Novel Higgs production and decays in supersymmetric models with R-parity violation

Signaling the Arrival of the LHC Era, Trieste

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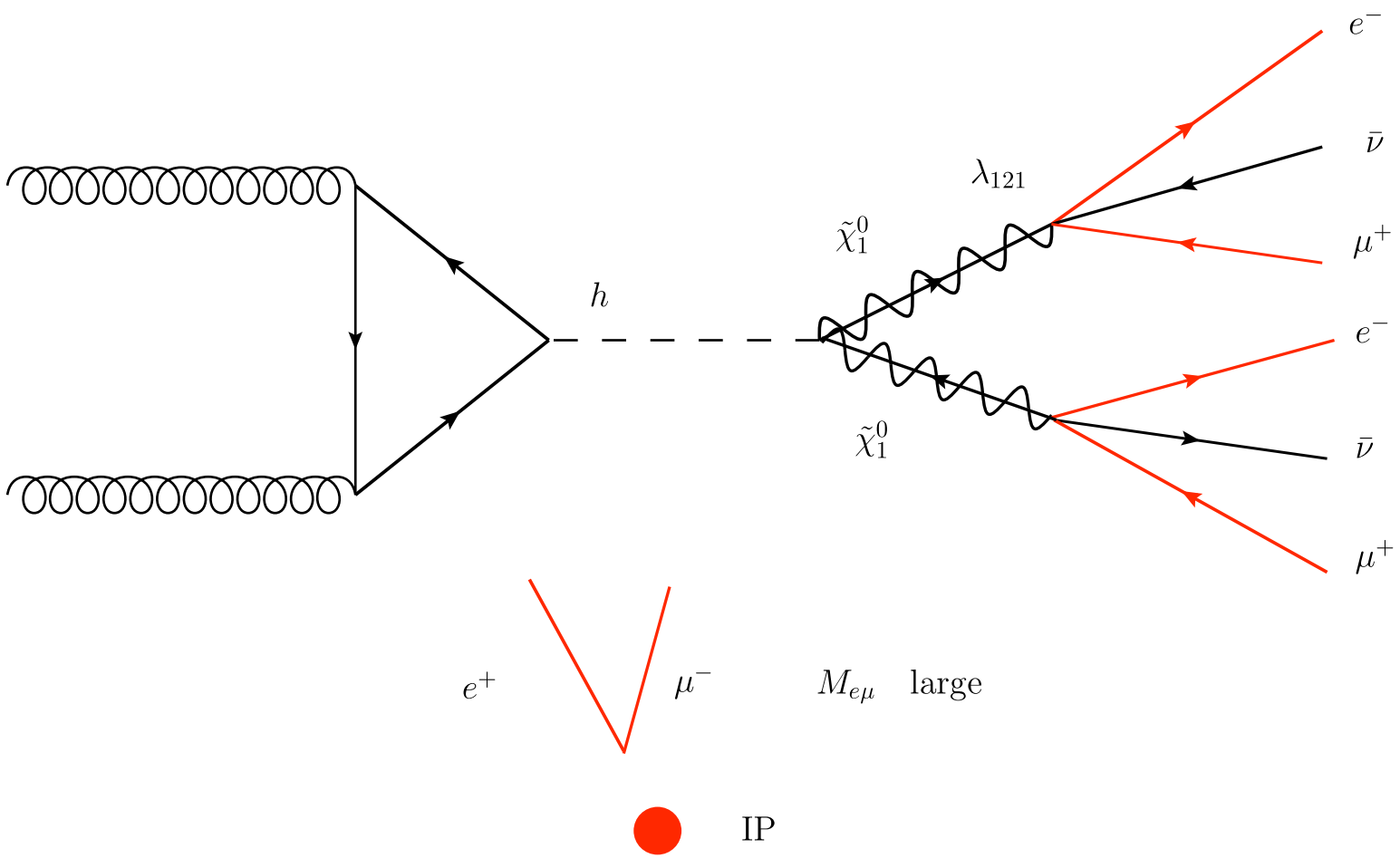
Ouline

- Displaced vertices (DV) with large invariant mass and large number of tracks as signal of new physics (NP)
- Show that the possibility of reconstruct something that decays far away of the interaction point into b-quarks and with the with the Higgs invariant mass, may be a way to overcome the huge QCD background for the $h \longrightarrow b\bar{b}$

Novel Higgs decays in RPV SUSY



D. Aristizabal Sierra, W. Porod, D. R and C. E. Yaguna, Phys. Rev. D **78** (2008) 015015

Bilinear R-parity Violation

$$W = W_{\text{MSSM}} + \epsilon_i \widehat{L}_i \widehat{H}_u$$
$$\mathcal{L}_{\text{soft}} = \epsilon_i B_i \widetilde{L}^\dagger H_u + \text{h.c}$$

$$\langle L_i \rangle = v_i$$

Sparticle mixing

$$\tilde{\chi}_i^0 \leftrightarrow \nu_i \qquad \tilde{\chi}_i^\pm \leftrightarrow \ell^\pm$$
$$H^\pm \leftrightarrow \tilde{\ell}^\pm \qquad h, H, A \leftrightarrow \tilde{\nu}_i$$

Decays and signals

Decays

$$\tilde{\chi}_1^0 \to h\nu$$
$$W^{\pm}\ell^{\mp}$$
$$Z\nu$$
$$\nu\ell^+\ell^-$$
$$\nu q\bar{q}$$
$$\ell q'\bar{q}$$
$$\nu\nu\nu$$

Signals

leptonic decays:

- $\tilde{\chi}_1^0 \to \nu\ell^+\ell^-$ with $\ell = e, \mu$
- $\tilde{\chi}_1^0 \to \nu\tau^+\tau^-$,
- $\tilde{\chi}_1^0 \to \tau\nu\ell$,

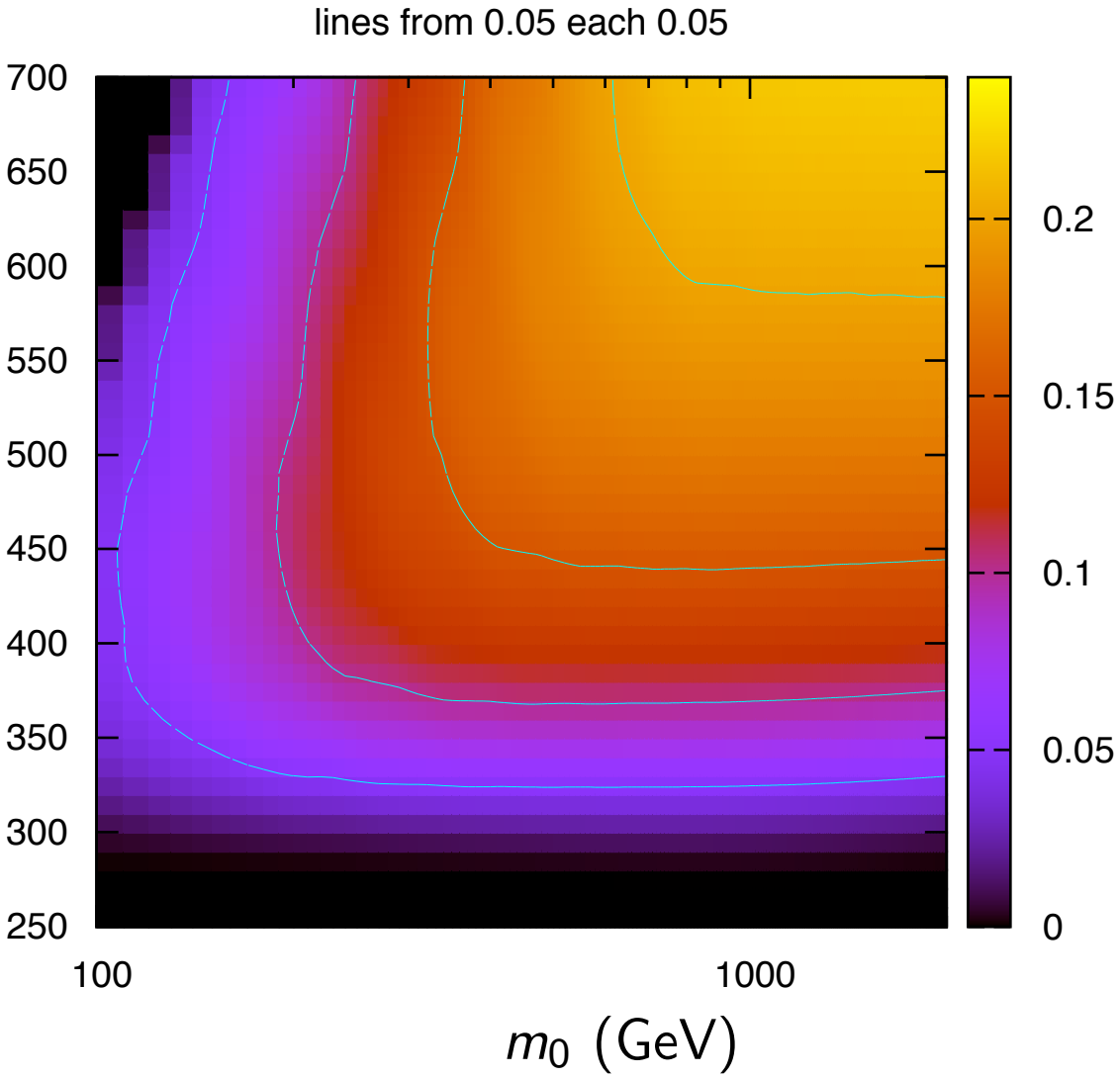
semi-leptonic decays:

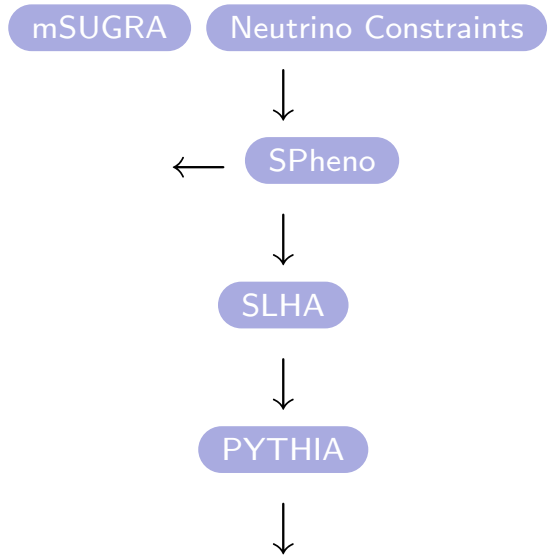
- $\tilde{\chi}_1^0 \to \nu q\bar{q}$
- $\tilde{\chi}_1^0 \to \tau q'\bar{q}$,
- $\tilde{\chi}_1^0 \to \ell q'\bar{q}$,
- $\tilde{\chi}_1^0 \to \nu b\bar{b}$,

