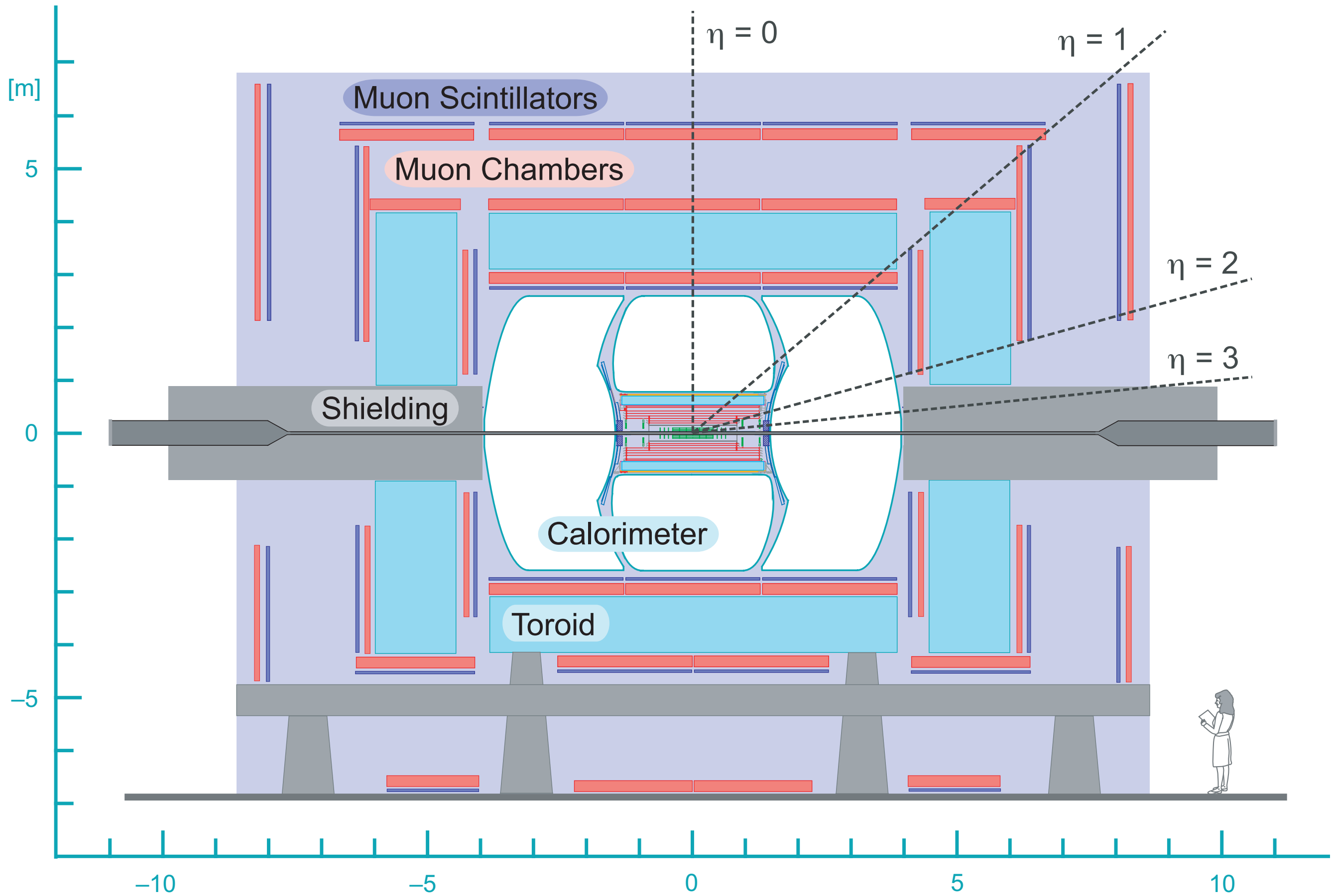
Part I: Heavy baryon forward-backward asymmetries in $p\bar{p}$ collisions

Part II: Confirmation of the exotic state $X(5568) \rightarrow B_s^0 \pi^\pm$ in $p\bar{p}$ collisions

B. Hoeneisen
Universidad San Francisco de Quito
Representing the DØ Collaboration

EPS-HEP 5-12 July 2017



The DØ detector at the $p\bar{p}$ Tevatron collider. $\sqrt{s} = 1.96$ TeV.

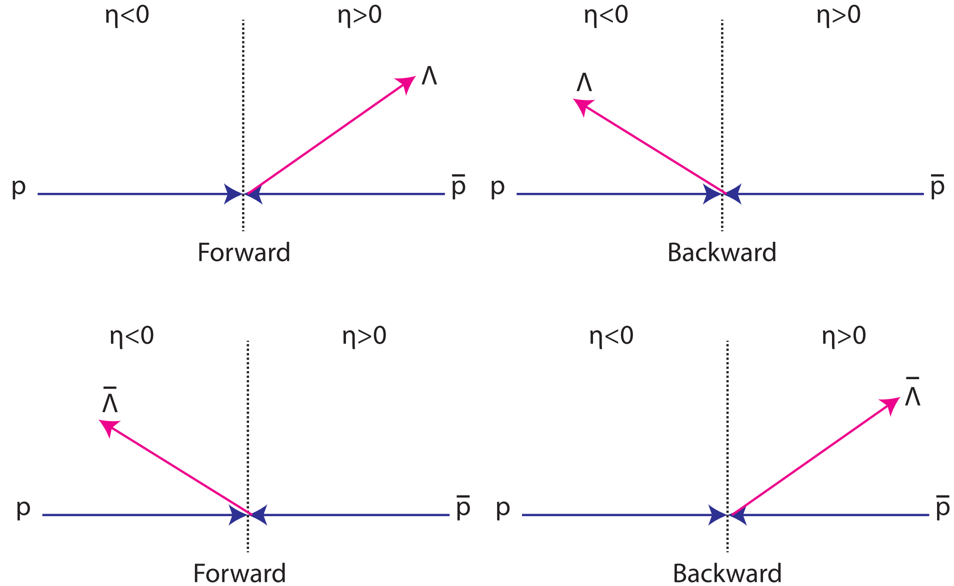
Part I: Heavy baryon forward-backward asymmetries in $p\bar{p}$ collisions

The DØ detector is well suited to measure forward-backward asymmetries:

- the initial state is CP eigenstate $p\bar{p}$,
- the solenoid and toroid magnetic fields are reversed periodically allowing studies and cancellations of systematic uncertainties.

Measurements of forward-backward asymmetries are a legacy of the Tevatron that test models of forward production.

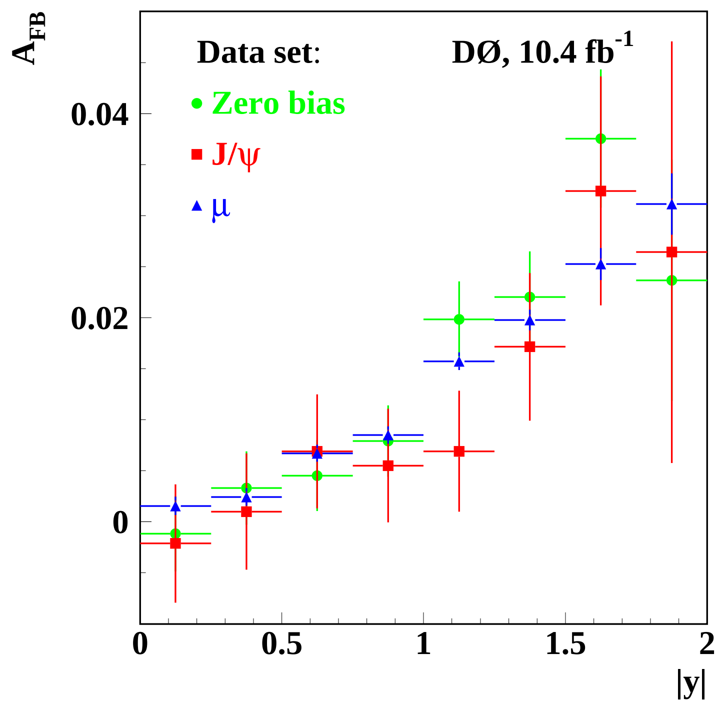
Definition of the forward-backward asymmetry $A_{FB}(\Lambda, \bar{\Lambda})$:



Forward Λ's have longitudinal momentum in the p direction.
Forward $\bar{\Lambda}$'s have longitudinal momentum in the $\bar{p}$ direction.

