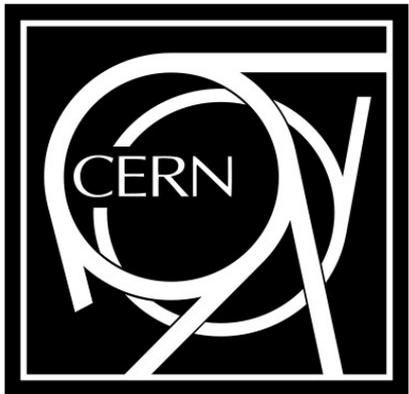


Dark Matter

P.Harris/P.Schwaller



Strategy

- Prepared an **outline for the document**
- Strategy :
 - **Ask people for individual contributions (in progress)**
 - Compile the document based on the contributions
- A dropbox has been setup with outline
- These slides we will go through the outline
 - For each section we have already targeted a contact

Overview (7 sections)

- 2 : Current bounds from experiments :
 - Direct detection/Relic density/Indirection detection
- 3: Dark matter from a SM mediator
 - EWK mediator/Higgs/EWK+Higgs
- 4: Dark matter from a generic mediator
 - Simplified models/t-channel/mono-H/light mediators
- 5: Dark matter from a mixed scenario
 - Co-annihilation/resonant annihilation/MSSM
- 6: Beyond classic dark matter scenarios
 - Axions/asymmetric DM/Dark QCD/Hidden valley
- 7: Detector constraints summary

Twiki (to be updated)

- <https://twiki.cern.ch/twiki/bin/view/LHCPhysics/DarkMatter>

Dark Matter studies for FCC-hh

Conveners: Pedro Schwaller (TH), Phil Harris (EXP)

Ongoing studies

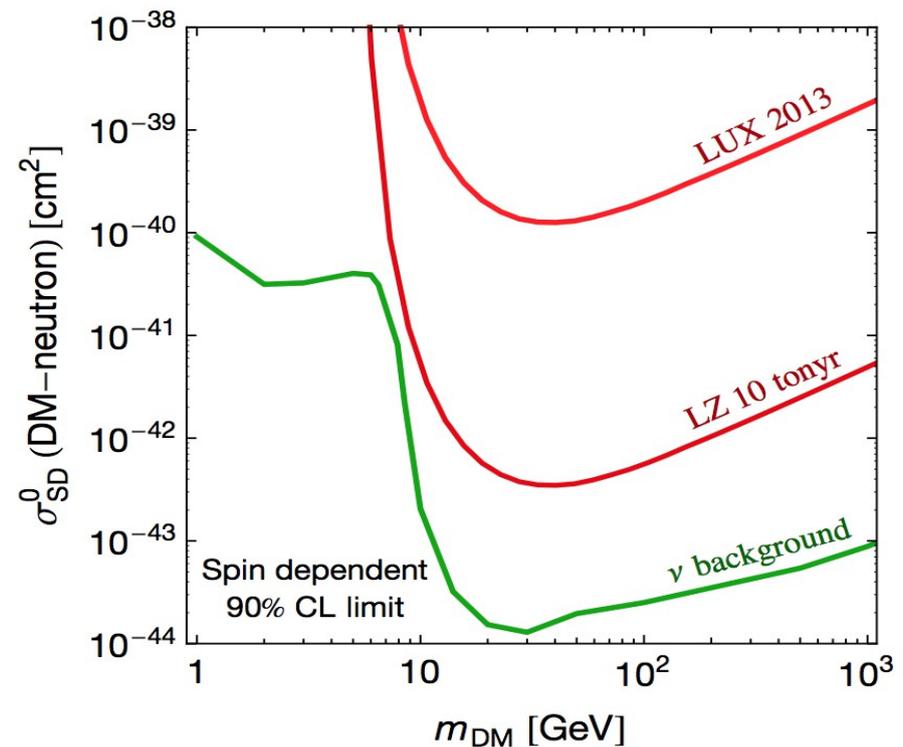
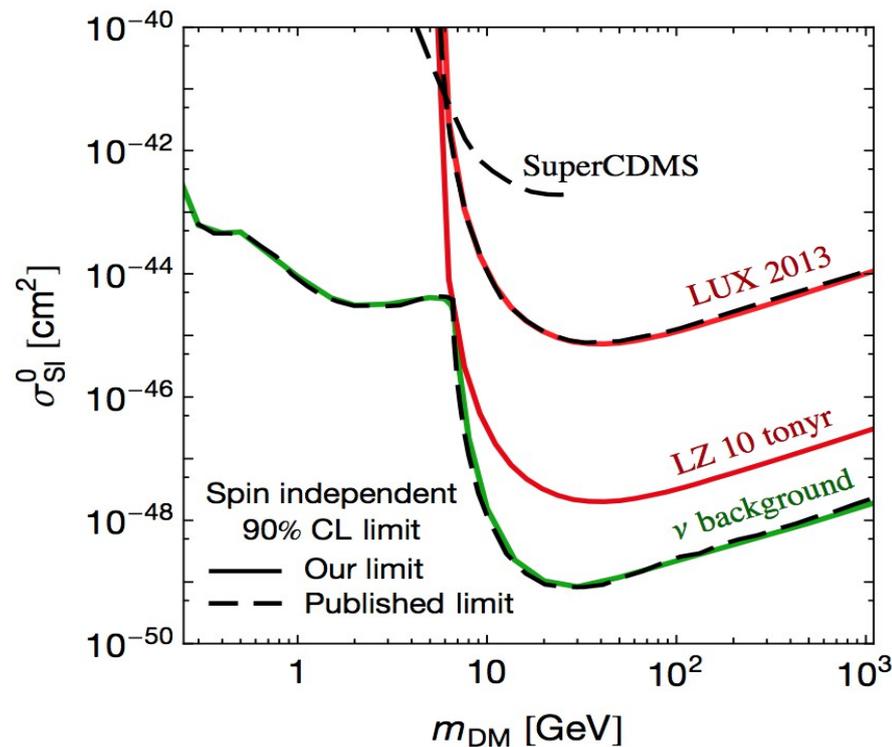
- Almost degenerate Higgsinos (Mahbubani, Schwaller, Zurita) [Show Details](#)
- Alternative signals with photons to discover neutralinos in compressed spectra (Delgado) [Show Details](#)
- Examining a monojet signal (Schwaller) [Show Details](#)
- Jet+MET and dijet+MET signatures of the Higgs portal (Mc Cullough, N.Craig, T.Lou, and A.Thalapillil) [Show Details](#)
- DM benchmarks (Doglioni, Boveia) [Show Details](#)
- Exploration of the pMSSM at 100 [TeV](#), and complementarities with DM searches (Arbey, Battaglia, Mahmoudi) [Show Details](#)
- Mono-Higgs DM searches at 100 [TeV](#) (Burns, Mulhearn) [Show Details](#)

Other Literature

- Searches at 100 [TeV](#)
 - *Neutralino Dark Matter at 14 and 100 TeV*, M. Low and L.-T. Wang, [arxiv:1404.0682](#)
 - *The Relic Neutralino Surface at a 100 TeV collider*, J. Bramante et al, [arxiv:1412.4789](#)
 - *Wino-like Minimal Dark Matter and future colliders*, M.Cirelli, F.Sala, M.Taoso, [arXiv:1407.7058](#)
 - *Hunting electroweakinos at future hadron colliders and direct detection experiments*, G. Grilli di Cortona, [arXiv:1412.5952](#)
- Higgs portals, Unitarity constraints
 - *Perturbative Unitarity Constraints on Gauge Portals*, S.El Hedri et al, [arXiv:1412.5660](#)
 - *Perturbative Unitarity Constraints on Charged/Colored Portals*, M.Cahill-Rowley et al, [arXiv:1501.03153](#)
 - *The Higgs Portal Above Threshold*, N.Craig et al, [arXiv:1412.0258](#)

