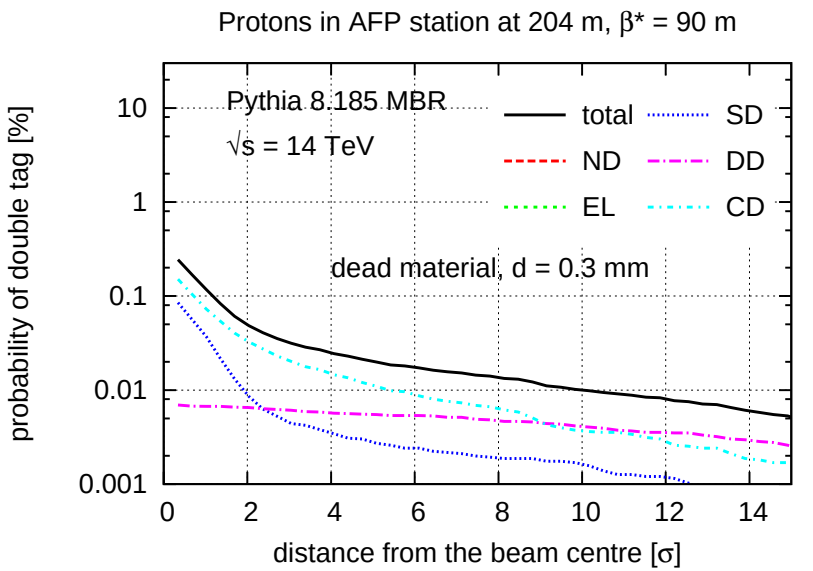
Single Tagged Events



Double Tagged Events

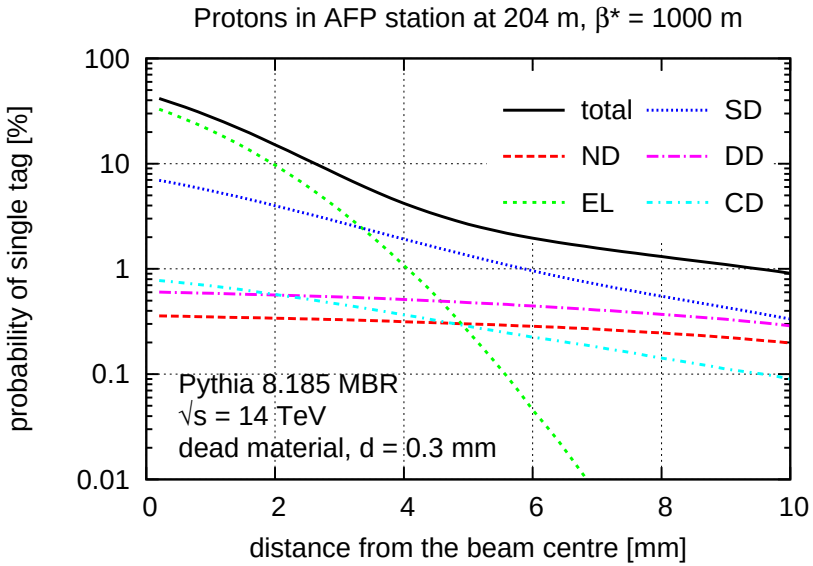


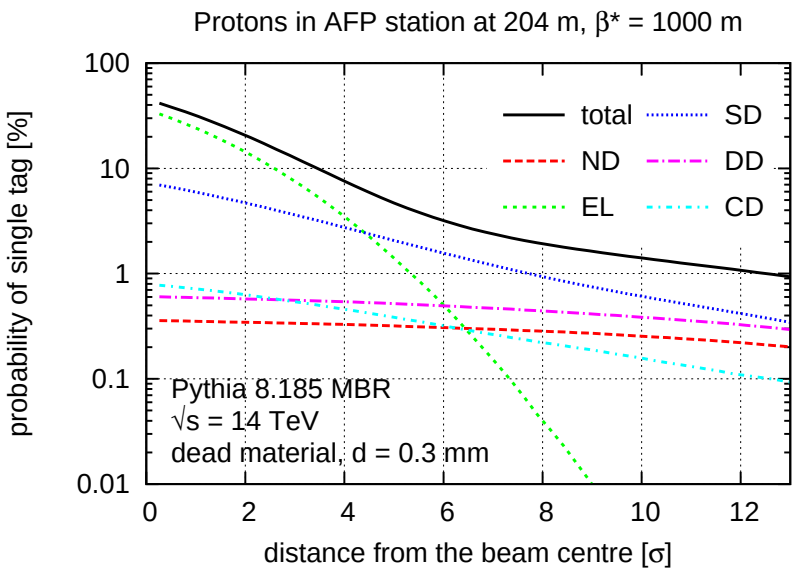




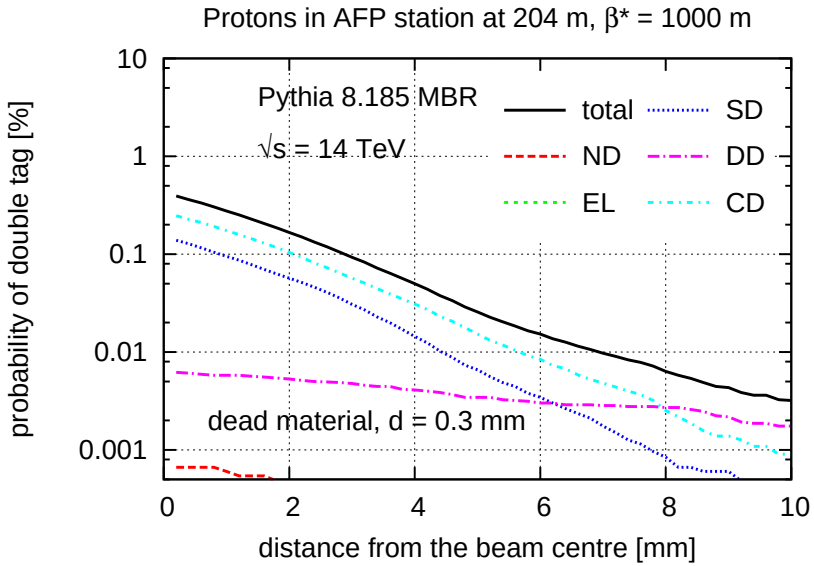
Minimum-bias Protons in AFP – Origin, $\beta^* = 1000$ m

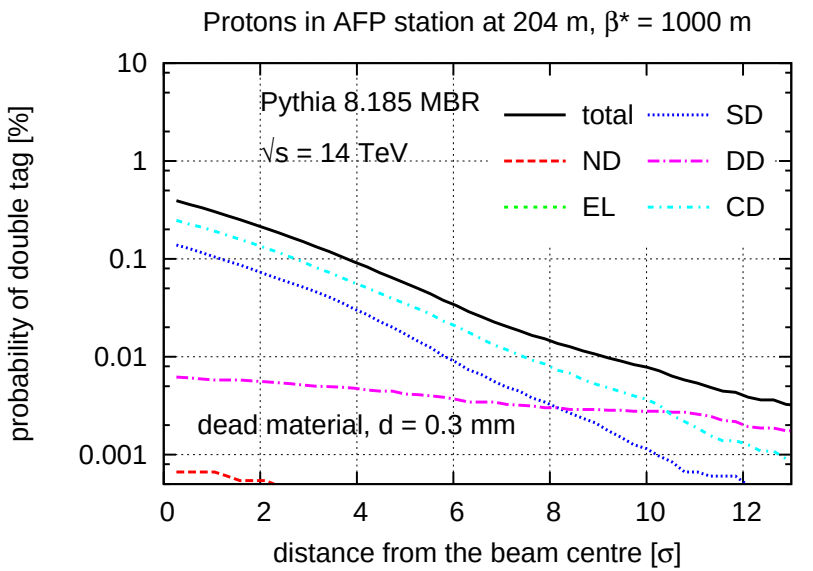
Single Tagged Events





Double Tagged Events

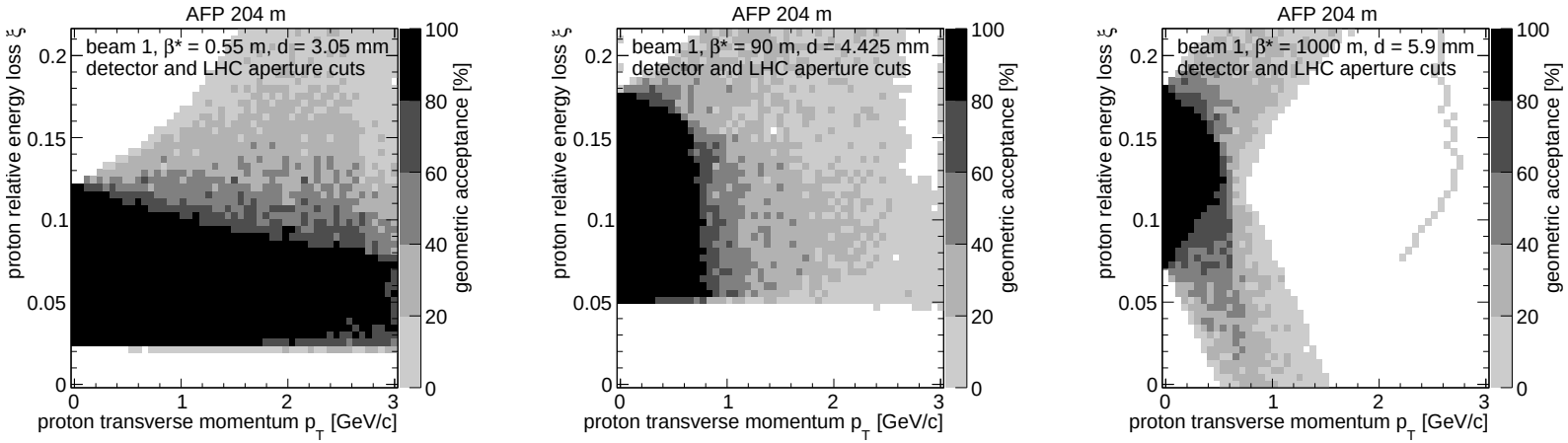




Summary

Summary

- Acceptance:



- Large differences in ST and DT predictions between MC generators and tunes – uncertainty on background level for hard diffractive productions.

- Assuming **realistic** values of 15 / 7.5 / 7.5 σ distance for $\beta^* = 0.55$ / 90 / 1000 m one can conclude that:
  - background is on the same level for all optic settings for both ST and DT events,
  - – ST probability is $\sim 2\%$,
  - – DT probability is $\sim 0.02\%$.

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