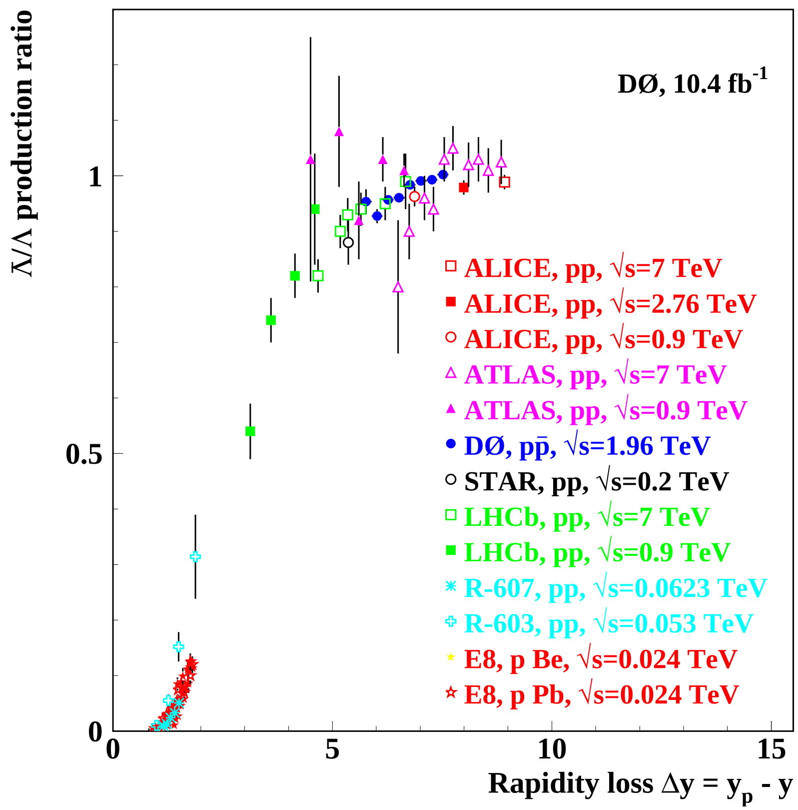
Asymmetry in a bin of rapidity $|y|$: $A_{FB} \equiv \frac{N_F - N_B}{N_F + N_B}$

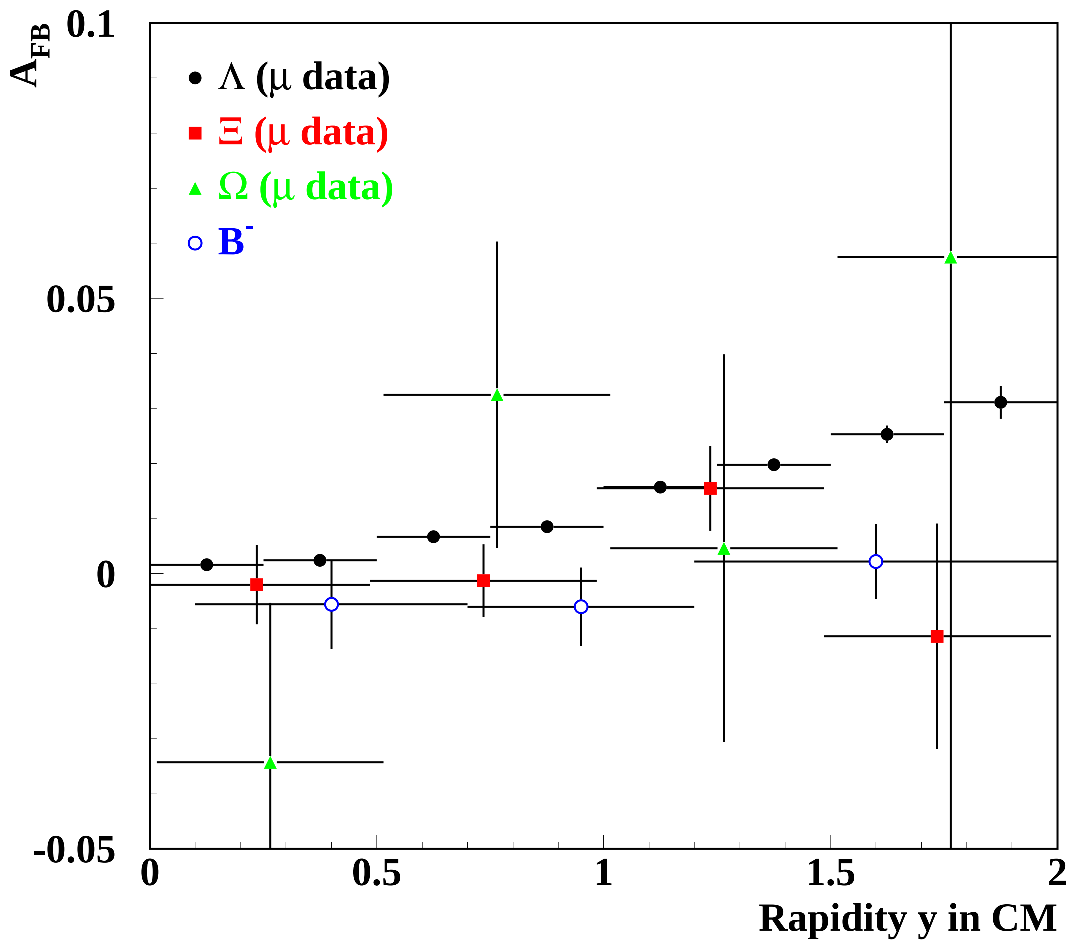
Forward-backward asymmetry $A_{FB}(\Lambda, \bar{\Lambda})$ in $p\bar{p}$ collisions.



Phys. Rev. **D** 93, 032002 (2016), arXiv:1511.05113

$\bar{\Lambda}/\Lambda$ production ratio vs "rapidity loss" $y_p - y$ for $pZ \to \Lambda(\bar{\Lambda})X$