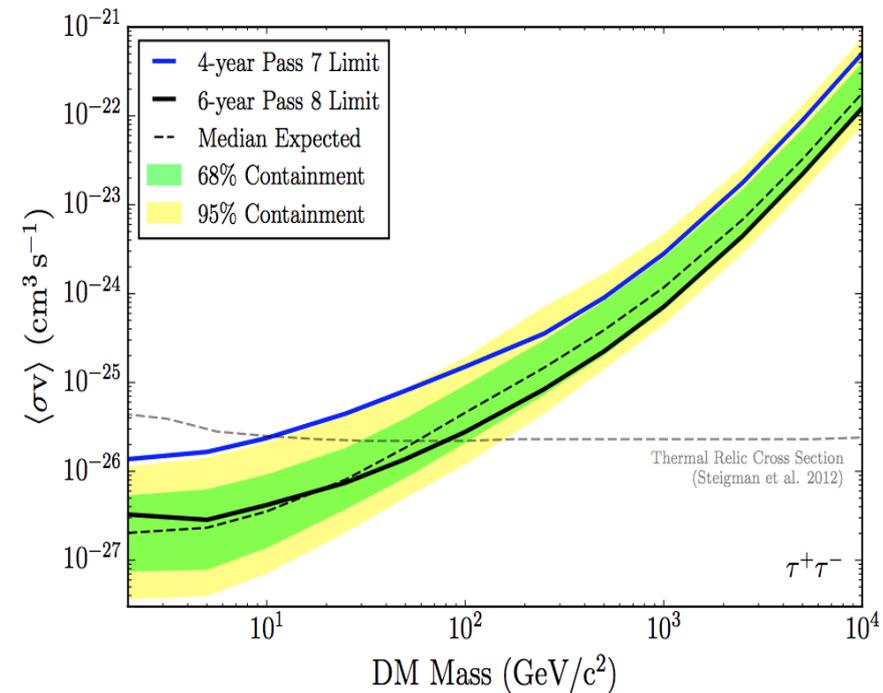
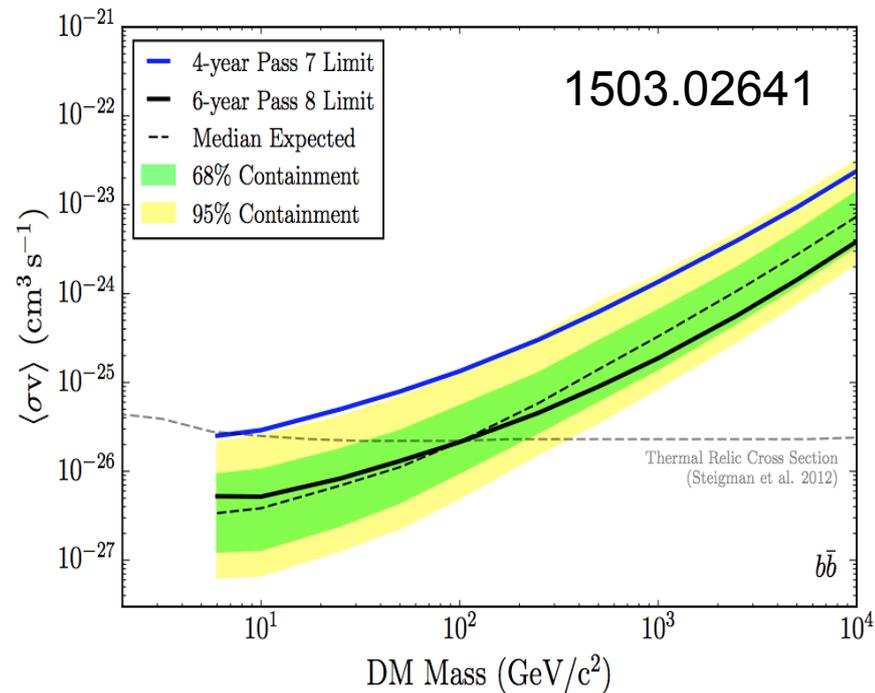
Section 2

- What are the bounds that we are up against?
- Direct detection :
 - Strongest bound from neutrino Wall



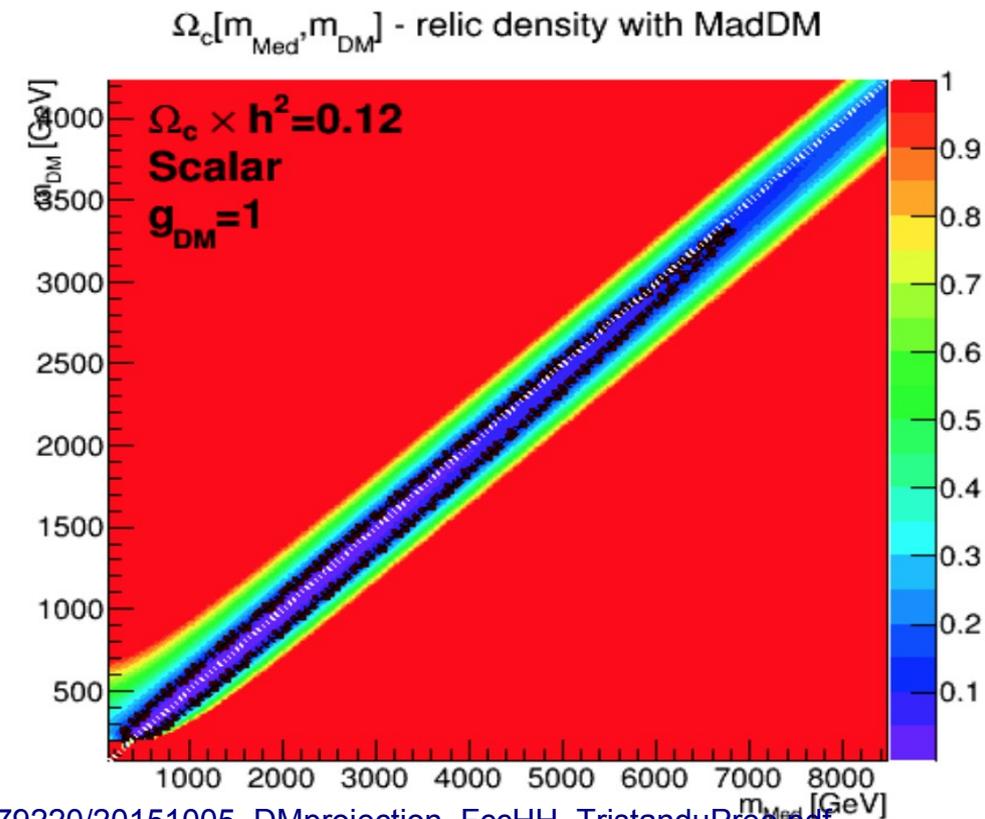
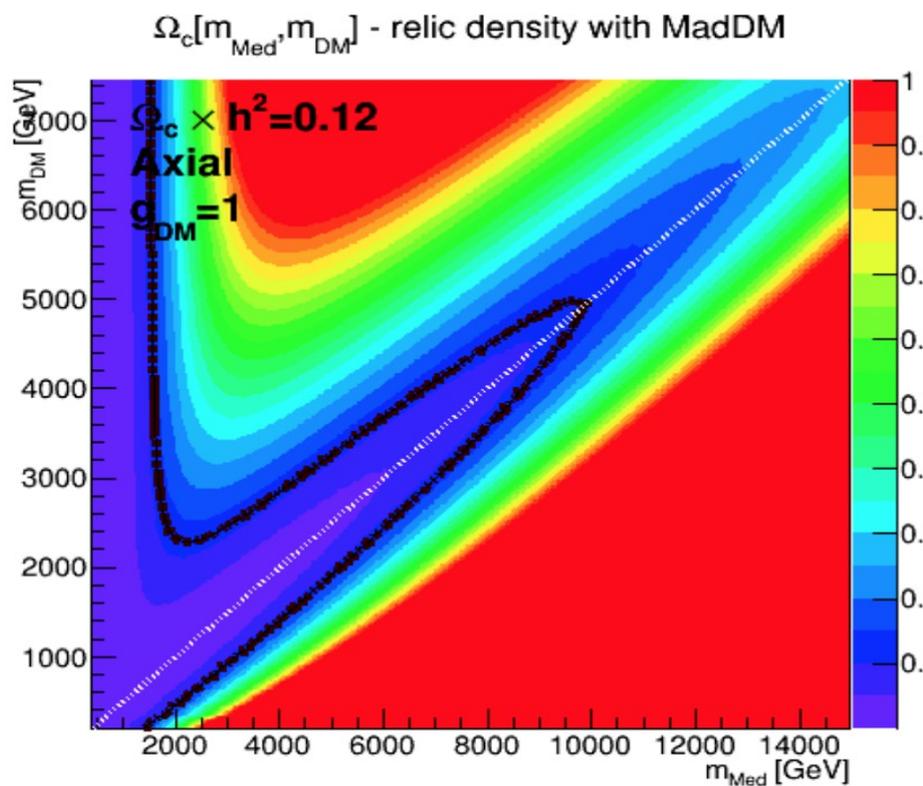
Section 2