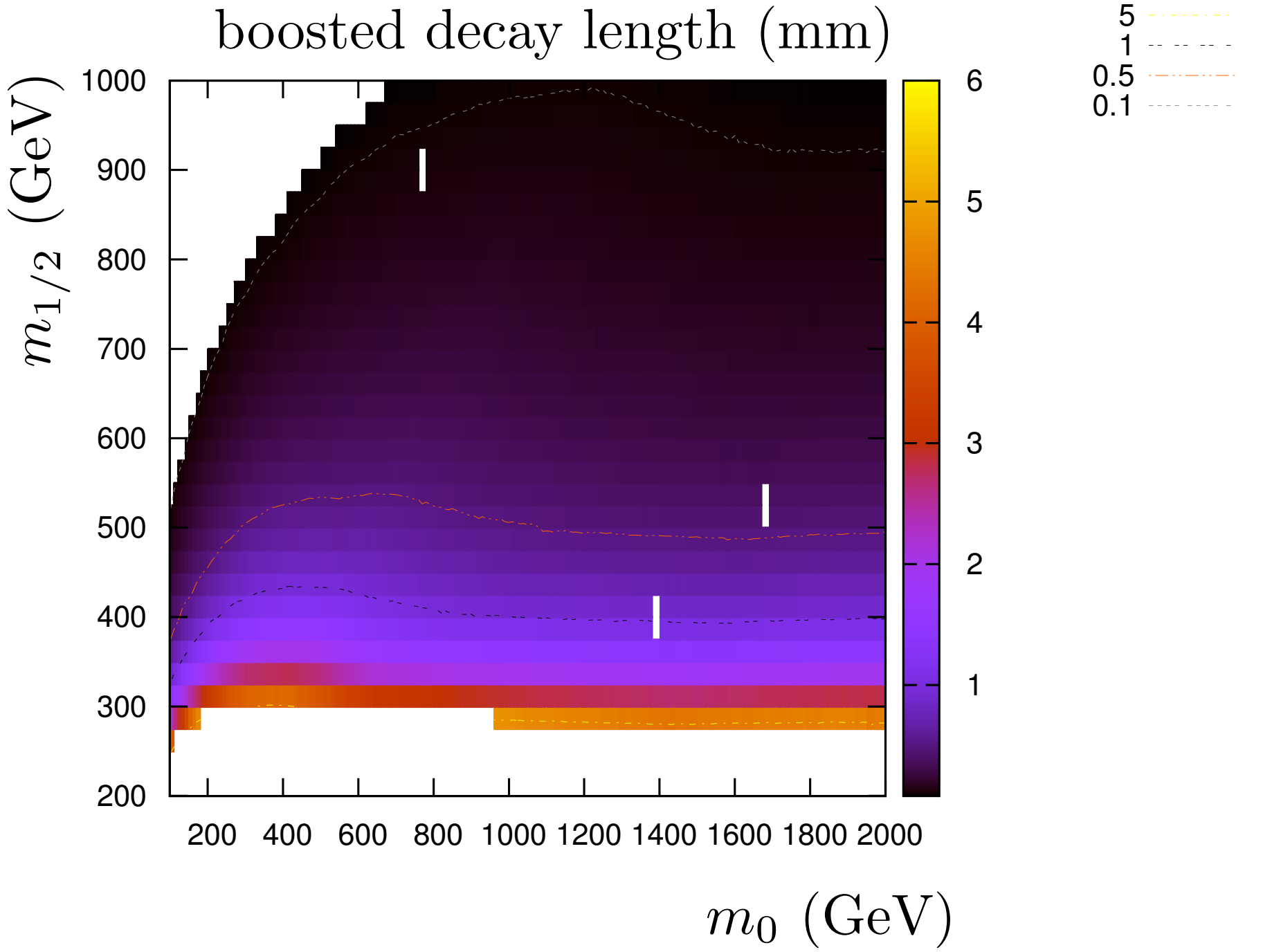
invisible decays: $\tilde{\chi}_1^0 \to \nu\nu\nu$;

$\tilde{\chi}_1^0 \rightarrow h\nu$

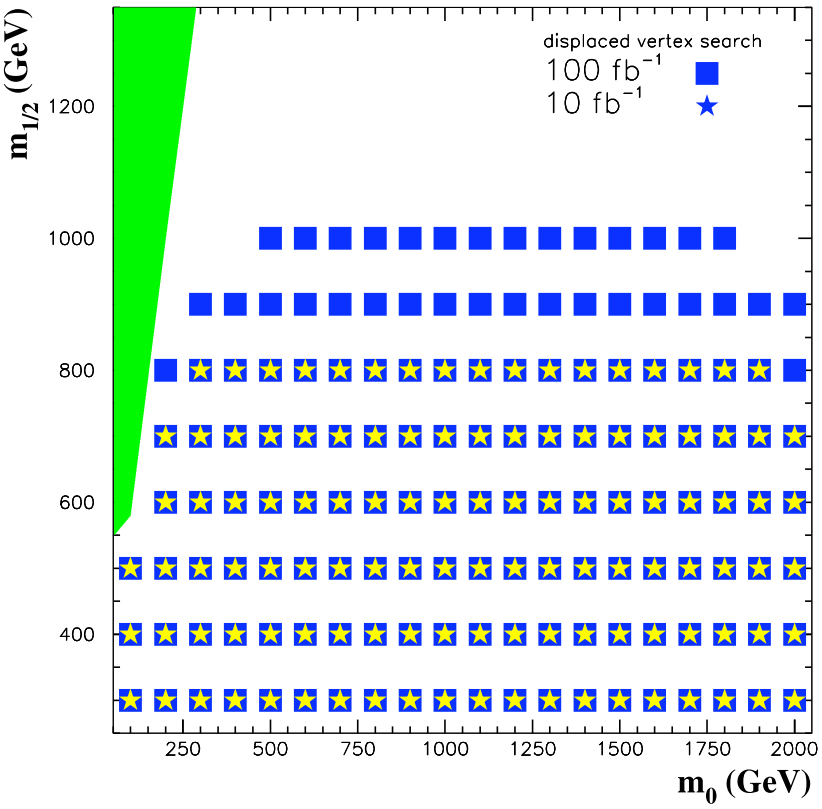
$m_{1/2}$ (GeV) $A_0 = -100$ GeV $\tan\beta = 10$ $\mu > 0$





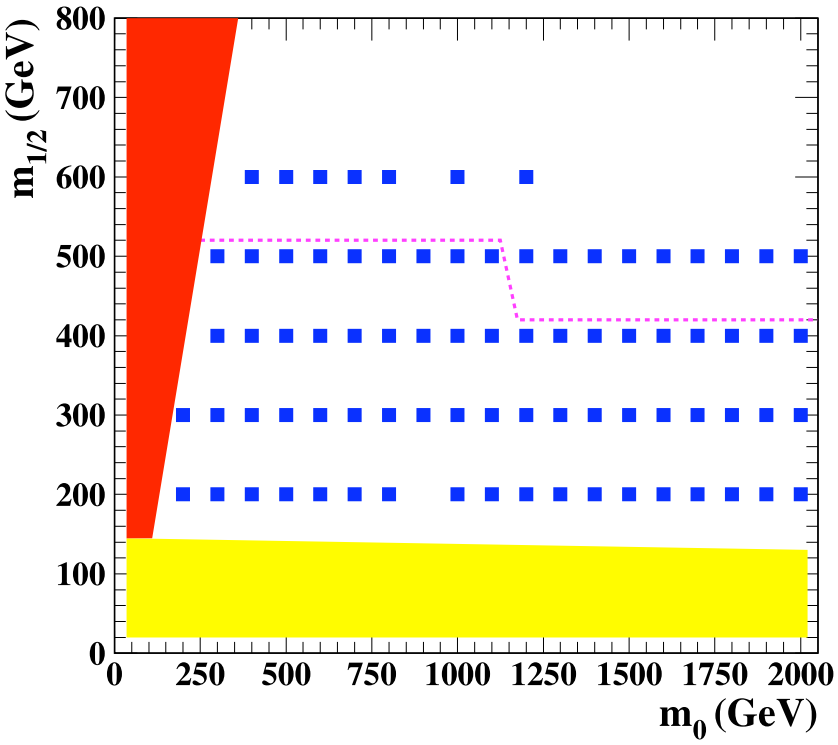

boosted decay length (mm)
5
1
0.5
0.1
$m_{1/2}$ (GeV)
1000
900
800
700
600
500
400
300
200
6
5
4
3
2
1
200 400 600 800 1000 1200 1400 1600 1800 2000
m_0 (GeV)

ATLAS & CMS



$A_0 = -100\,\text{GeV}$ $\tan\beta = 10$ $\mu > 0$
JHEP **0805** (2008) 048
"ATLAS and CMS assume no NP displaced vertices in their analysis"