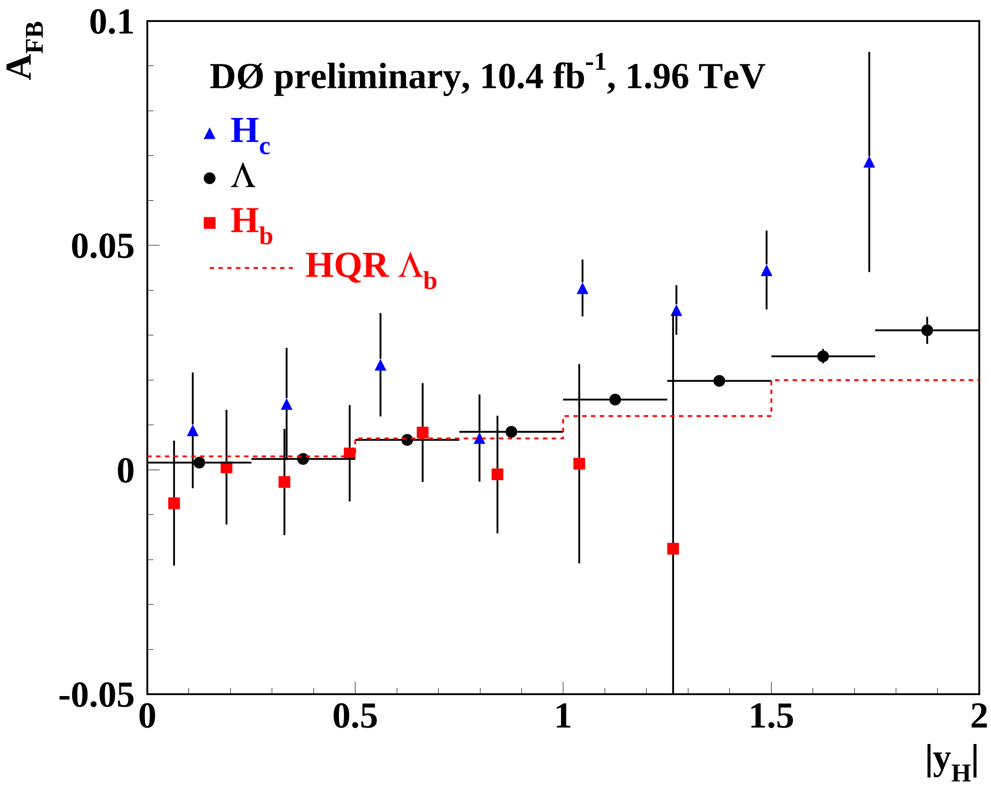


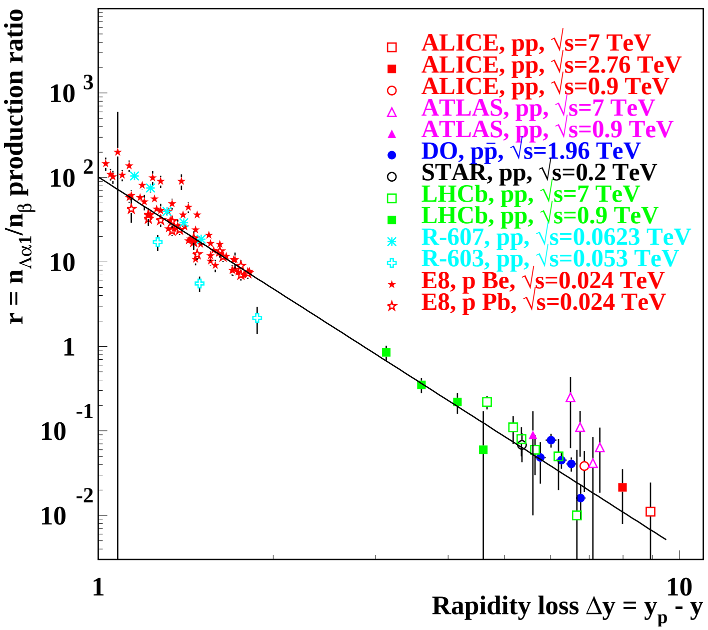
Phys. Rev. **D** 93, 032002 (2016), arXiv:1511.05113
Phys. Rev. **D** 93, 112001 (2016), arXiv:1605.03513

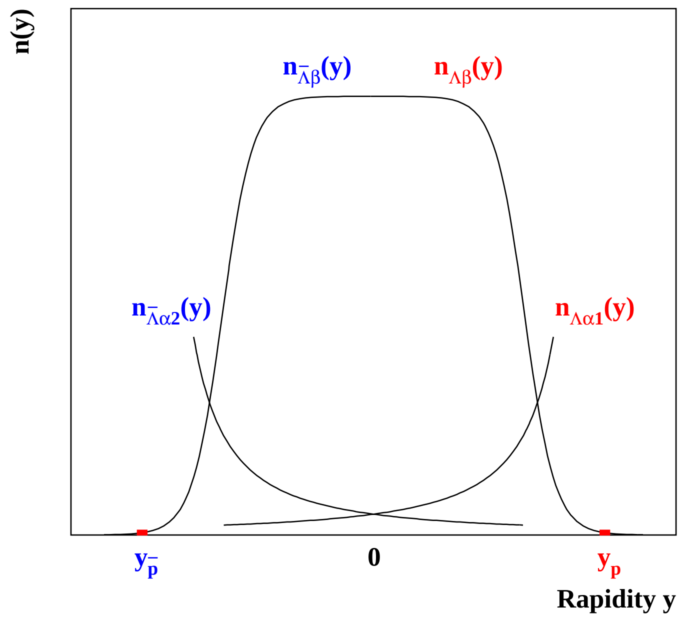
Phys. Rev. Lett. 114, 051803 (2015), arXiv:1411.3021

New preliminary result. A_{FB} of Λ and heavy baryons with a c or b quark.

$H_c \rightarrow \mu^+ \Lambda X$. $H_b \rightarrow \mu^- H_c$ followed by $H_c \rightarrow \Lambda X$. HQR: Phys. Rev. D91, 054022 (2015)







Conclusions: A simple 2 component production model (central production β and forward production α) adequately represents all data. At small rapidity loss, the presence of the α component depends on having a shared (di)quark between the outgoing baryon and the parent proton.

$r \equiv \sigma(\Lambda)/\sigma(\bar{\Lambda}) - 1$, B.H., Phys. Lett. B 760, p. 242 (2016), arXiv:1604.05379

Part II: Confirmation of the exotic state $X(5568) \to B_s^0\pi^\pm$ in $p\bar{p}$ collisions.

$X(5568)(bu\bar{s}\bar{d}) \to \bar{B}_s^0(b\bar{s})\pi^+(u\bar{d})$

DØ saw $B_s\pi^\pm$ resonance at $M = 5568$ MeV, slightly above threshold. B_s^0 is fully mixed so quark anti-quark composition is undetermined. The non-zero width implies a strong decay. (Phys. Rev.Lett., 117, 022003 (2016))

Models:
Molecular state, e.g. colorless $\bar{B}_d^0(b\bar{d})$ loosely coupled to colorless $K^+(u\bar{s})$ should have a mass close to $m(B_d^0) + m(K^+) = 5773$ MeV. This model is disfavored.

Tightly bound tetraquark e.g. $(bd)(\bar{s}\bar{u})$, $(bu)(\bar{s}\bar{d})$, $(su)(\bar{b}\bar{d})$, or $(sd)(\bar{b}\bar{u})$.

See arXiv:1705.03741 for scalar-scalar diquark-antidiquark 0^+ state.

Published: B_s^0 is reconstructed in hadronic channel:

$$B_s^0 \to J/\psi\phi, \qquad J/\psi \to \mu^+\mu^-, \qquad \phi \to K^+K^-.$$

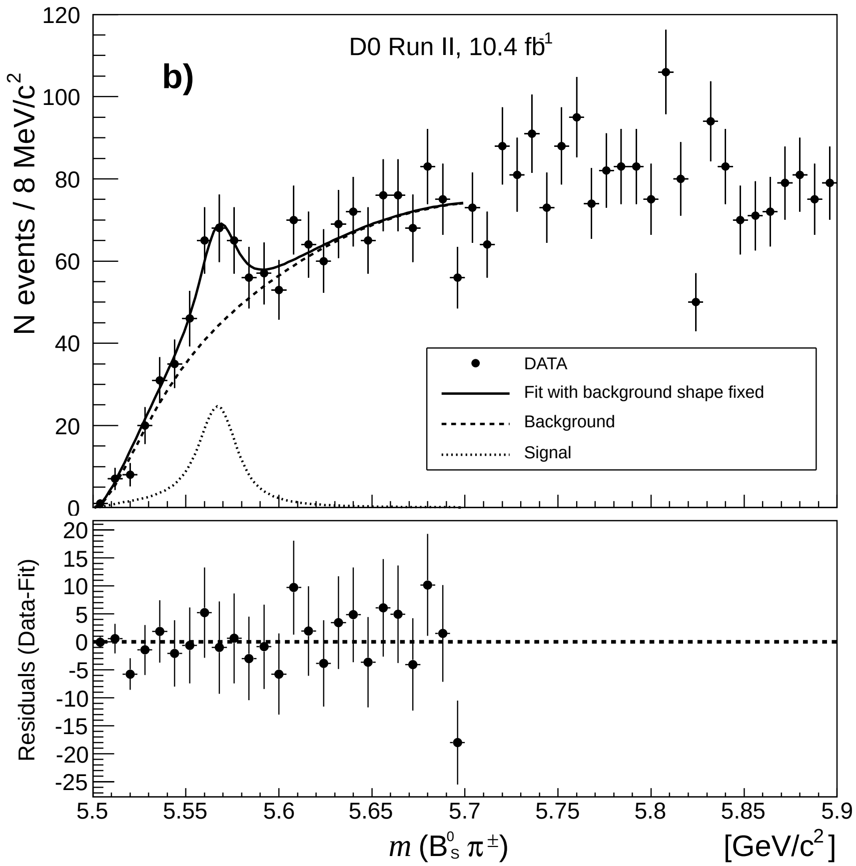
Confirmation: B_s^0 is reconstructed in semi-leptonic channel:

$$B_s^0 \to \mu^\mp D_s^\pm X, \qquad D_s^\pm \to \phi\pi^\pm, \qquad \phi \to K^+K^-.$$

4.5 GeV $< m(\mu^+ D_s^-) < m(B_s^0)$ to reduce ν_μ contribution.

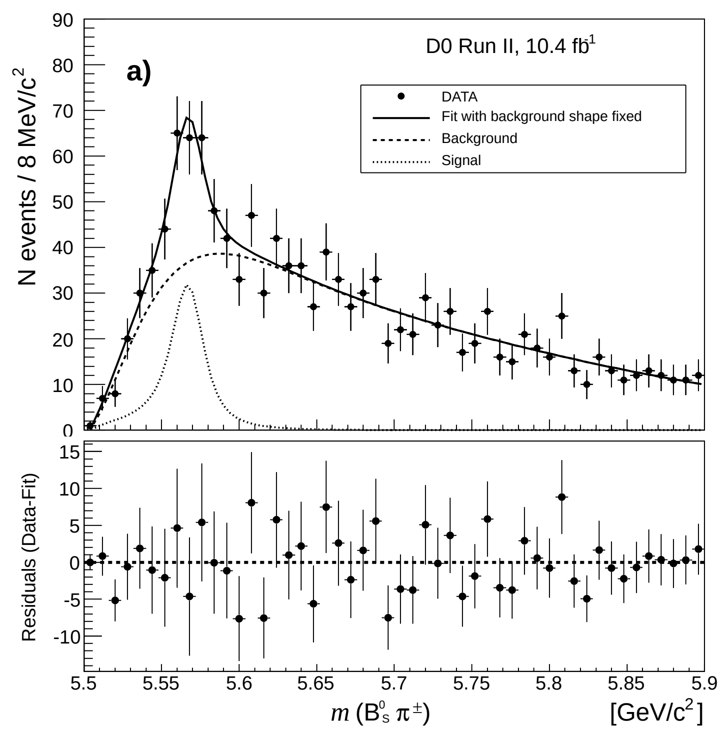
The hadronic and semileptonic channels have independent events, signals, backgrounds and triggers.

$X(5568) \to B_s^0 \pi^\pm$



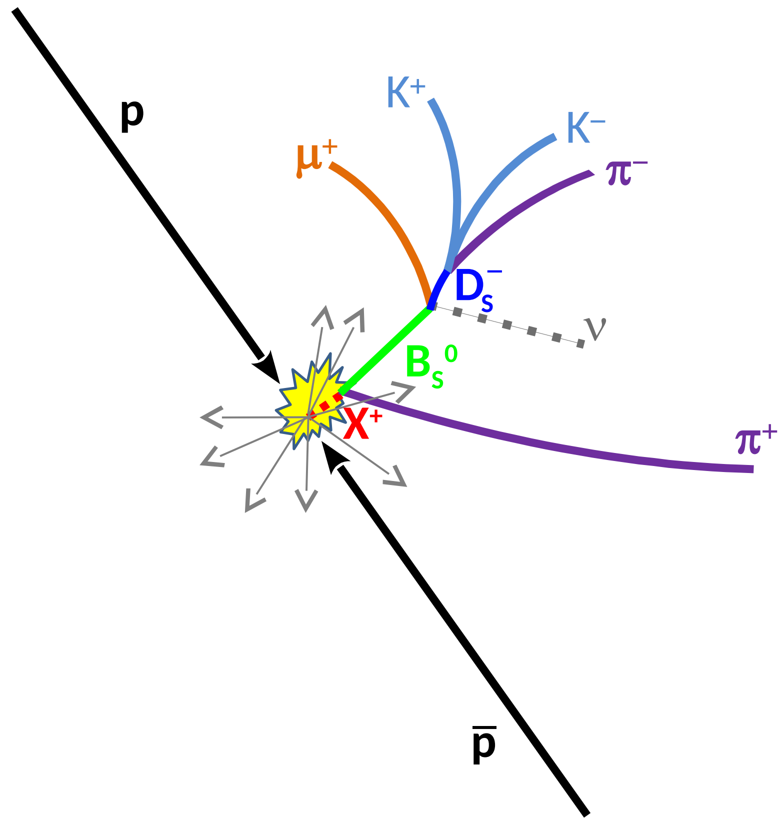
$X(5568) \to B_s^0 \pi^\pm$

with cone cut $\Delta R(B_s^0, \pi) = \sqrt{\Delta\eta^2 + \Delta\phi^2} < 0.3$

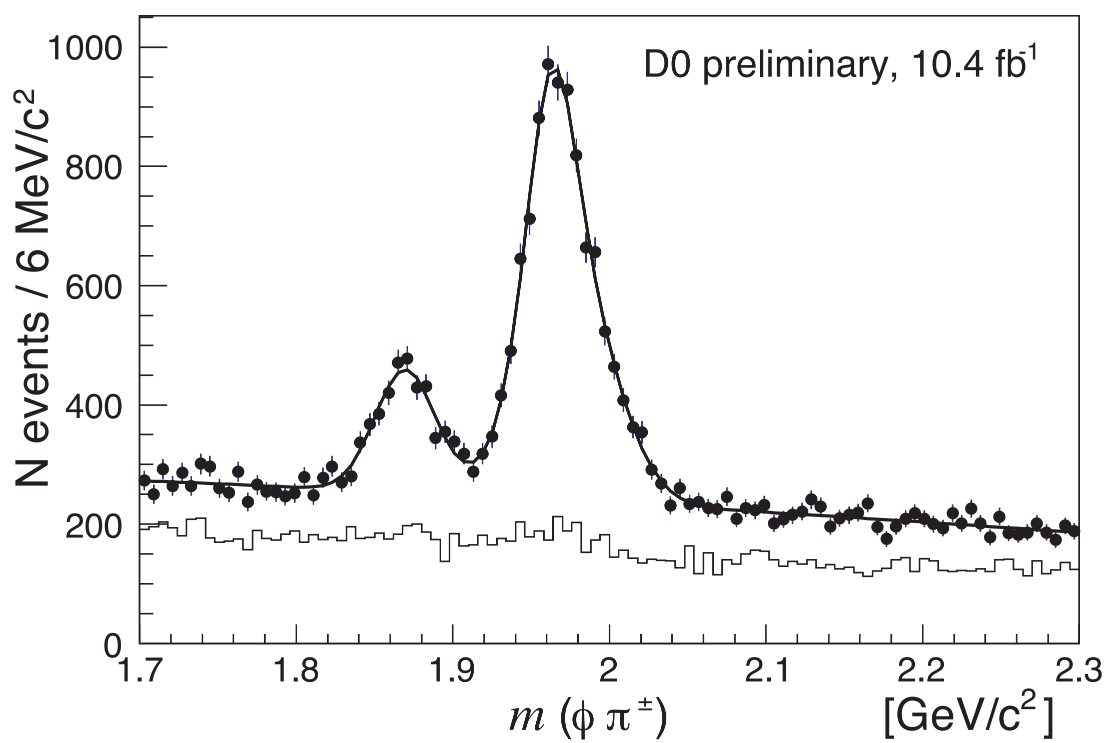


$X(5568) \to B_s^0 \pi^\pm$ with B_s in semi-leptonic channel.