- What are the bounds that we are up against?
- Indirect detection :
 - Re-survey of max bound required



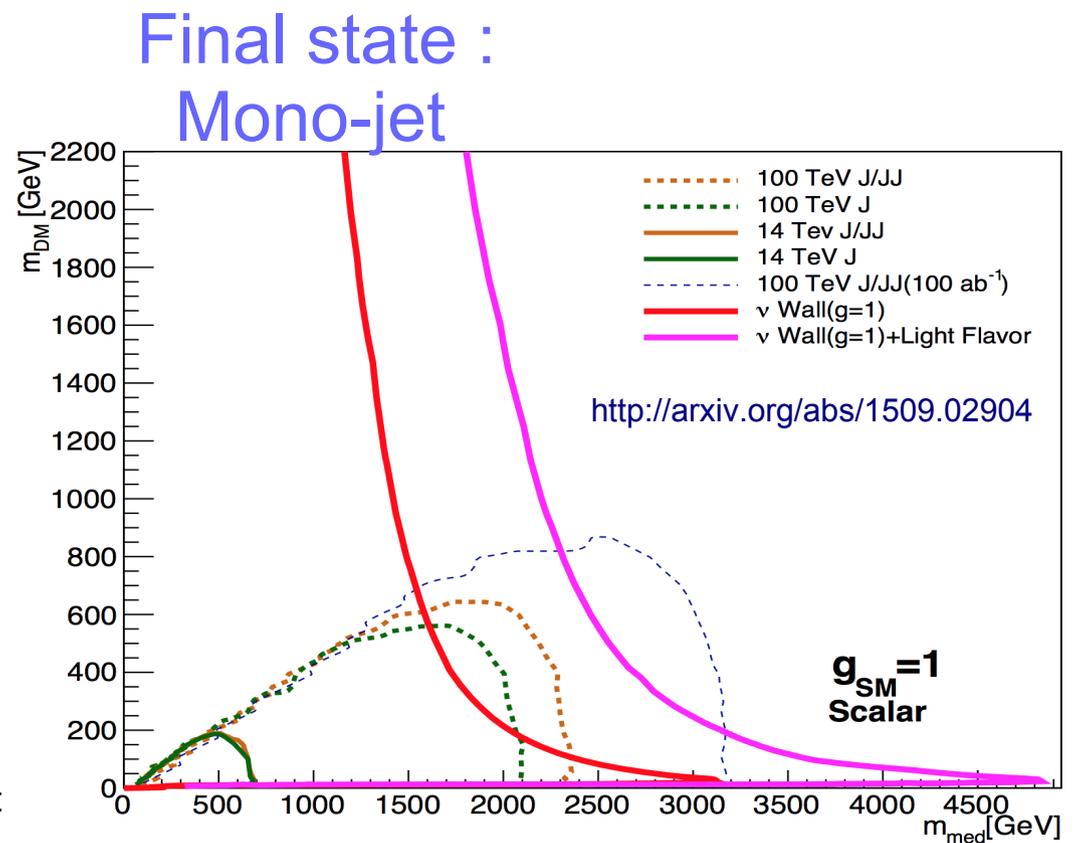
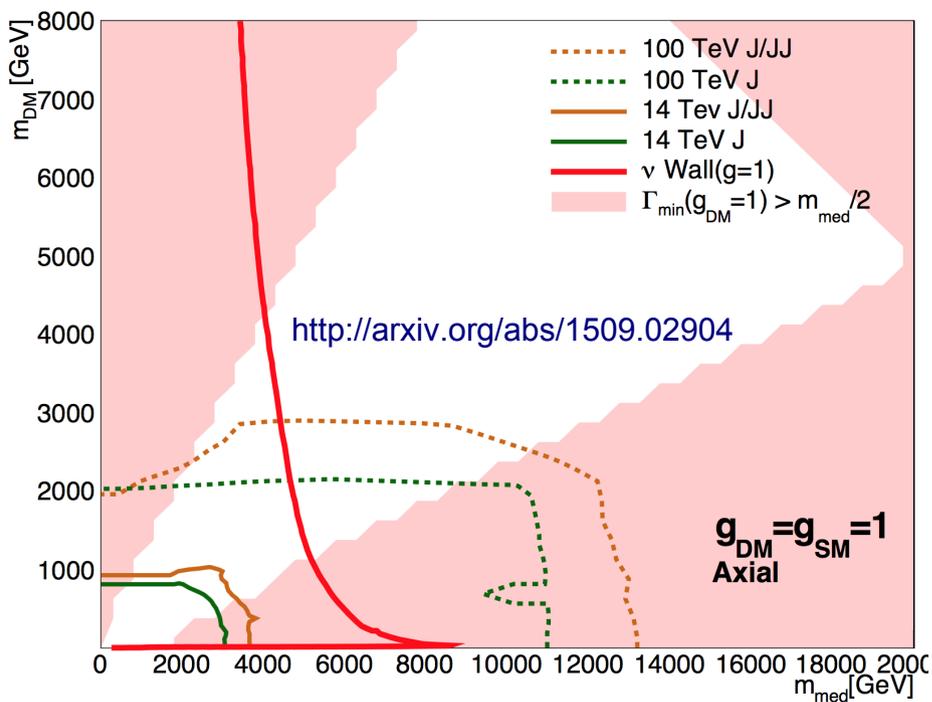
Section 2

- What are the bounds that we are up against?
- Relic density bounds :
 - Tristan's talk



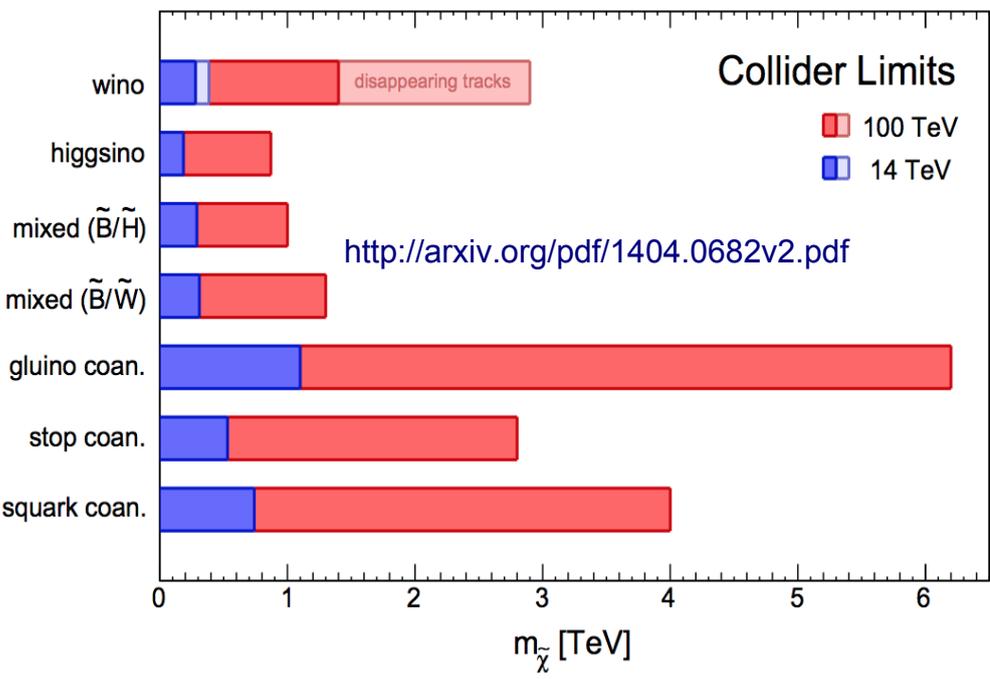
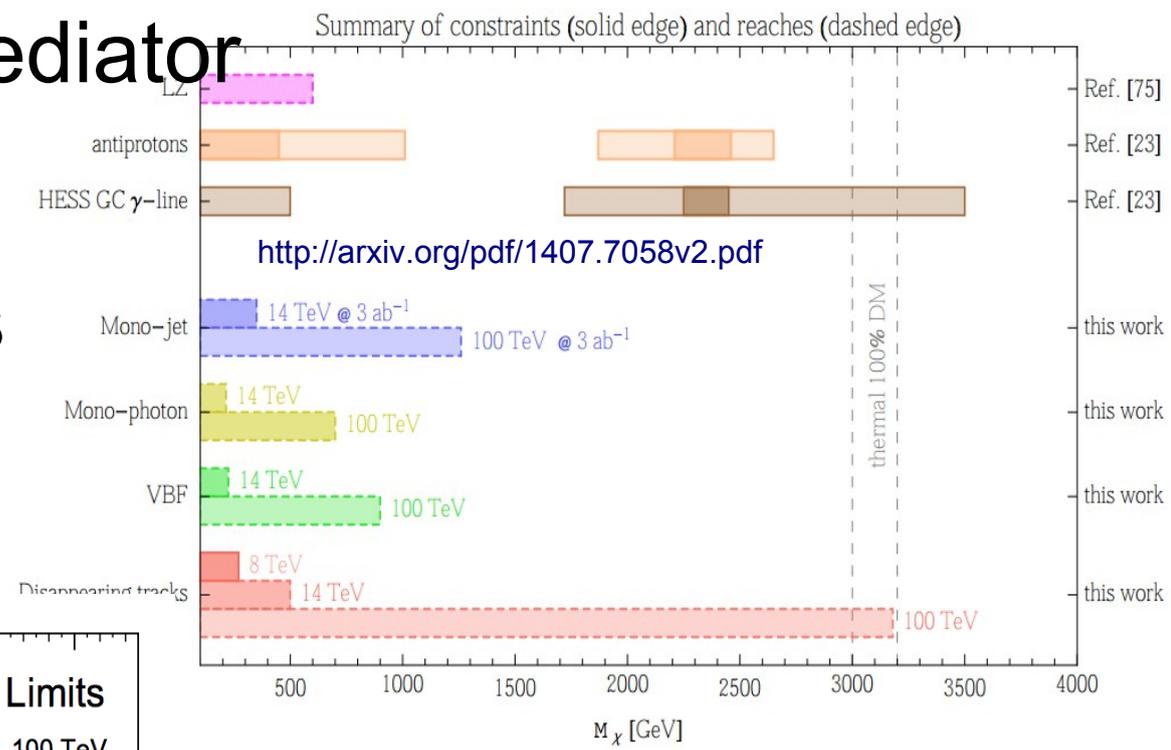
Section 2