LHCb



$\mathcal{L} = 2\,\text{fb}^{-1}$, arXiv:0809.0007

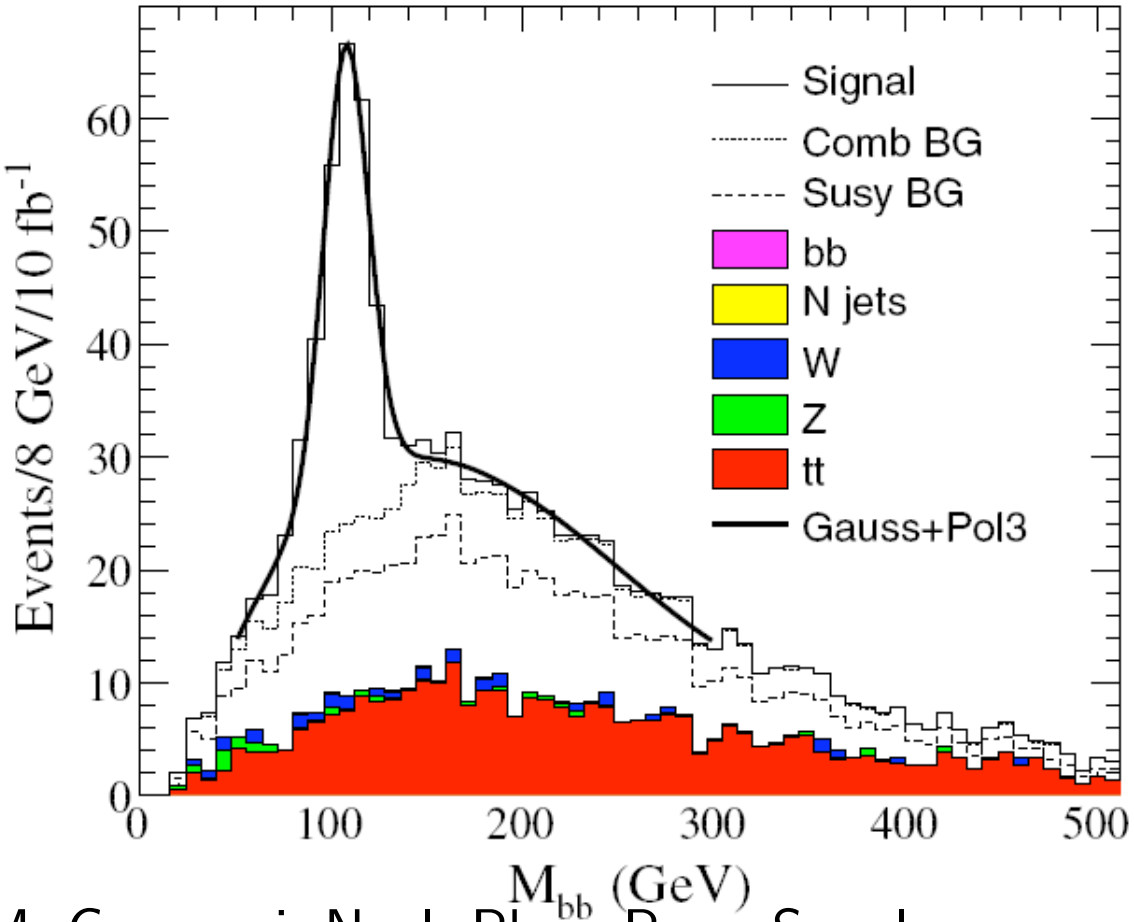
`twiki.cern.ch/twiki/bin/view/LHCb/HiggsExotica`

"strong hope [...] that events can be selected based on DV with high invariant mass and high number of tracks"

Cascade SUSY Higgs production

$\tilde{q}_L \rightarrow \tilde{\chi}_2^0 q \rightarrow \tilde{\chi}_1^0 h q \rightarrow \tilde{\chi}_1^0 b\bar{b} q$

$m_0 = 300$ GeV $m_{1/2} = 425$ $A_0 = 200$ GeV $\tan\beta = 20$ $\mu > 0$



M. Consonni, Nucl. Phys. Proc. Suppl. **177-178**, 271 (2008).

Cuts

$E_T^{\text{miss}} > 300$ GeV;

2 b-jets with $p_T > 50$ GeV

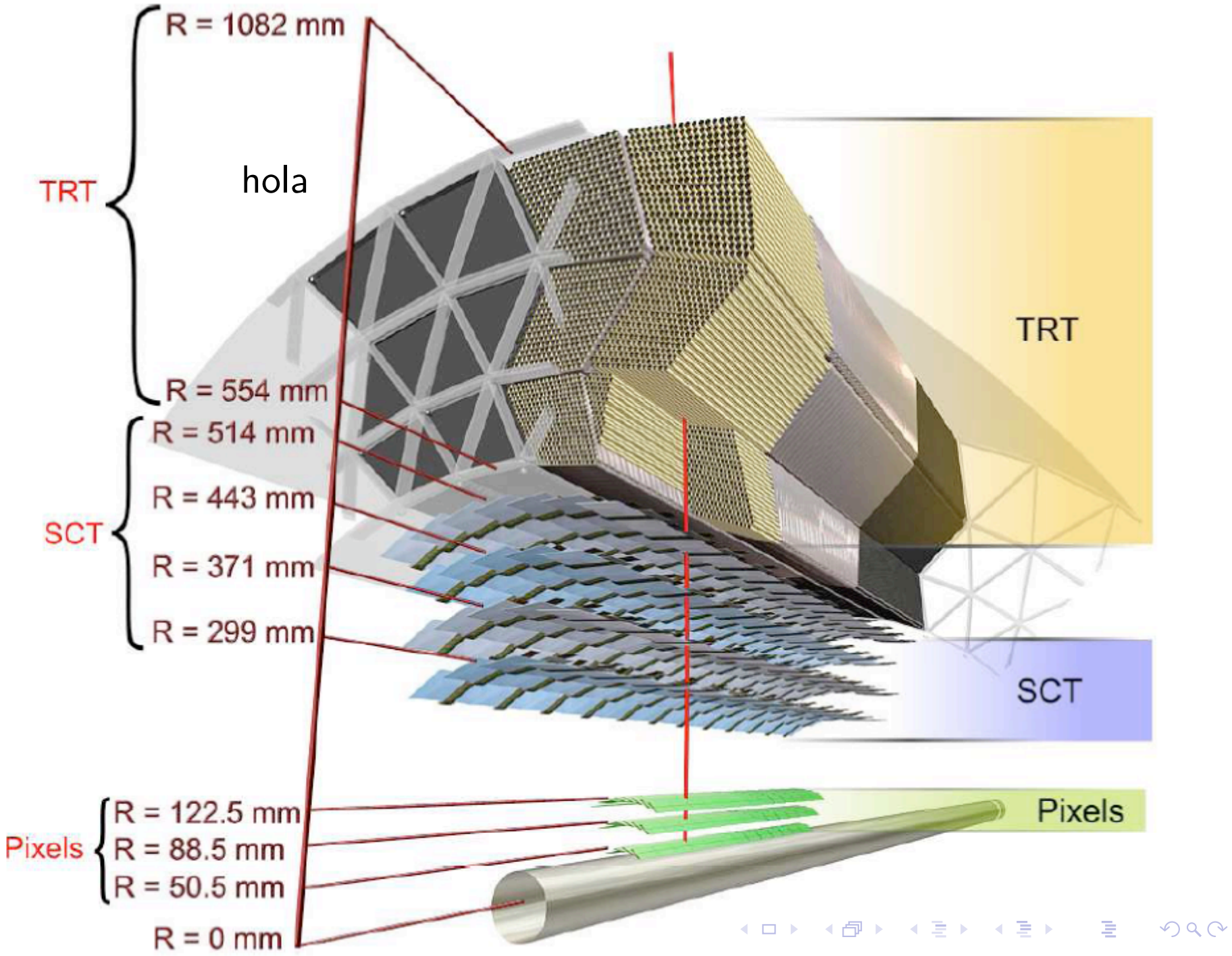
two light flavoured jets with $p_T > 100$ GeV;