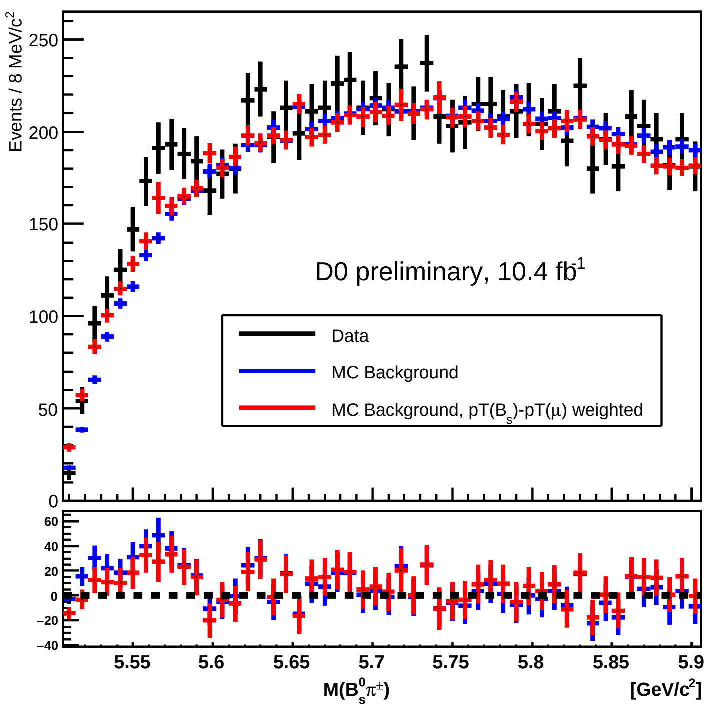
$B_s^0 \to \mu^\mp D_s^\pm X, \quad D_s^\pm \to \phi \pi^\pm, \quad \phi \to K^+ K^-$

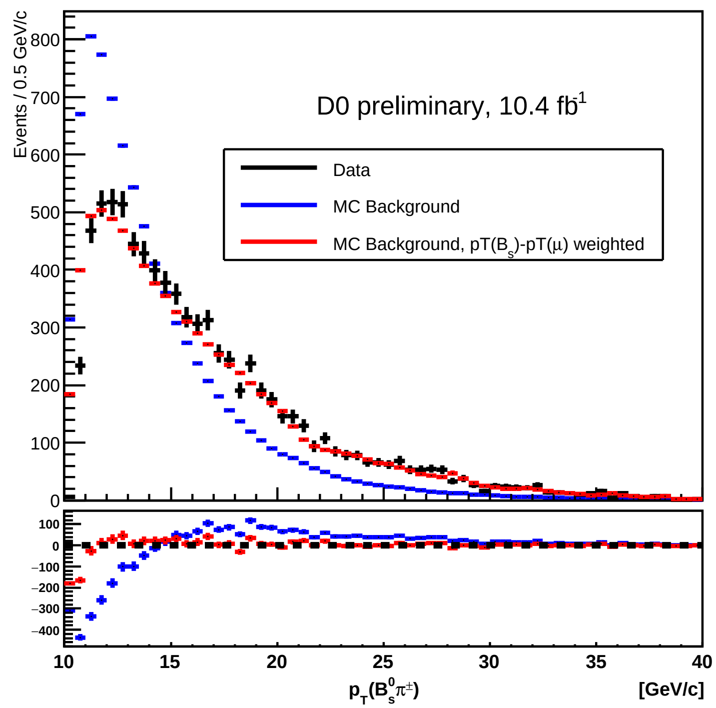


$m(K^+K^-\pi^\pm)$ for right sign $\mu^\pm\phi\pi^\mp$ showing $D^\pm$ and $D_s^\pm$ meson decays (and wrong sign combination).



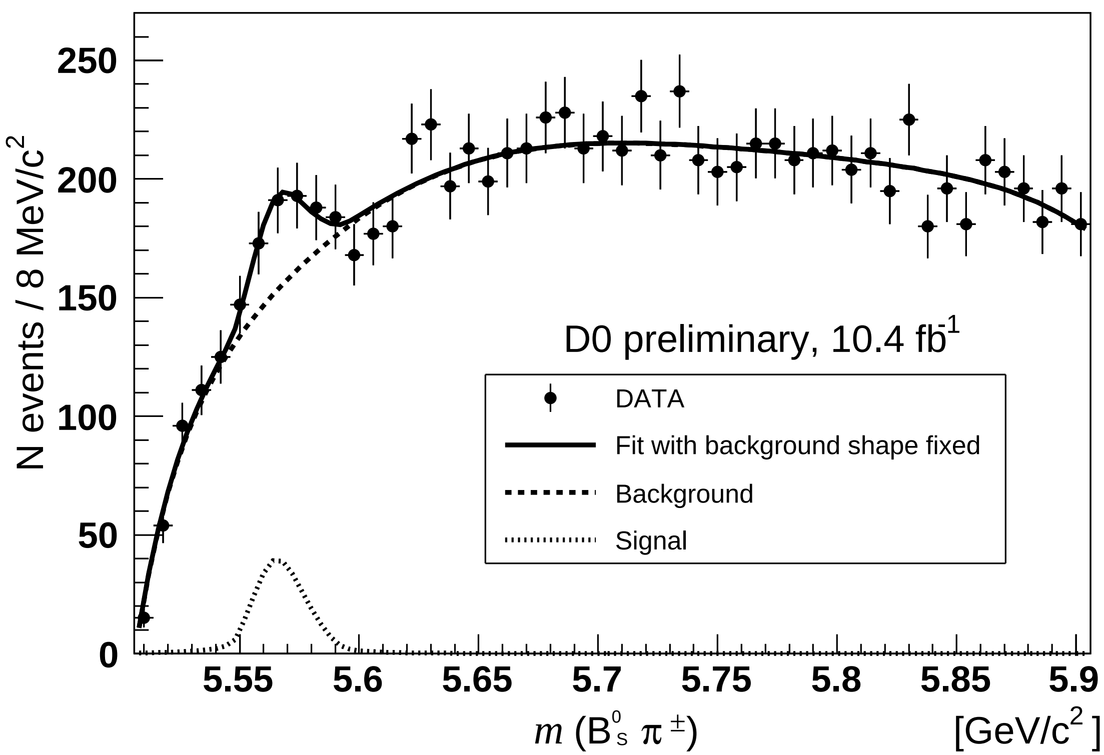
$m(B_s^0\pi^\pm)$ and $p_T(B_s^0\pi^\pm)$





Weight MC in $p_T(\mu)$ and $p_T(\mu D_s)$ to fit data.