- What are the bounds that we are up against?
- Collider bounds :
 - Tristan's talk



Section 3

- DM particle + SM mediator
- Weak gauge bosons
 - to DM



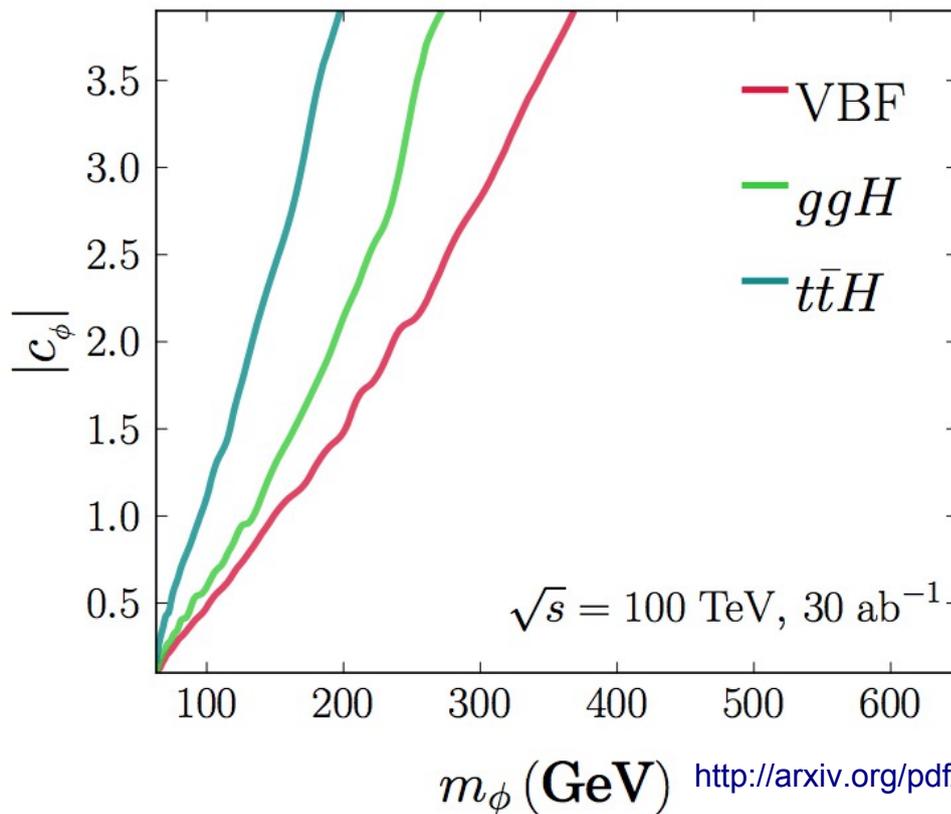
Final state :
 Mono-X
 Disappearing tracks