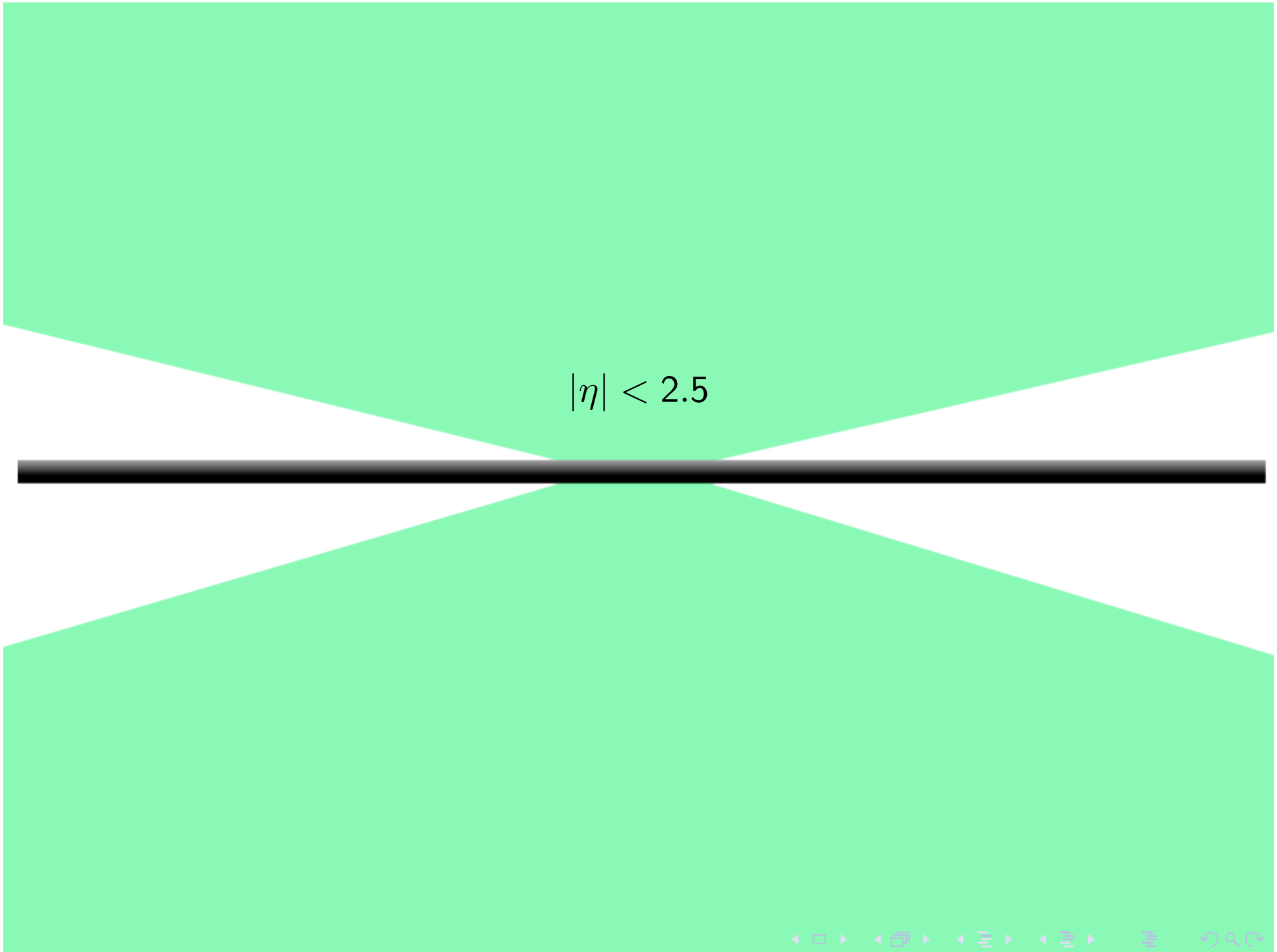
no leptons with $p_T > 10$ GeV

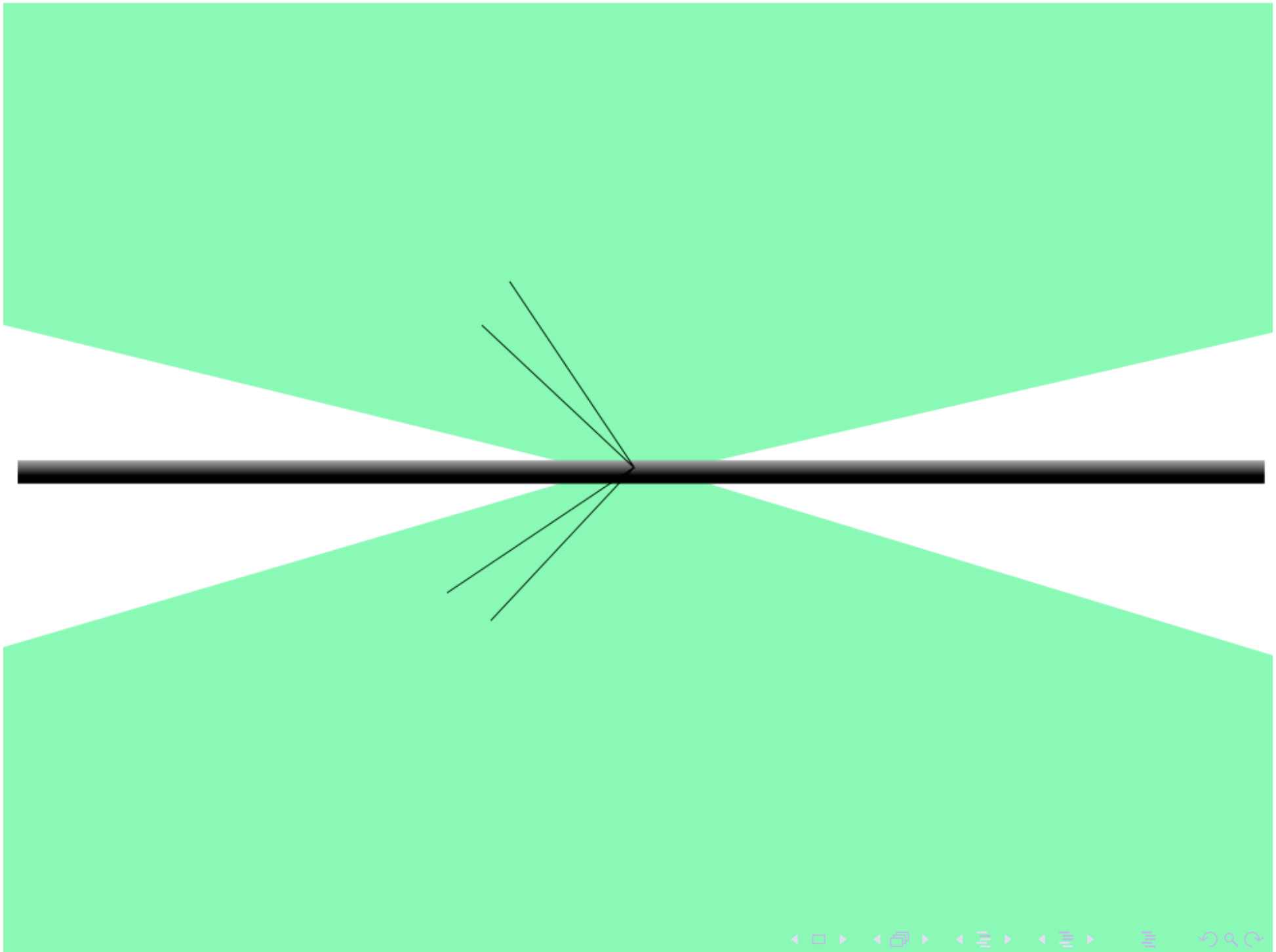
Cascade SUSY Higgs production in BRPV

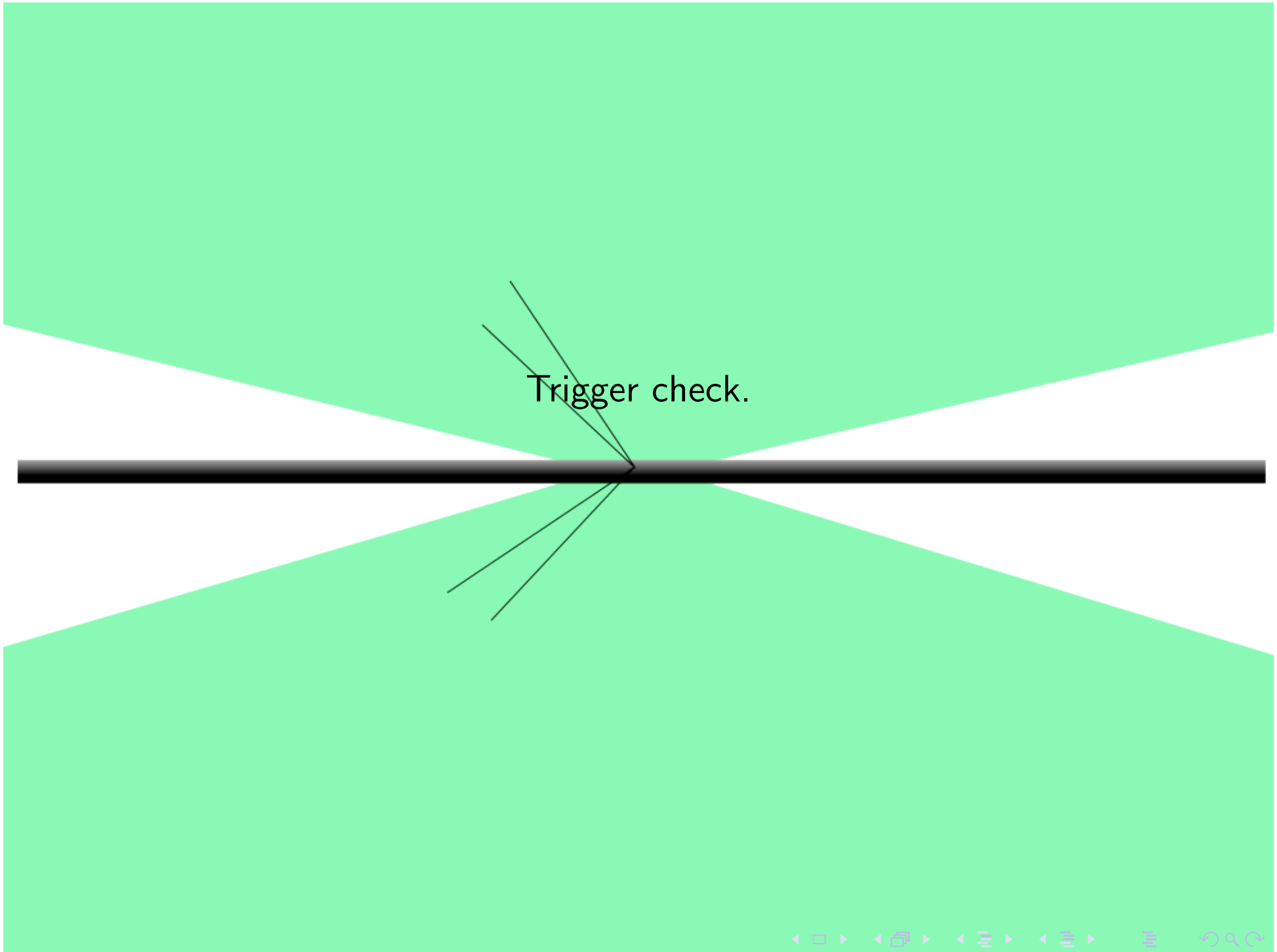
- Independent of SUSY Higgs production mechanism;
- Independent of spectrum (valid when $m_{\tilde{\chi}_2^0} < m_h + m_{\tilde{\chi}_1^0}$);
- Same cuts should also work;
- $m_{1/2} > 250\,\text{GeV}$, instead of < 320 GeV);
- Displaced vertices!.