Semileptonic channel (no cone cut is applied)



	Semileptonic	Hadronic with cone cut	Hadronic no cone cut
Mass [MeV]	$5566.7^{+3.6}_{-3.4} \pm 1.0$	$5567.8 \pm 2.9^{+0.9}_{-1.9}$	5567.8
Width [MeV]	$6.0^{+9.5}_{-6.0}{}^{+1.9}_{-4.6}$	$21.9 \pm 6.4^{+5.0}_{-2.5}$	21.9
Events	$139^{+51}_{-63}{}^{+10.9}_{-31.5}$	$133 \pm 31 \pm 15$	106 ± 23
Significance*	3.2σ	5.1σ	3.9σ
Fraction**	$7.3^{+2.8}_{-2.4}{}^{+0.6}_{-1.7}\%$	$8.6 \pm 1.9 \pm 1.4\%$	

* with systematics (and LEE for hadronic). ** Fraction of B_s^0 from $X(5568)$.

Combined semileptonic and hadronic channel signficance with (without) hadronic channel cone cut is 5.7σ (4.7σ), including systematics and LEE.

Conclusions

- Confirmed observation of $X(5568)$ in $p\bar{p}$ collisions with B_s^0 decaying in semileptonic channel.

- $X(5568)$ is not observed by LHCb or CMS in pp collisions, so the production may be enhanced in the $p\bar{p}$ initial state.

References

V.M. Abazov et al. (D0 Collaboration), "Confirmation of the $X(5568)$ with semileptonic decays of the B_s^0 meson", conference note, https://www-d0.fnal.gov/Run2Physics/WWW/results/prelim/B/B68/.

V.M. Abazov et al. (D0 Collaboration), "Evidence for a $B_s\pi^\pm$ state", Phys. Rev. Lett. 117, 022003 (2016), arXiv:1602.07588.

V.M. Abazov et al. (D0 Collaboration), "Measurement of the forward-backward asymmetries in the production of Ξ and Ω baryons in $p\bar{p}$ collisions" Phys. Rev. **D** 93, 112001 (2016), arXiv:1605.03513.

B. Hoeneisen, "Ratio between two Λ and $\bar{\Lambda}$ production mechanisms in p scattering",

Phys. Lett. B 760, p. 242 (2016), arXiv:1604.05379.

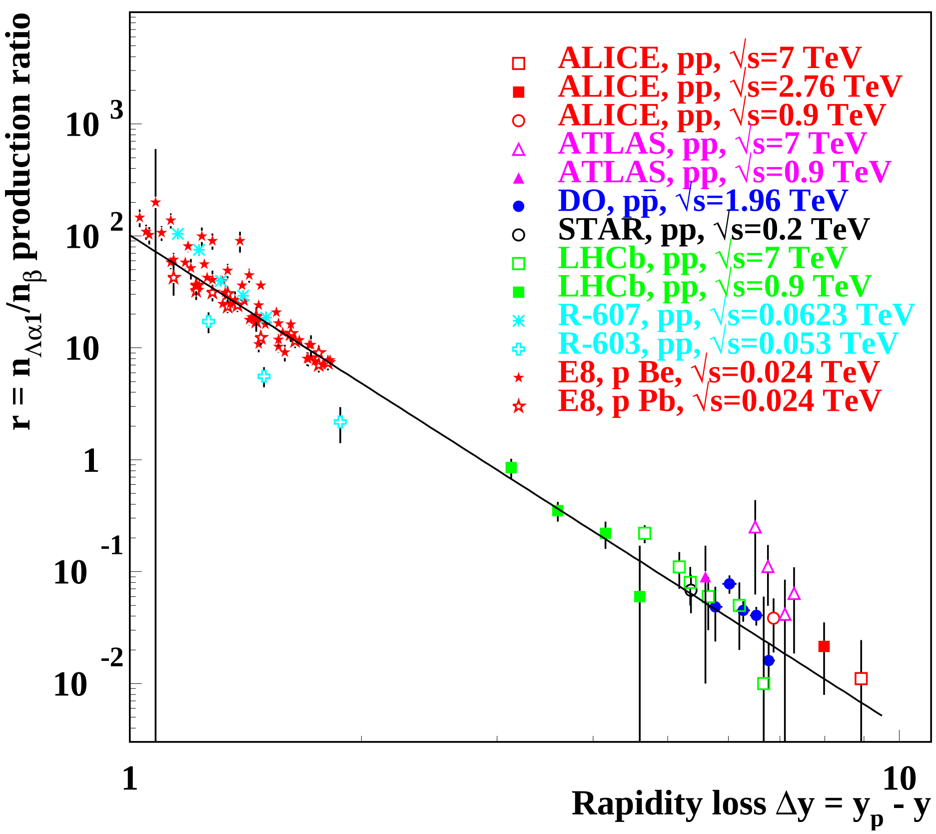
V.M. Abazov et al. (D0 Collaboration), "Measurement of the forward-backward asymmetry of Λ and $\bar{\Lambda}$ production in $p\bar{p}$ collisions", Phys. Rev. **D** 93, 032002 (2016), arXiv:1511.05113.

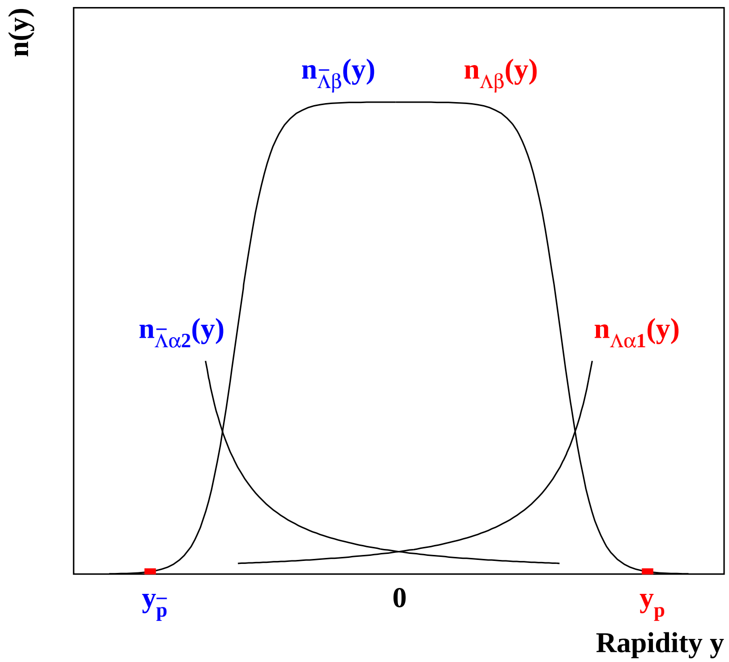
V.M. Abazov et al. (D0 Collaboration), "Measurement of the forward-backward asymmetry in Λ_b^0 and $\bar{\Lambda}_b^0$ baryon production in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV", Phys. Rev. **D** 91, 072008 (2015). arXiv:1503.03917.

V.M. Abazov et al. (D0 Collaboration), "Measurement of the forward-backward asymmetry in the production of $B^{\pm}$ in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV", Phys. Rev. Lett. 114, 051803 (2015), arXiv:1411.3021.

Backup slides

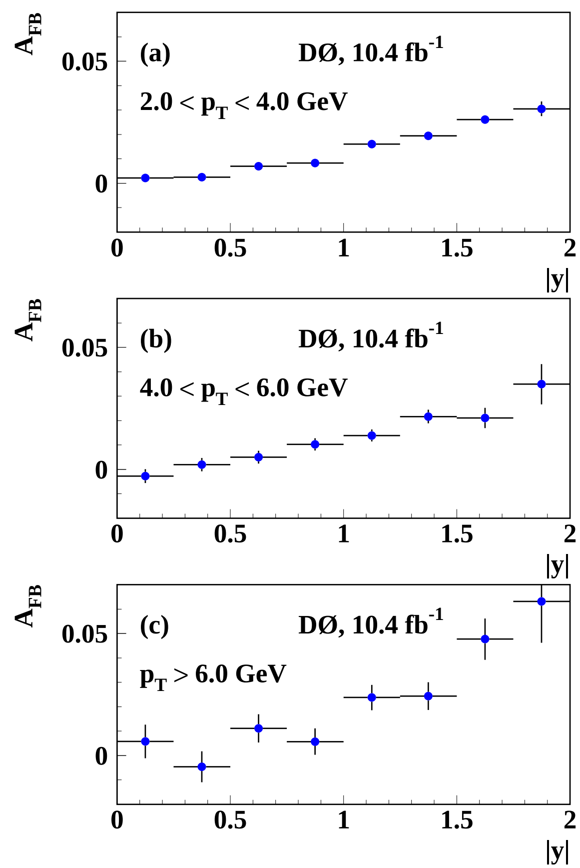
Ratio r as a function of rapidity loss $y_p - y$ from the listed experiments.