Section 3

- DM particle + SM mediator

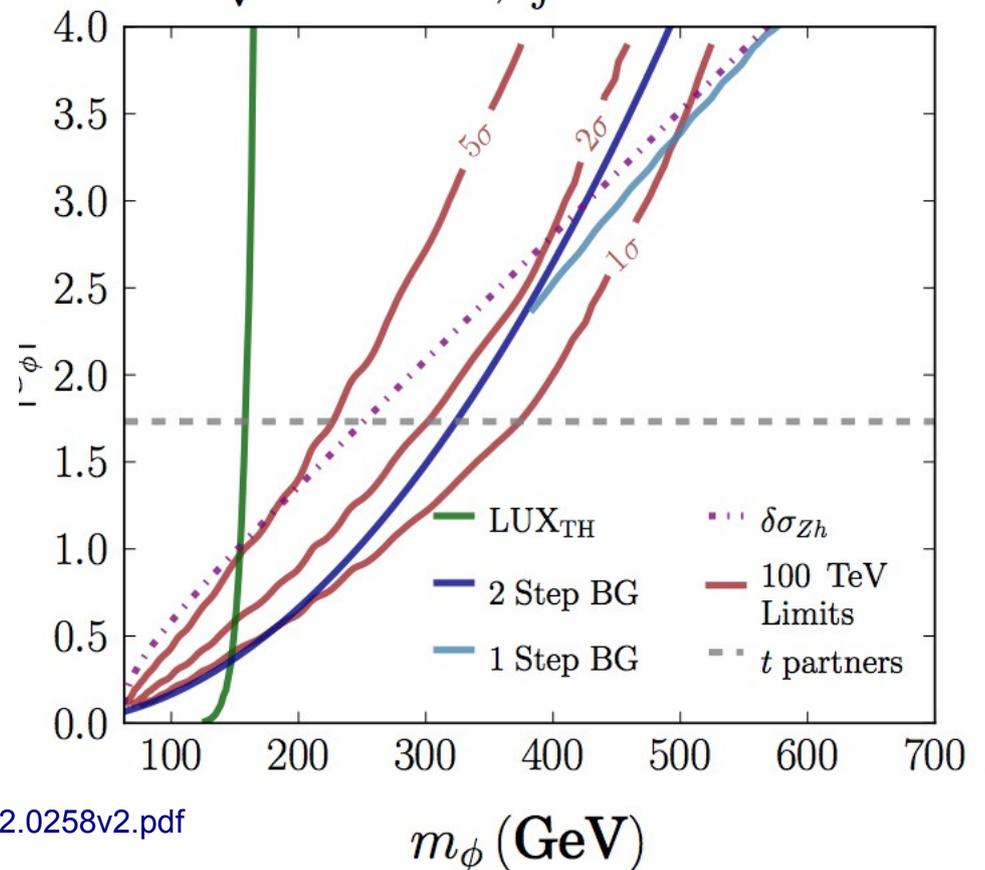
- Higgs to invisible

5 σ Discovery



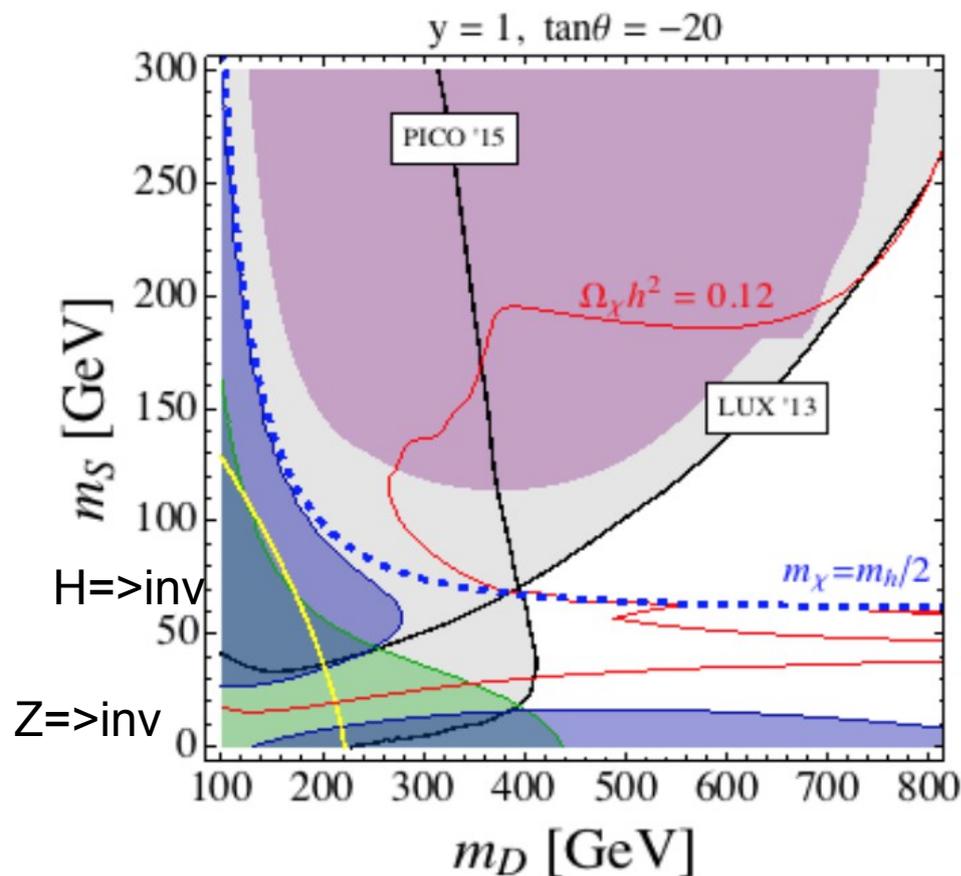
Final state :
Mono-X

$\sqrt{s} = 100$ TeV, $\int L dt = 30 \text{ ab}^{-1}$



Section 3

- DM particle + SM mediator
- Mixed scenario (singlet/doublet)



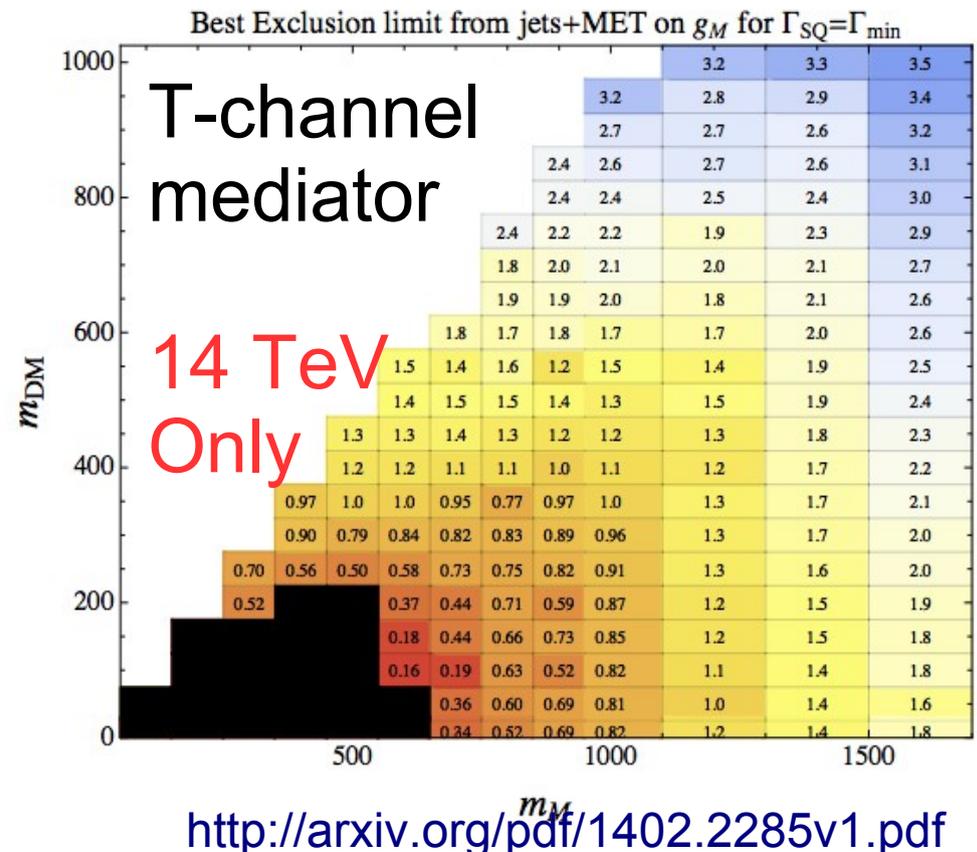
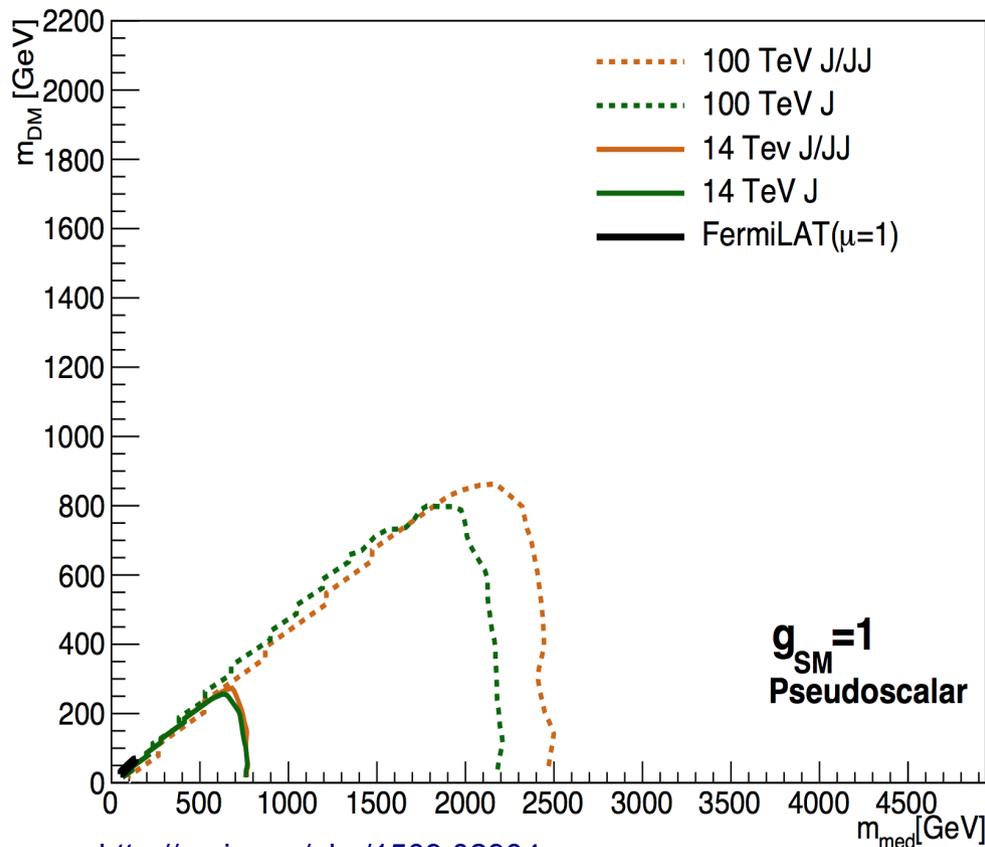
Final state :
Mono-X