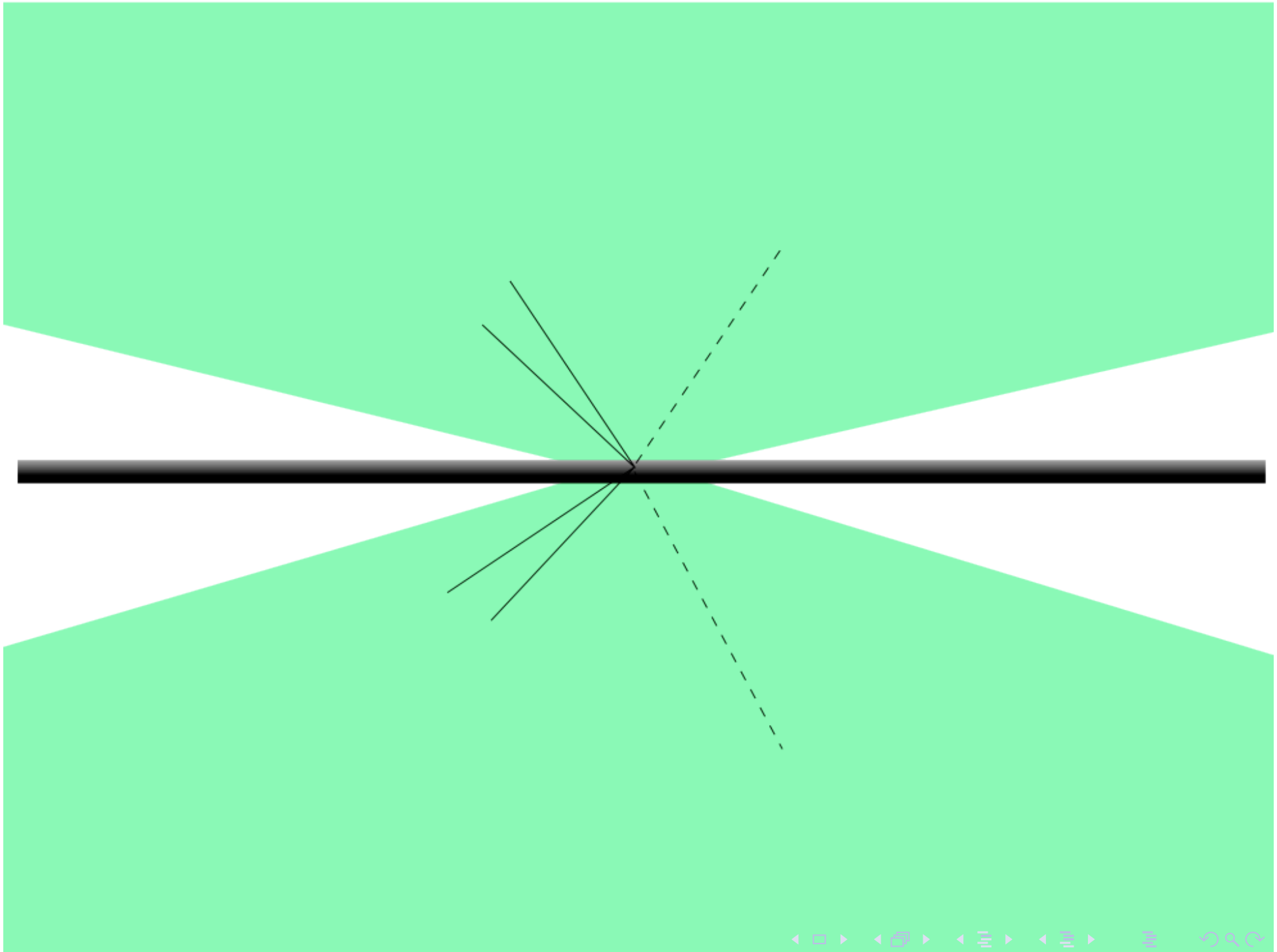
The complementary signals can be exploited to reduce the background, making it possible to study the channel $h \longrightarrow \bar{b}b$, otherwise covered by the enormous QCD continuum.

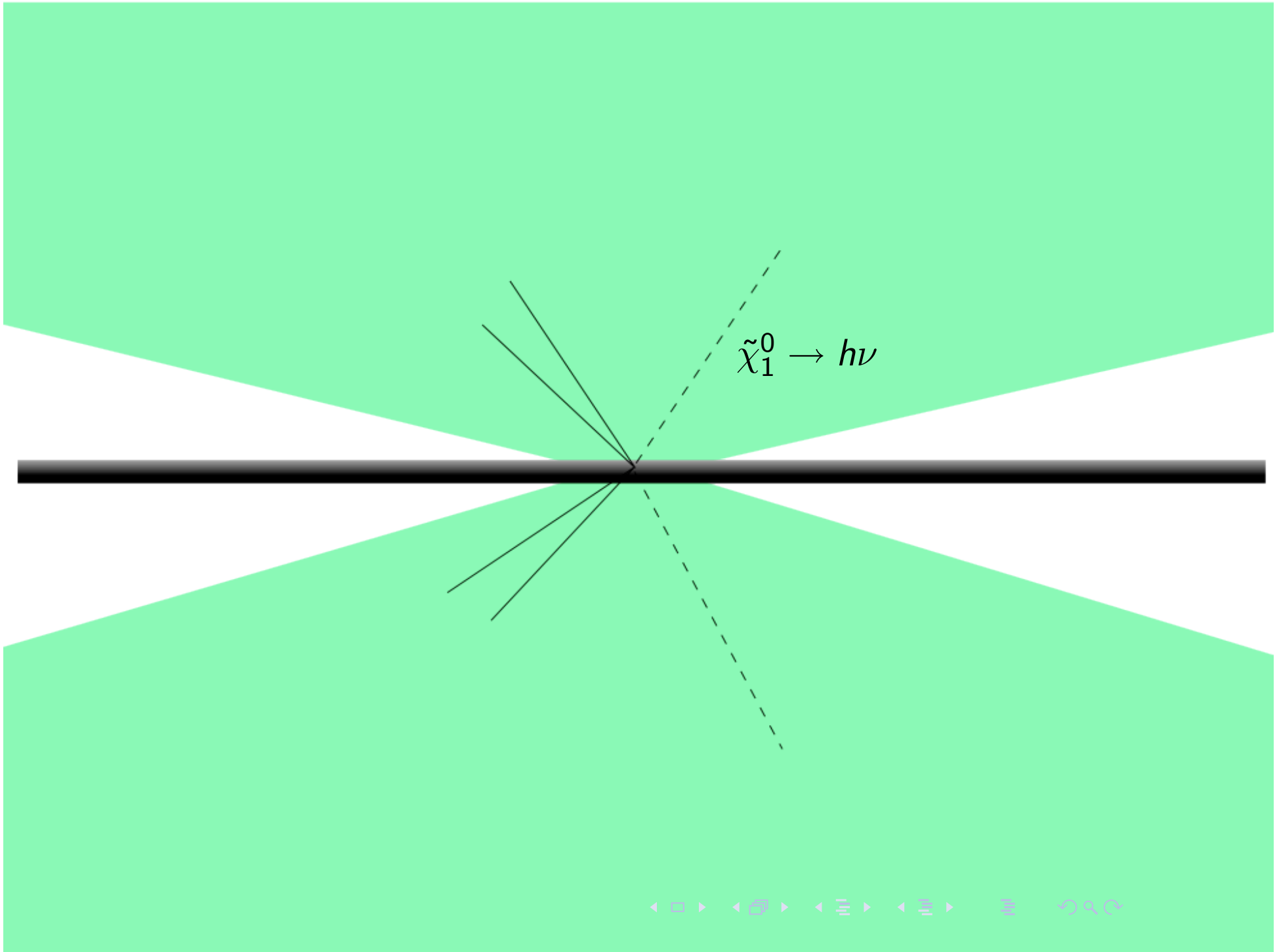

R = 1082 mm
TRT
hola
R = 554 mm
R = 514 mm
R = 443 mm
SCT
R = 371 mm
R = 299 mm
Pixels
R = 122.5 mm
R = 88.5 mm
R = 50.5 mm
R = 0 mm
TRT
SCT
Pixels