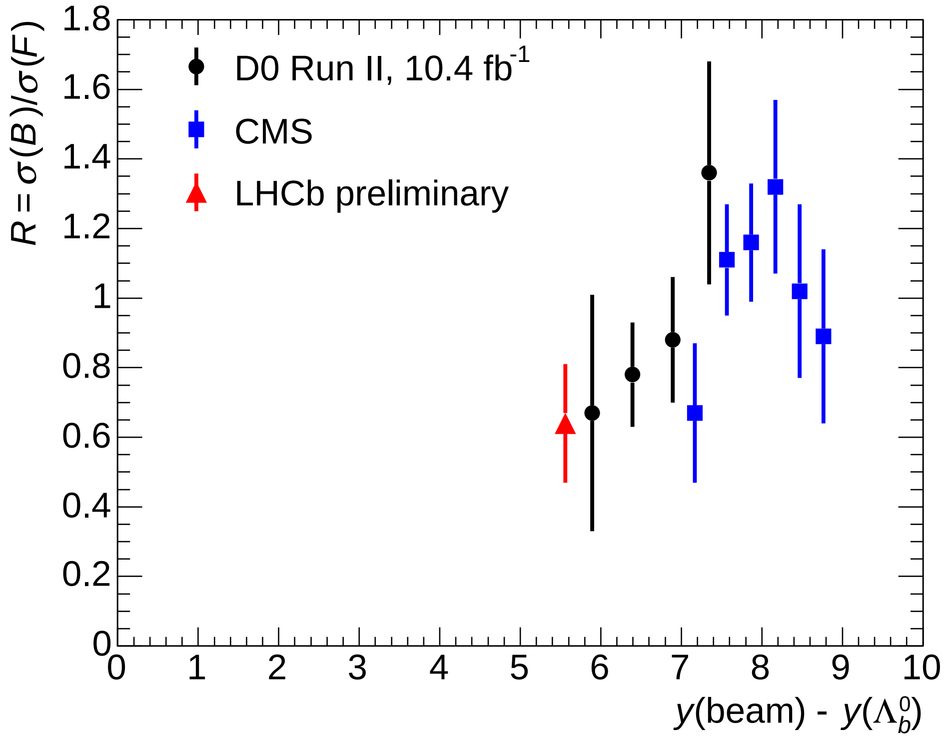
$$r \equiv \frac{n_{\Lambda\alpha 1}(y)}{n_\beta(y)},$$

$$A_{FB} \equiv \frac{r}{2+r} \quad \text{if } p\bar{p}; \qquad \frac{\sigma(\bar{\Lambda})}{\sigma(\Lambda)} \equiv \frac{1}{1+r} \quad \text{if } pp.$$



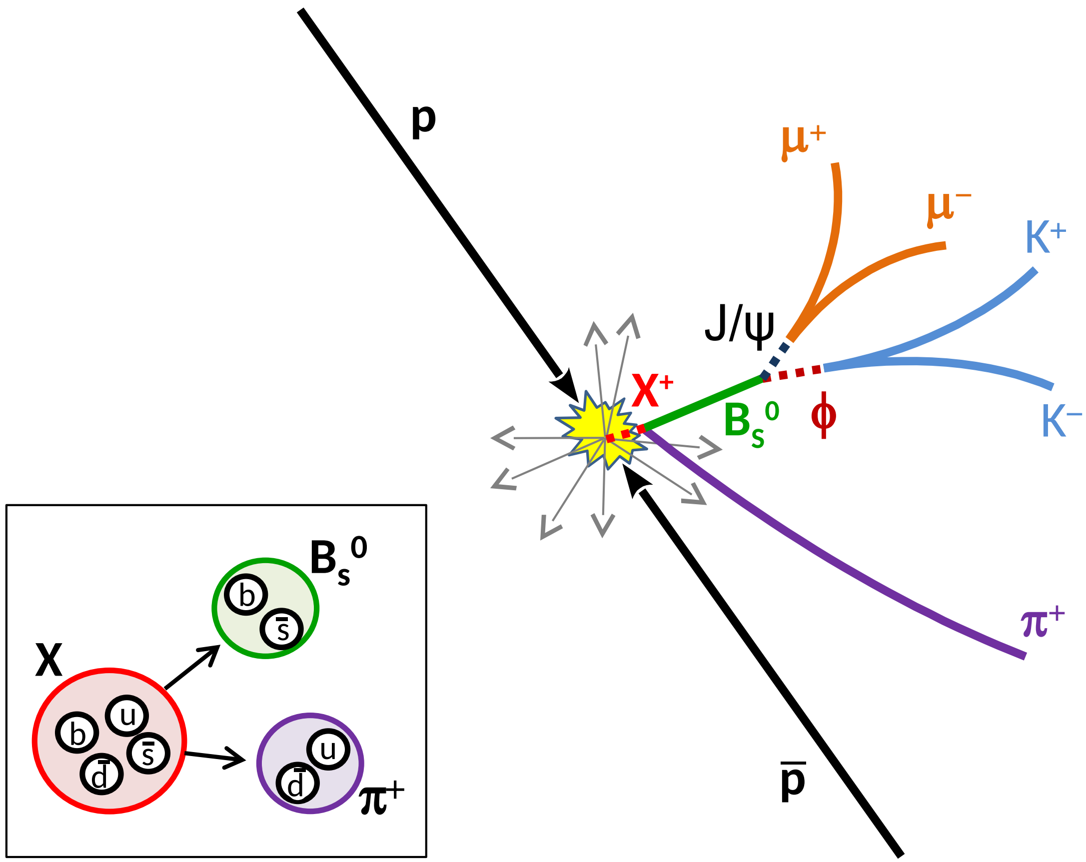
Dependence of $A_{FB}(\Lambda, \bar{\Lambda})$ on p_T.

Ratio $\bar{\Lambda}_b/\Lambda_b$ vs "rapidity loss" $y(\text{beam}) - y(\Lambda_b)$, from CMS, LHCb and DØ.