Section 4

- DM particle + New Mediator

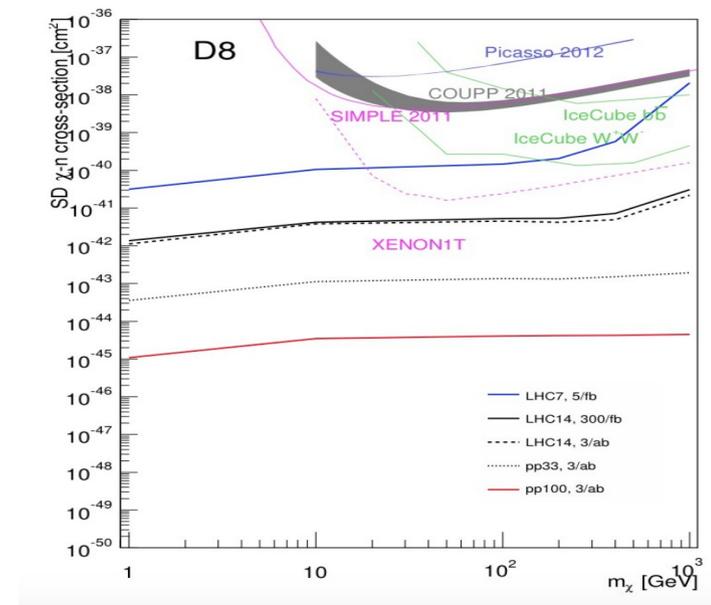
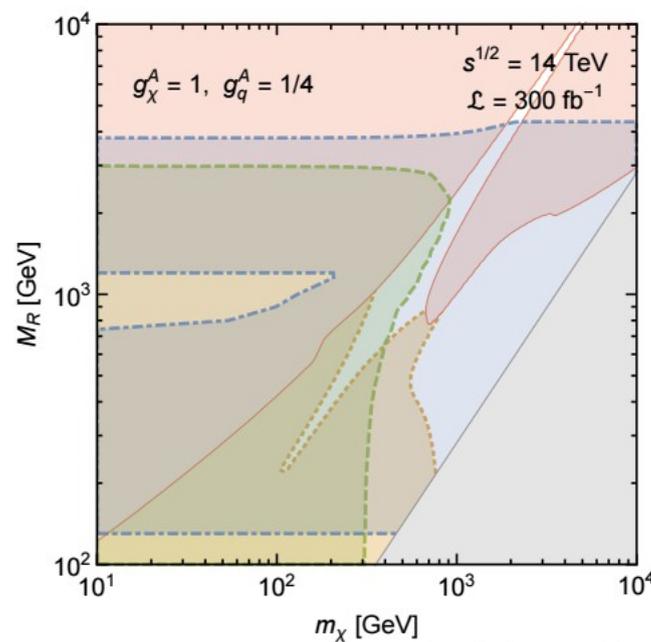
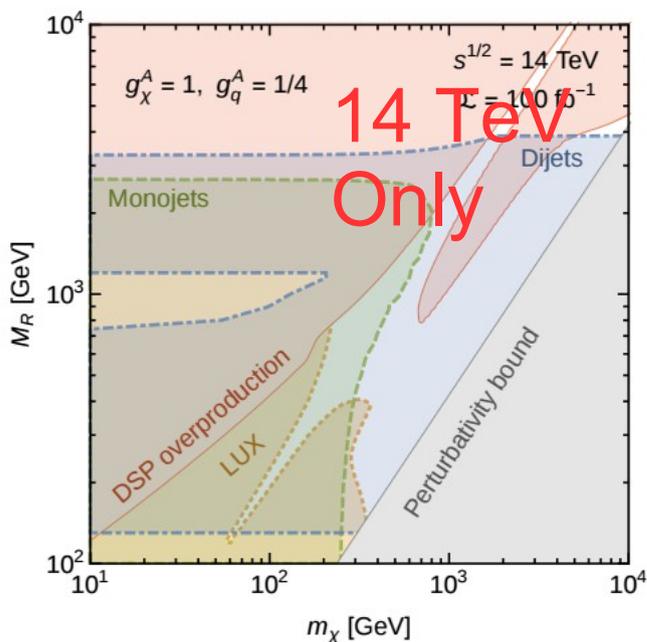
Final state :
Mono-X

- What are the bounds from simplified models



Section 4

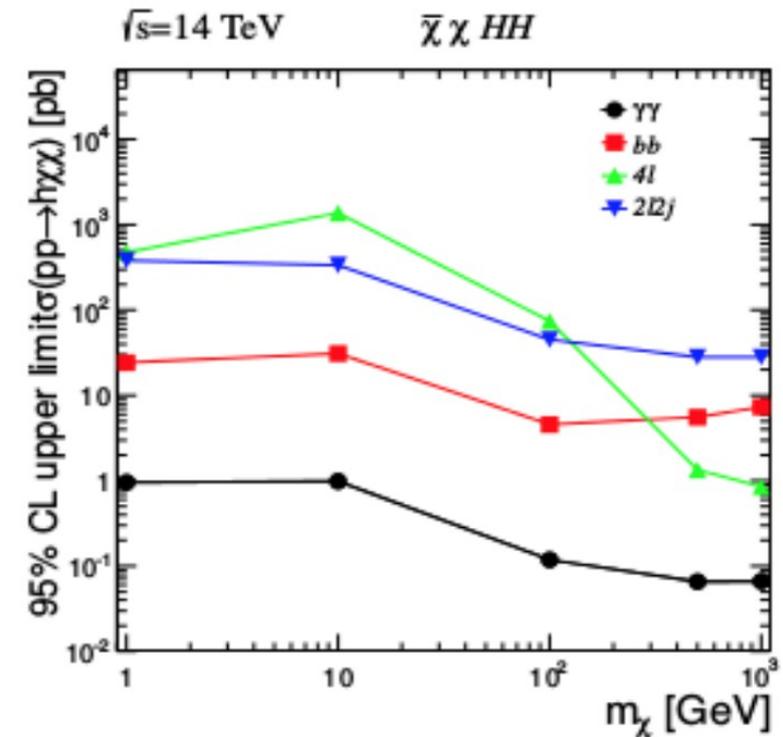
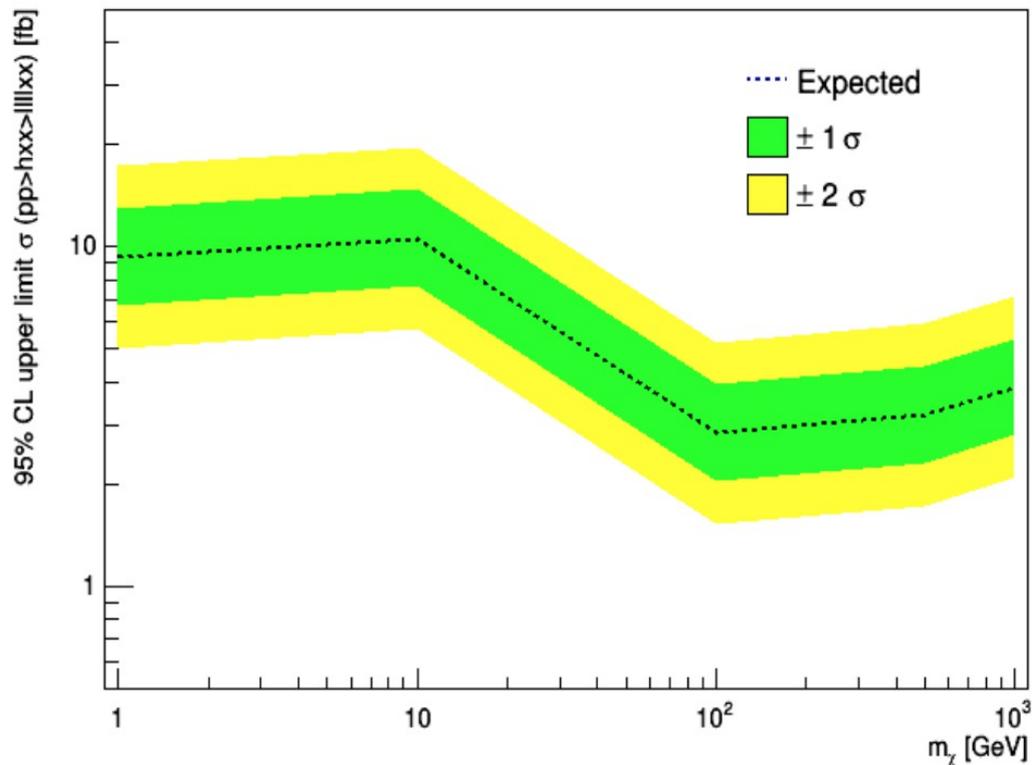
- DM particle + New Mediator
- Mixed SMS/EFT? scenarios (+ dijets)
 - EFTs are slowly dying for DM Final state :
Mono-jet/di-jets