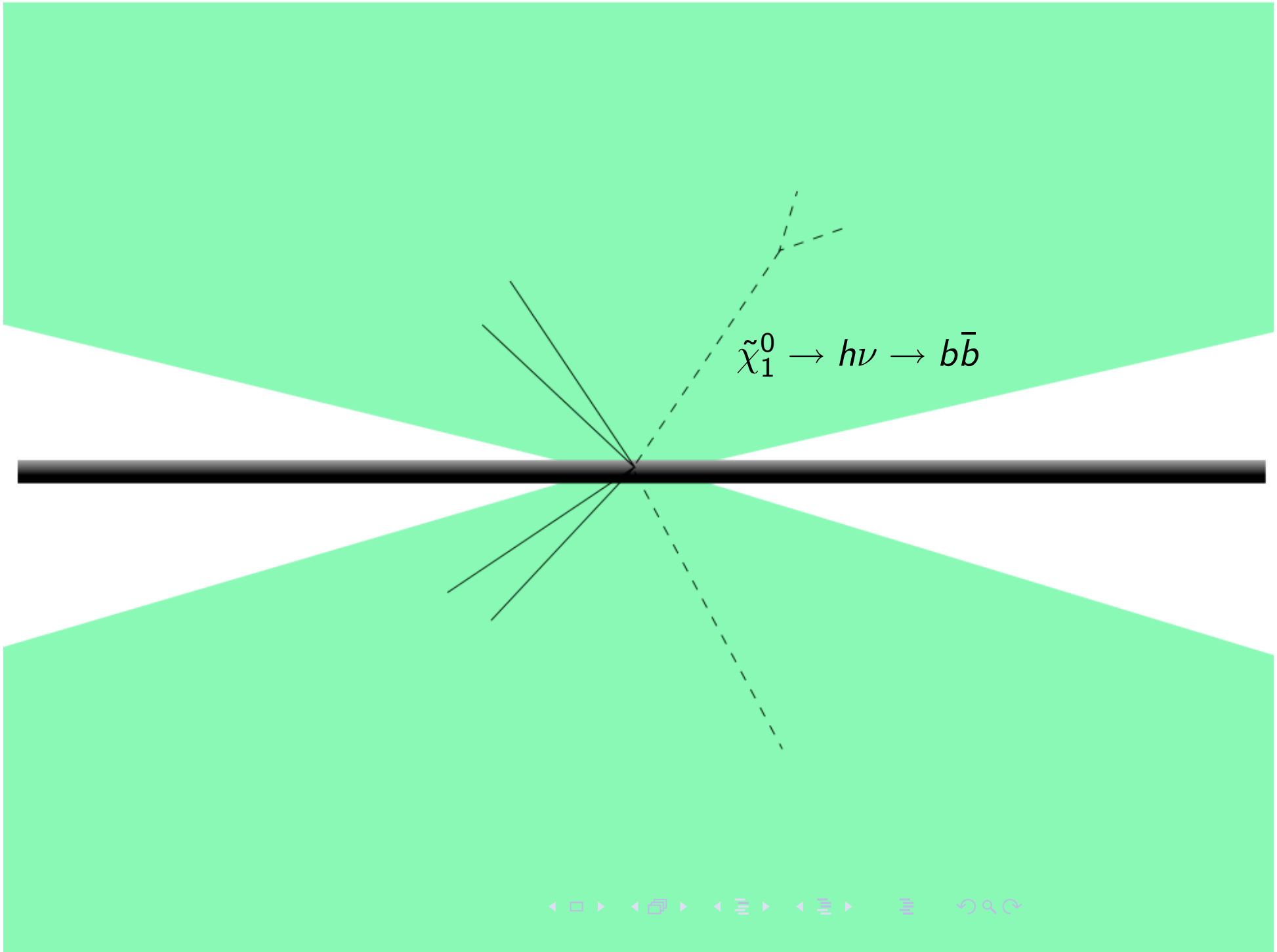

$|\eta| < 2.5$

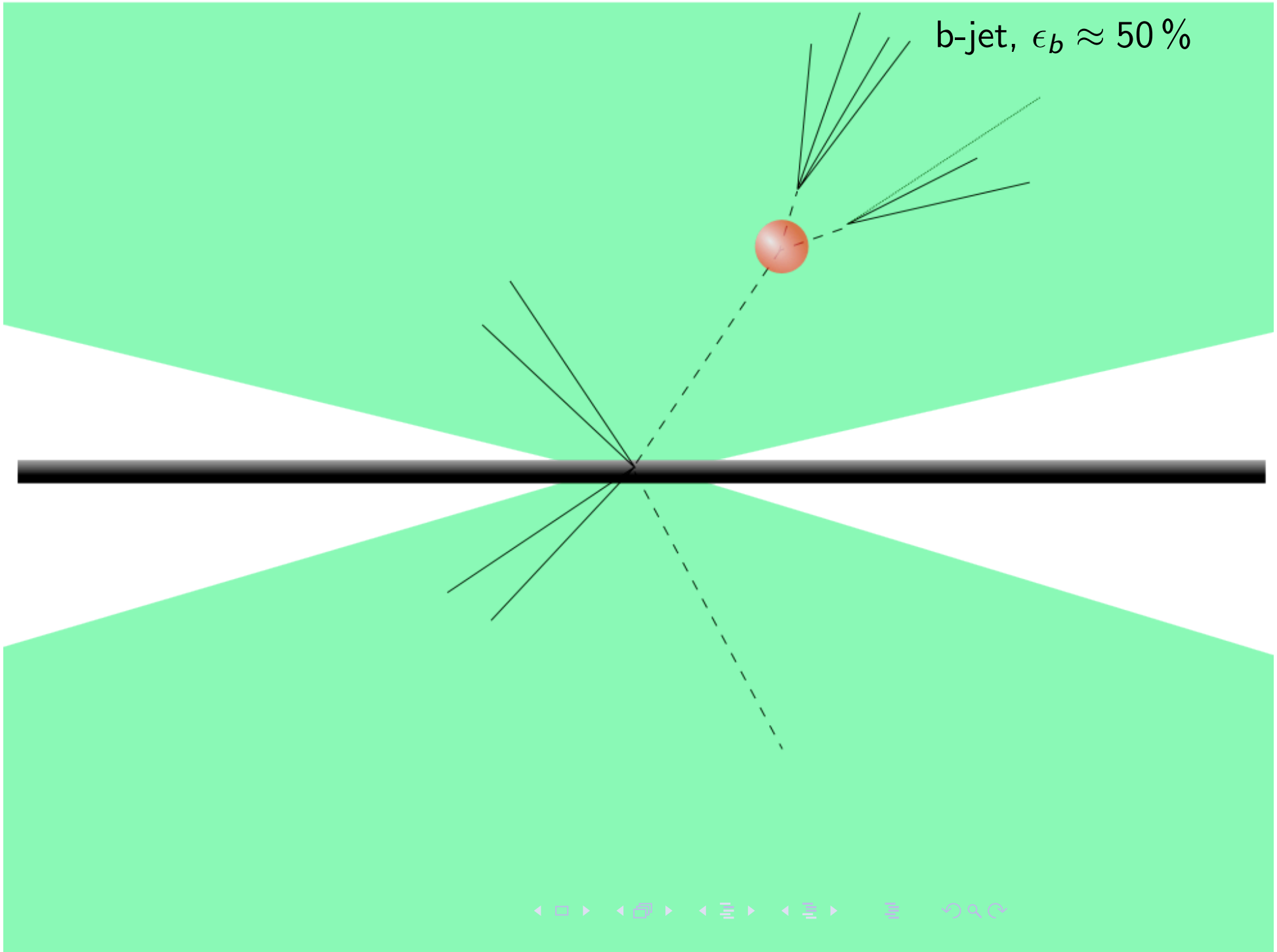


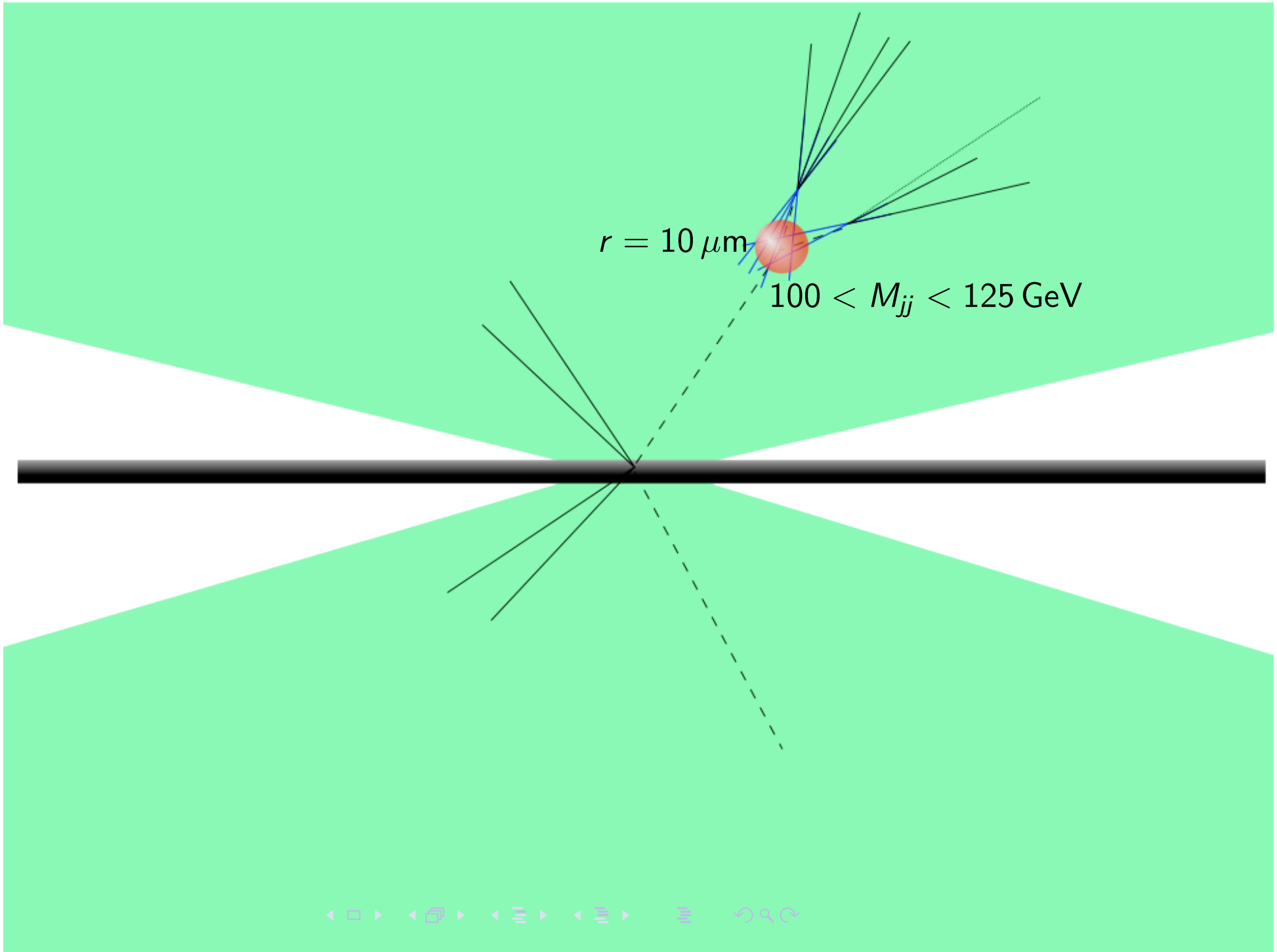

Trigger check.