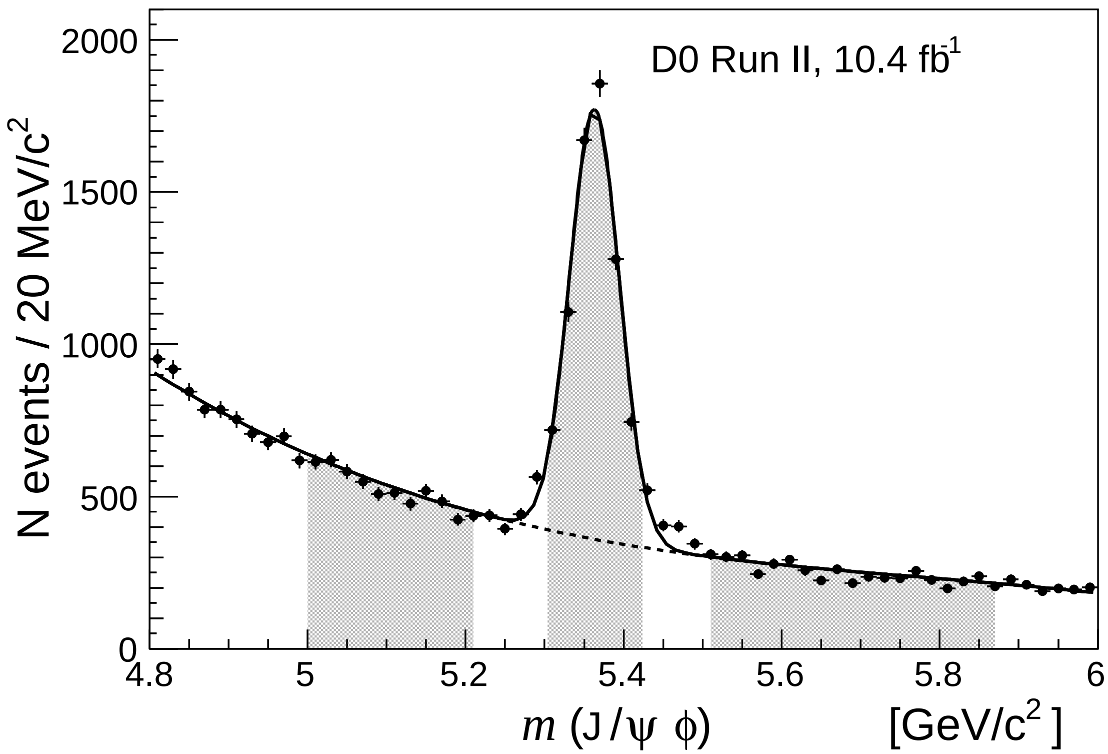


$\bar{\Lambda}_b/\Lambda_b$ and $\bar{\Lambda}/\Lambda$ vs "rapidity loss" are similar.

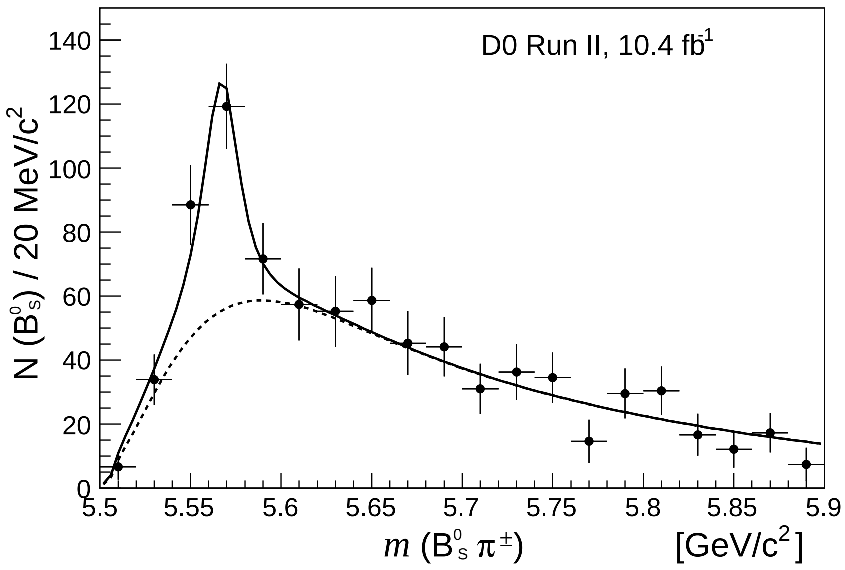
$X(5568) \to B_s^0\pi^\pm$ with B_s in hadronic channel

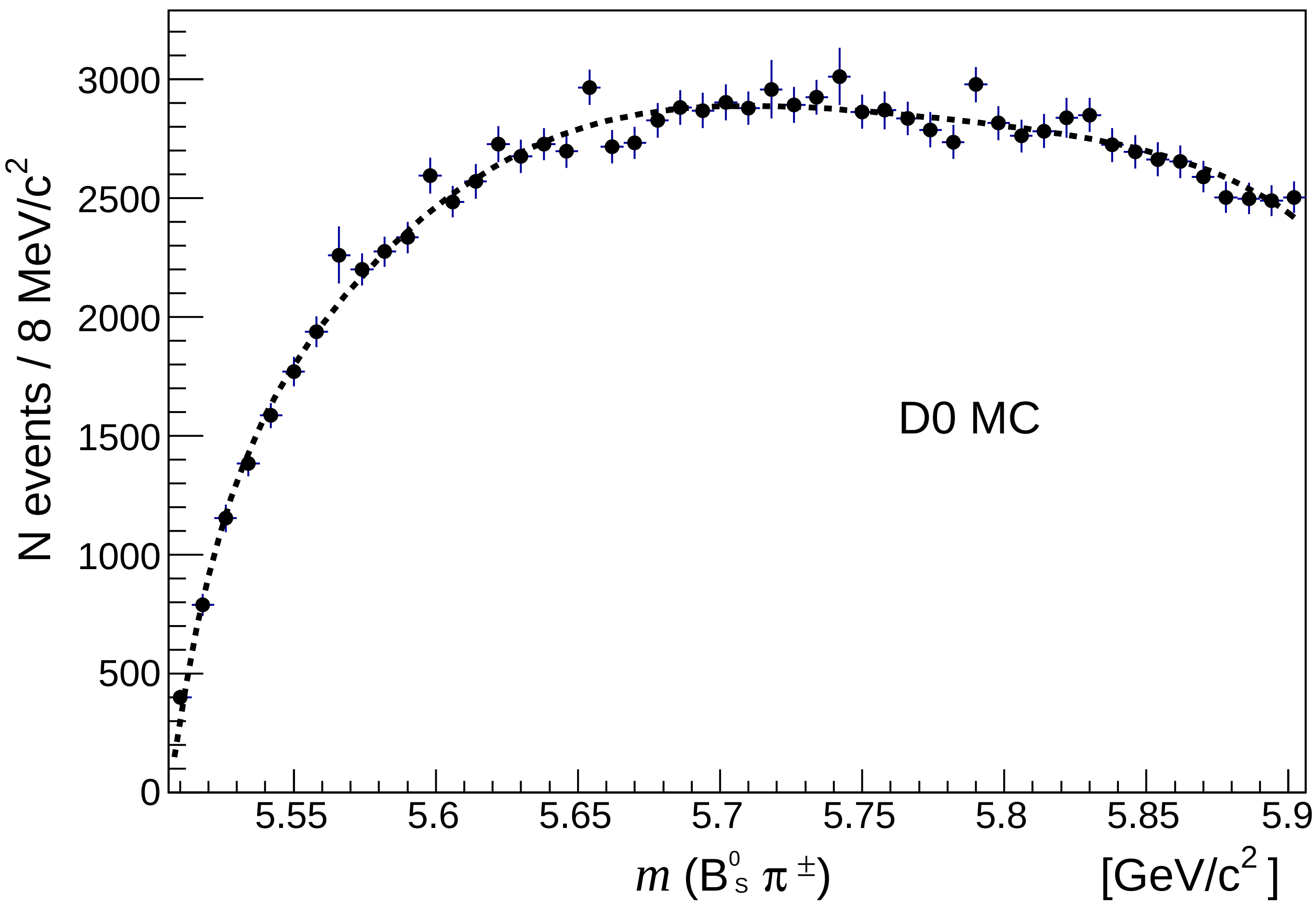


$B_s \to J/\psi\phi$



From fits to $m(J/\psi\phi)$ instead of sideband subtraction




N events / 8 MeV/c^2
0
500
1000
1500
2000
2500
3000
5.55
5.6
5.65
5.7
5.75
5.8
5.85
5.9
D0 MC
m (B^0_s π^±) [GeV/c^2]

Universal $\bar{\Lambda}/\Lambda$ production ratio vs "rapidity loss" $\Delta y \equiv y_p - y$ (with logarithmic scale).