Section

- DM particle + new Mediator
- Mono-Higgs

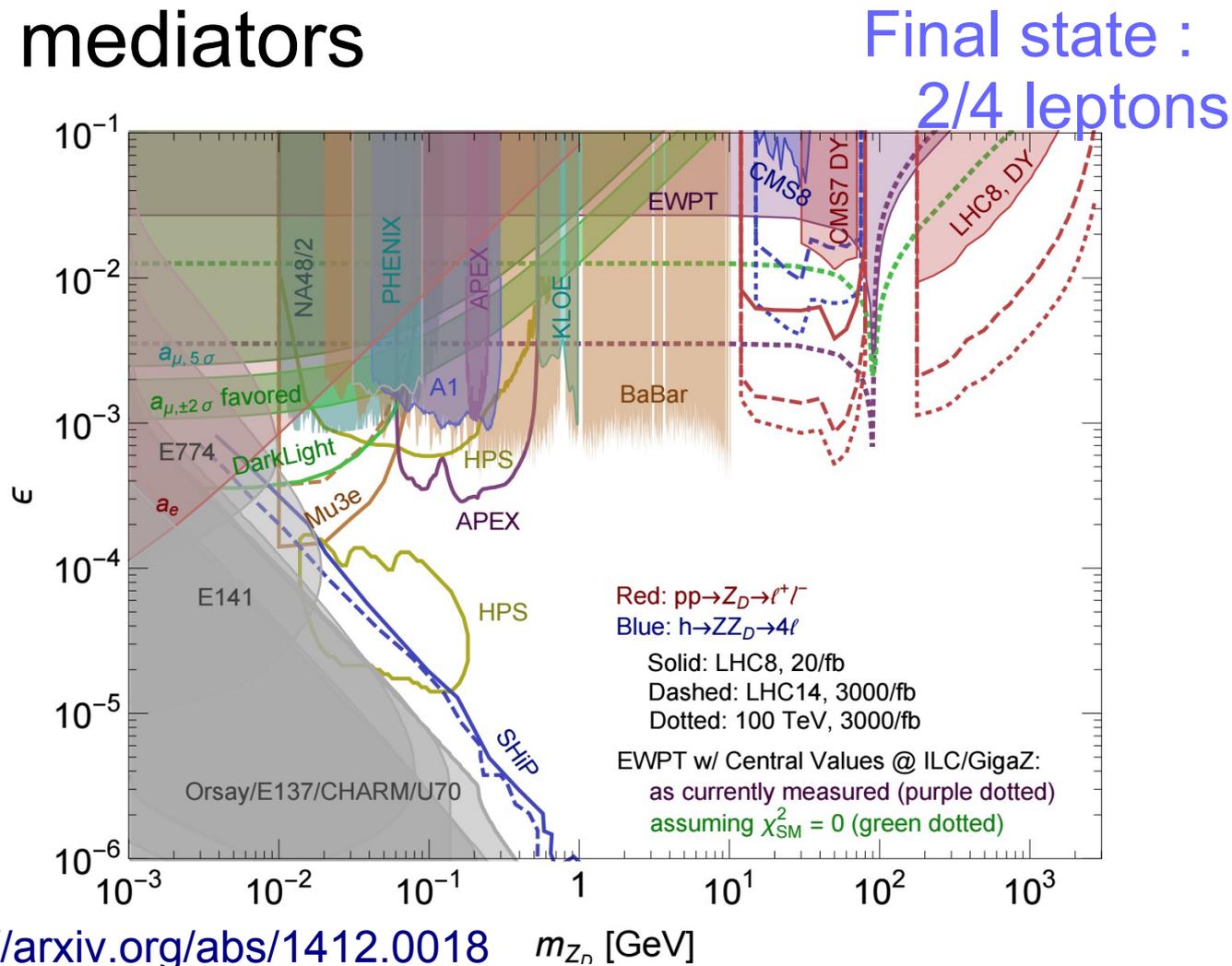
Final state :
Mono-Higgs



Section 4

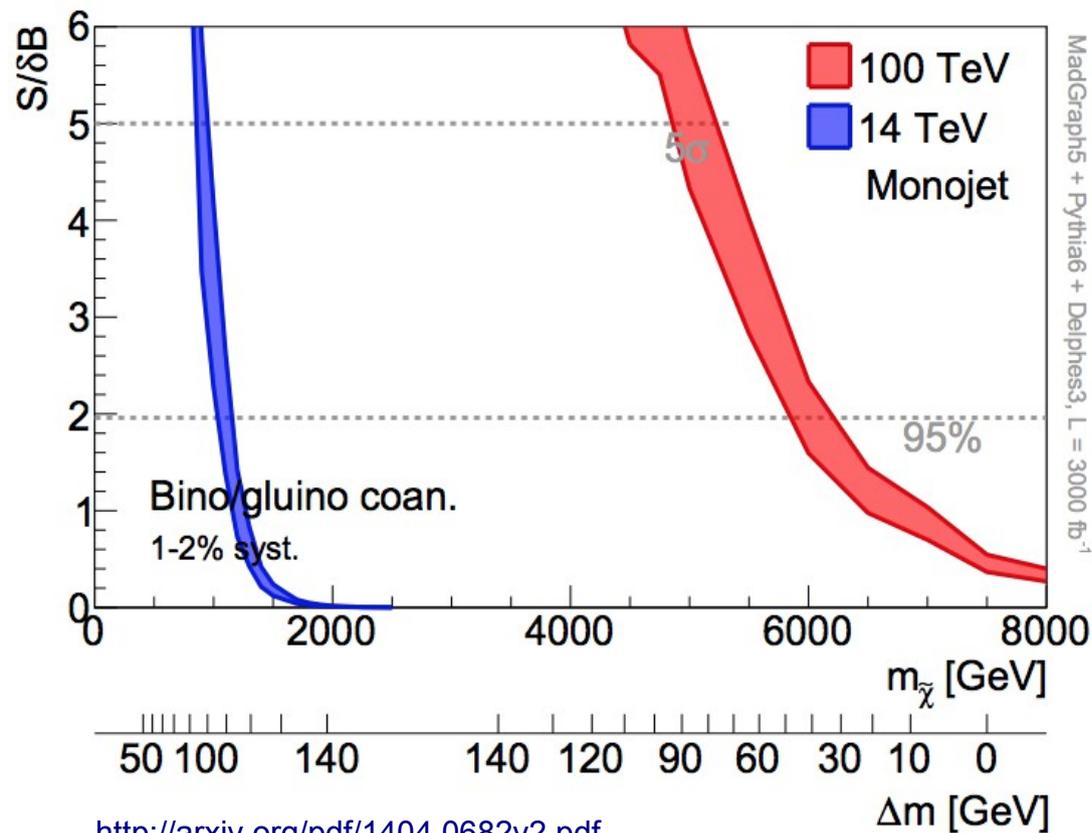
- DM particle + New Mediator

- Light mediators



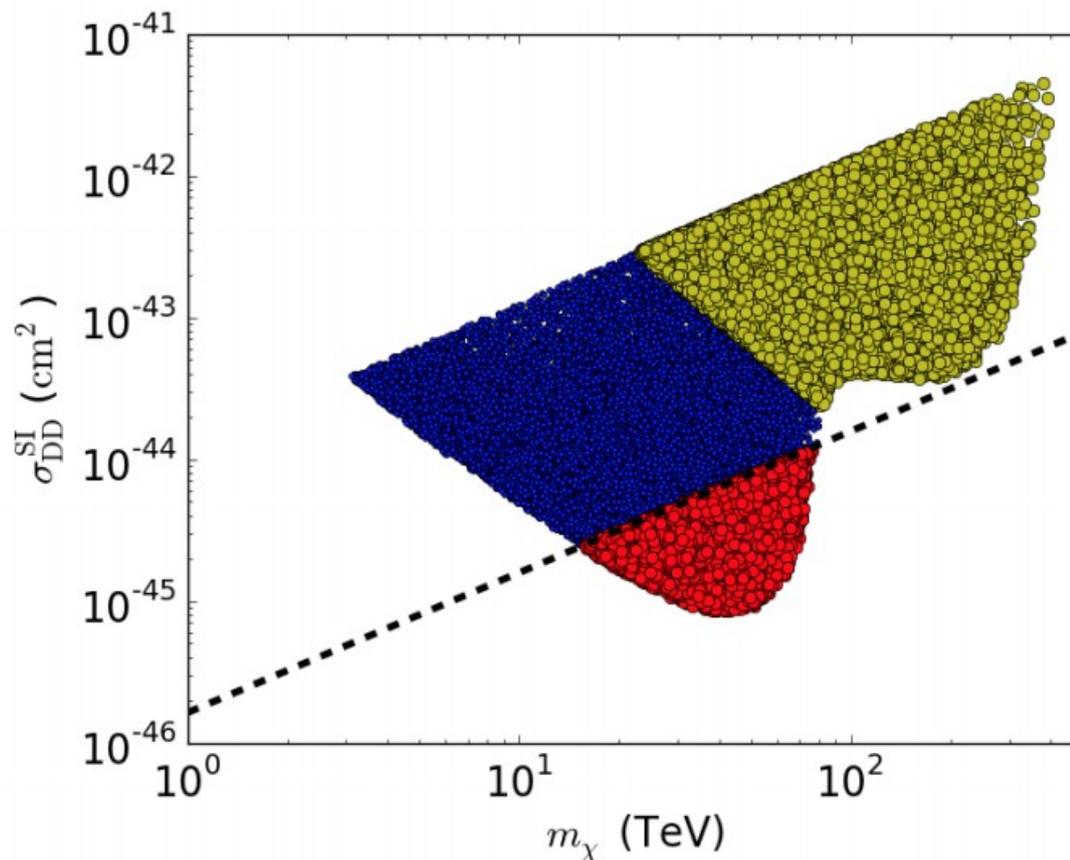
Section 5

- DM particle + more than a mediator
- Co-annihilation (coordinated w/SUSY)