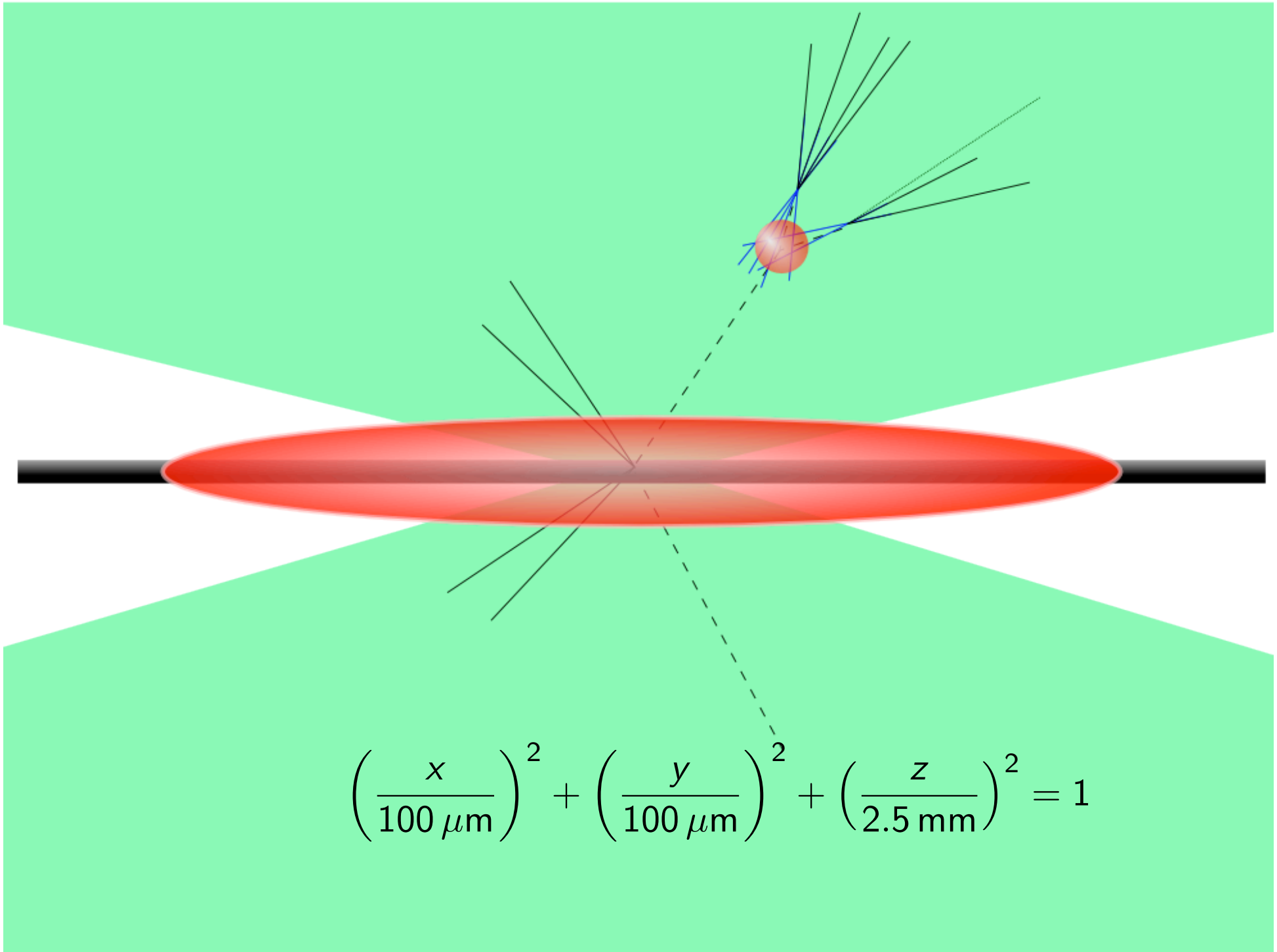


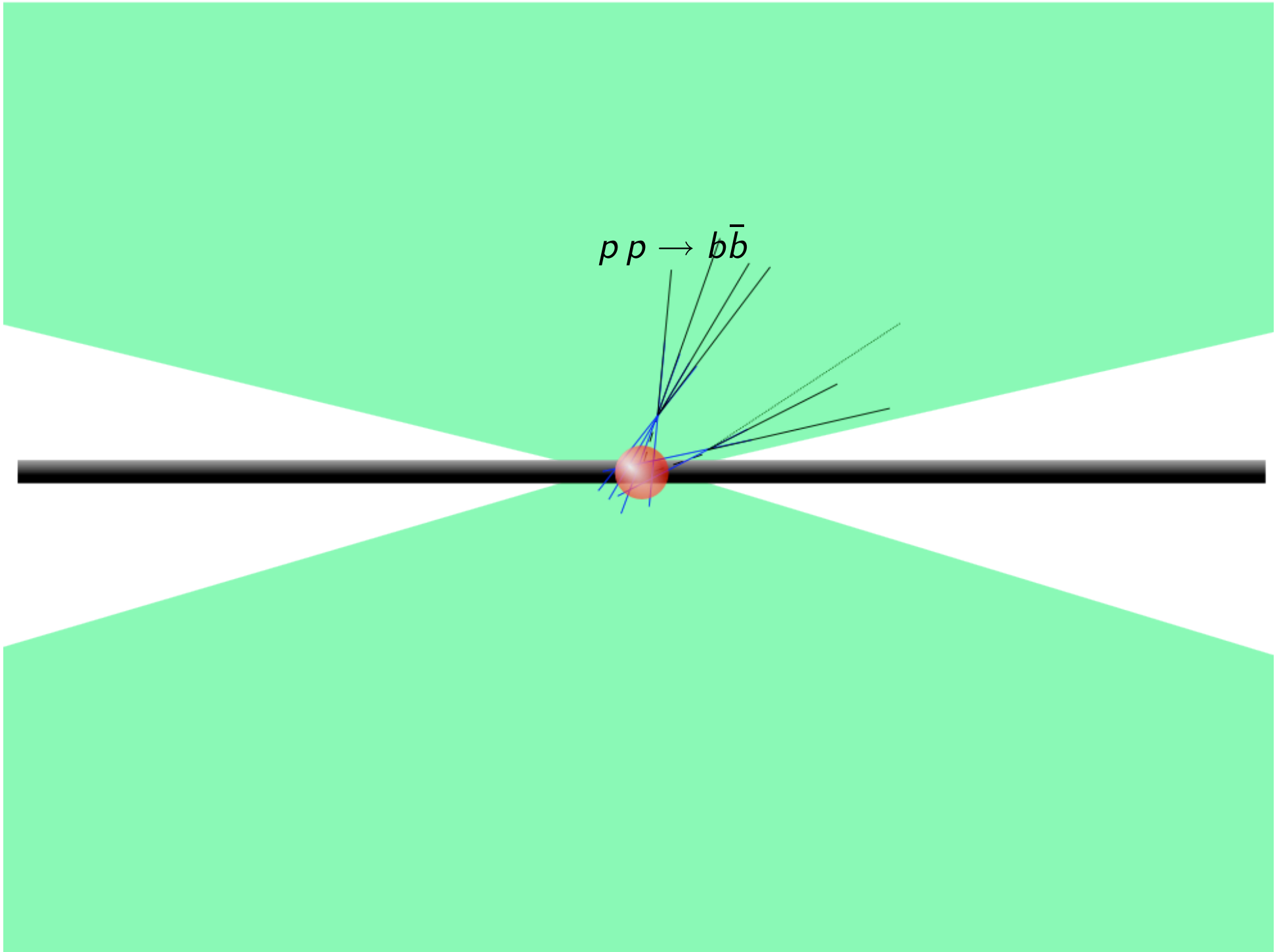

$\tilde{\chi}_1^0 \to h\nu$

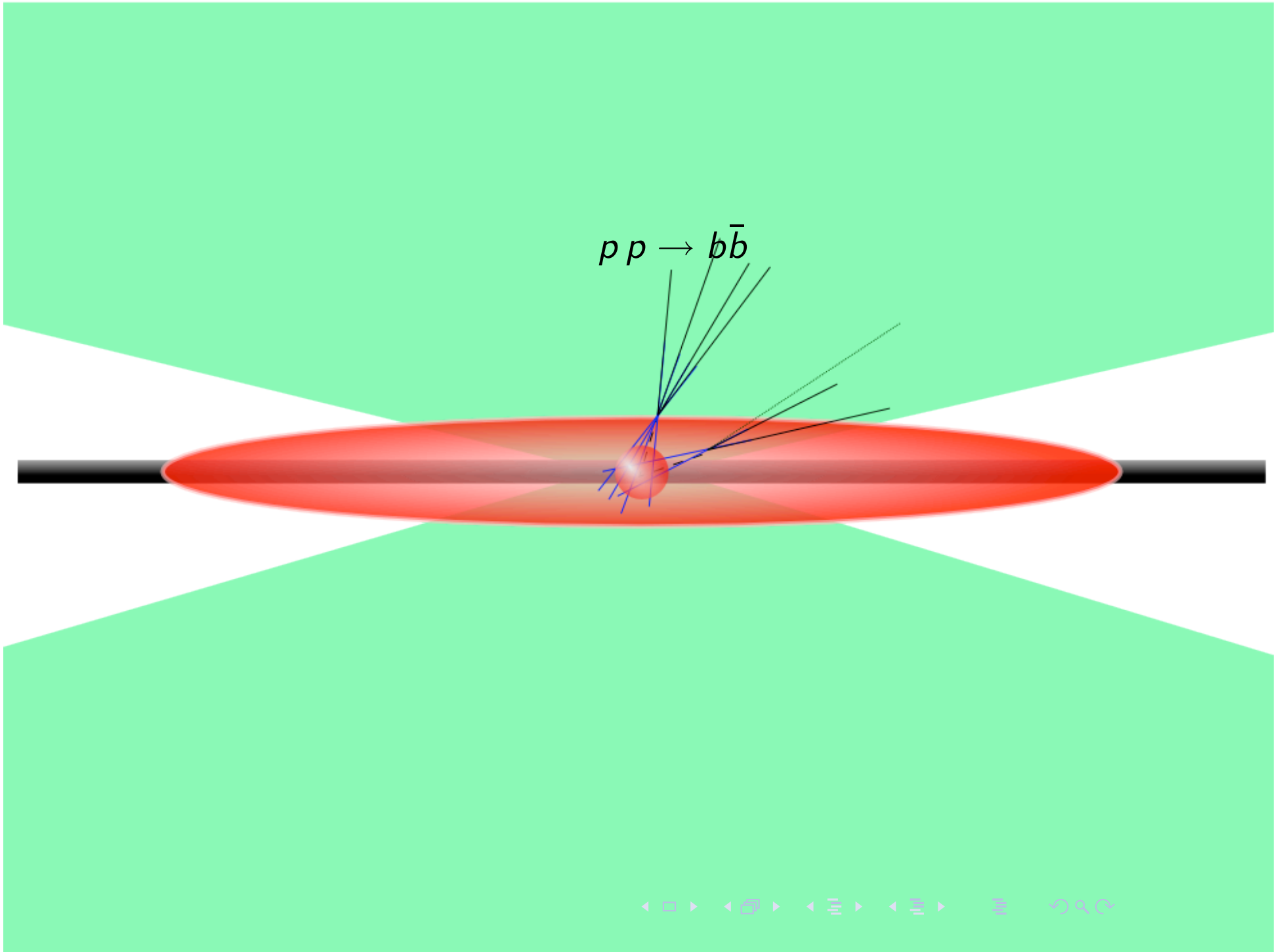

$\tilde{\chi}_1^0 \to h\nu \to b\bar{b}$


b-jet, $\epsilon_b \approx 50\,\%$


$r = 10\,\mu$m
$100 < M_{jj} < 125\,$GeV

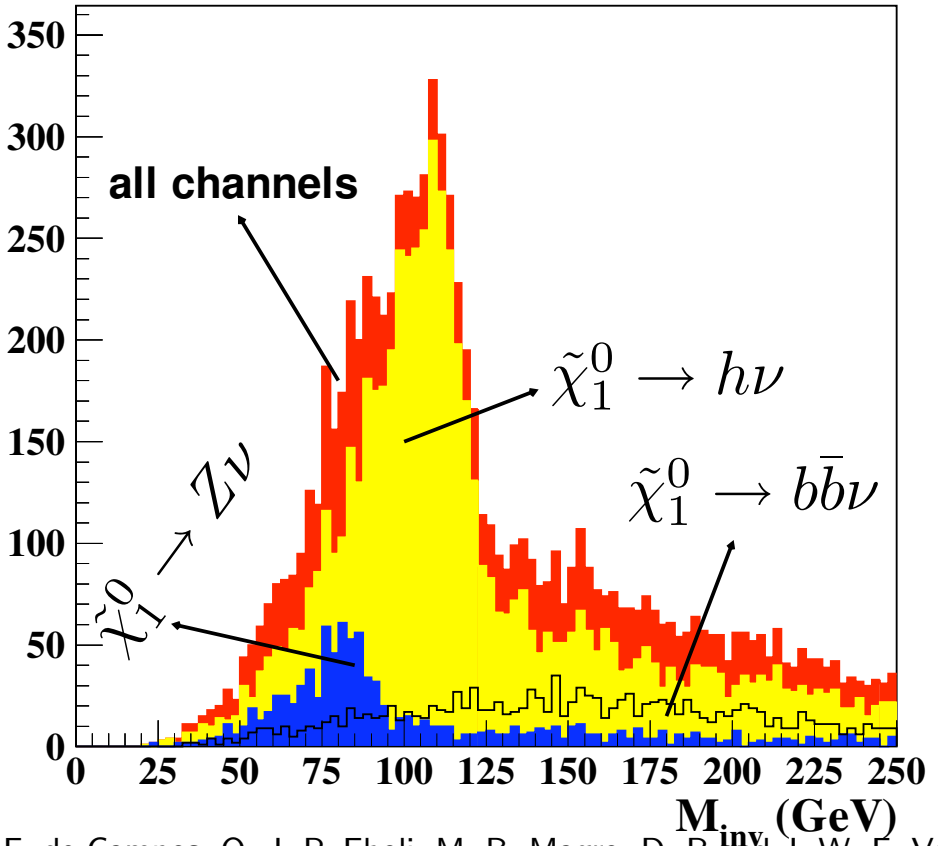

$\left(\frac{x}{100\,\mu\text{m}}\right)^2 + \left(\frac{y}{100\,\mu\text{m}}\right)^2 + \left(\frac{z}{2.5\,\text{mm}}\right)^2 = 1$


$p\,p \longrightarrow b\bar{b}$


$p\,p \longrightarrow b\bar{b}$

Cascade SUSY Higgs production in BRPV

susy cross section$\longrightarrow \tilde{\chi}_1^0 X \longrightarrow h\nu X$

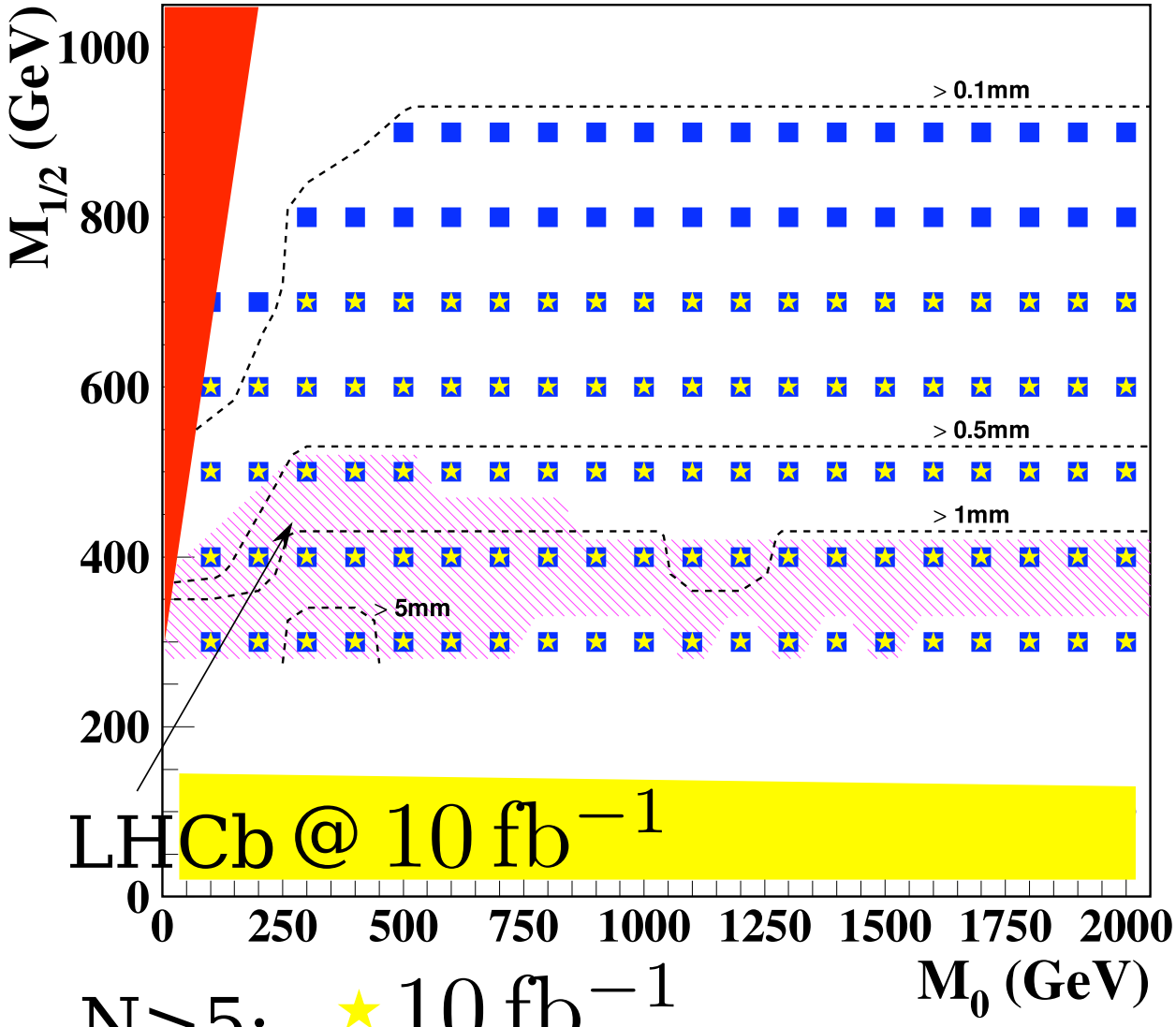


F. de Campos, O. J. P. Eboli, M. B. Magro, D. R and J. W. F. Valle, "Finding the Higgs Boson through Supersymmetry," arXiv:0809.1637 [hep-ph].

Cuts

- $|\eta| < 2.5$;
- at least 1 b-jets;
- $110 < M_{jj} <$ 125 GeV. All visible tracks cross a resolution sphere of 10μm;
- resolution sphere outside minimum ellipsoid;

ATLAS Reach

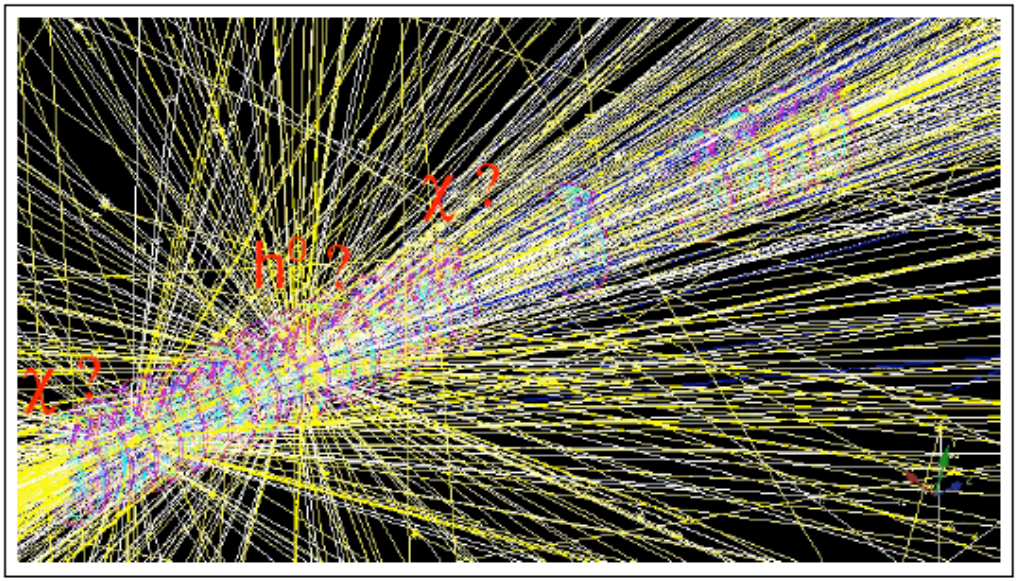


N>5: ★ 10 fb^{-1}

■ 100 fb^{-1}

Conclusion

- The NP DV information is underestimated by experimentalists.
- For models ① - ⑤ ATLAS and CMS will have weakened sensitivity because their triggers are designed to exploit missing transverse energy and isolated leptons.
  - For some parts of ② ③ huge statistics will be necessary to distinguish between R-parity conservation and violation.
- LHCb could be a front-runner and give precious infos!
  - We need to search in LHCb for anything new that decays far away from PV into b quarks.
  - Could get a measurement of the mass and the lifetime of the long-live particles
- Even a small excess of anomalous events with DV could guide ATLAS and CMS studies.



`http://indico.cern.ch/conferenceDisplay.py?confId=26043`
Non-Standard Model discovery from events with displaced vertices, Neal Gueissaz.
"strong hope [...] that events can be selected based on DV with high invariant mass and high number of tracks"

Conclusions II

Exploiting the capabilities of ATLAS in b-tagging and secondary vertex reconstruction, it may be possible to study the dominant channel $h \rightarrow \bar{b}b$, otherwise covered by the enormous QCD continuum.

The same physics which will make the $\tilde{\chi}_1^0$ long lived may also cause a large branching for $\tilde{\chi}_1^0 \rightarrow h\nu \rightarrow b\bar{b}$

In fact since all SM background with large invariant mass will be produced at the primary vertex, the signal in principle will be free of SM background.

Displaced vertices containing two b-jets at LHC may not only provide evidence for supersymmetric particles but also lead to the discovery of the Higgs boson.