Section 5

- DM particle + more than a mediator
- Resonant annihilation (coordinated w/SUSY)

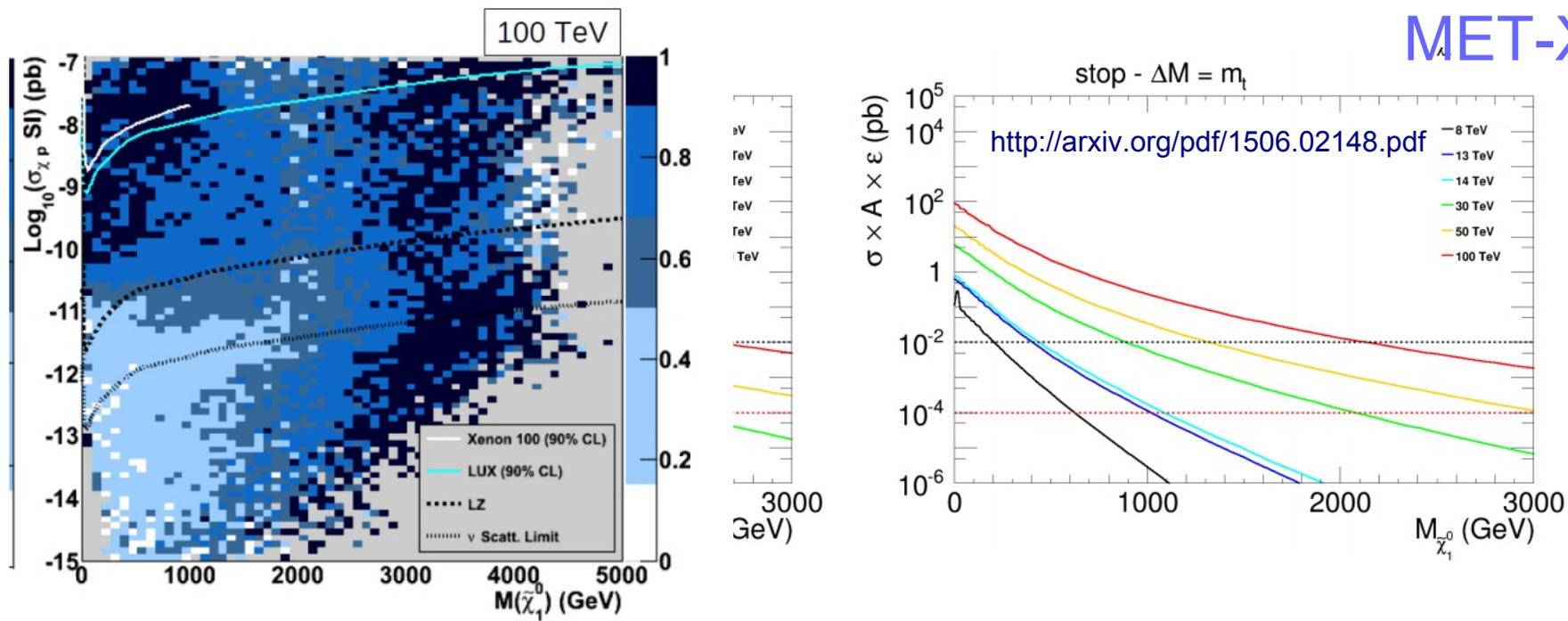


Final state :
Mono-X

Section 5

- DM particle + more than a mediator
- MSSM dark matter (to be coordinated with SUSY)

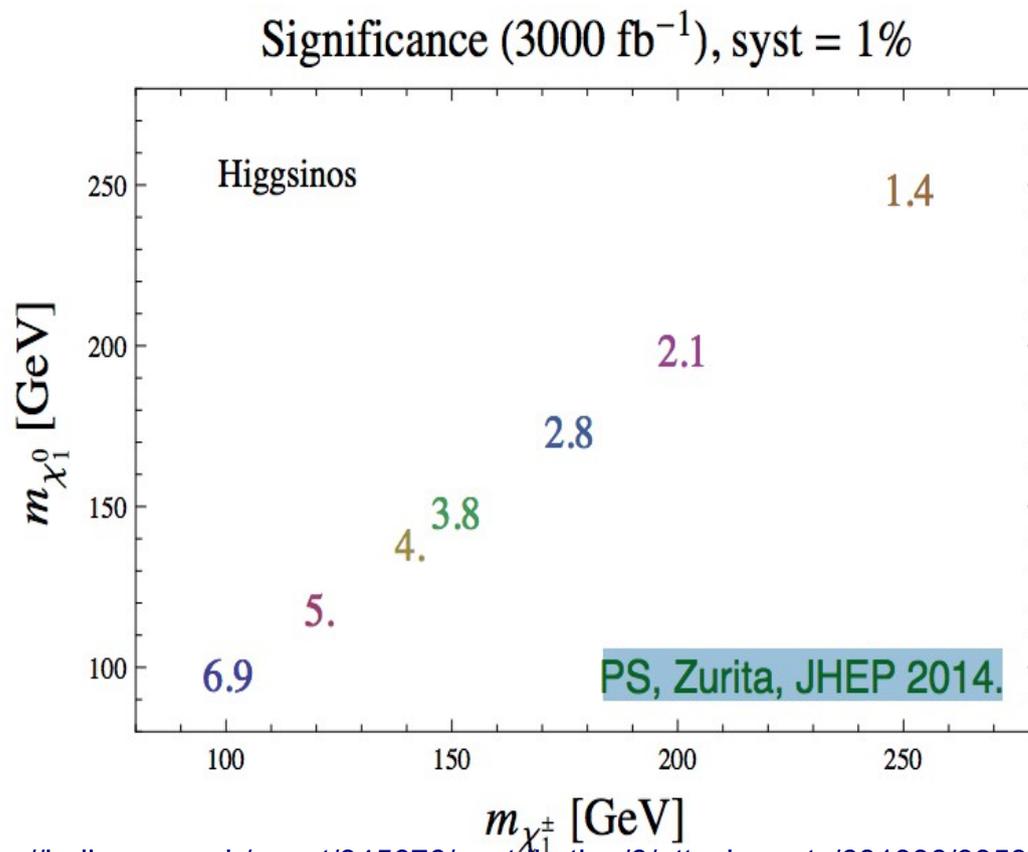
Final state :
MET-X



Section 4/5

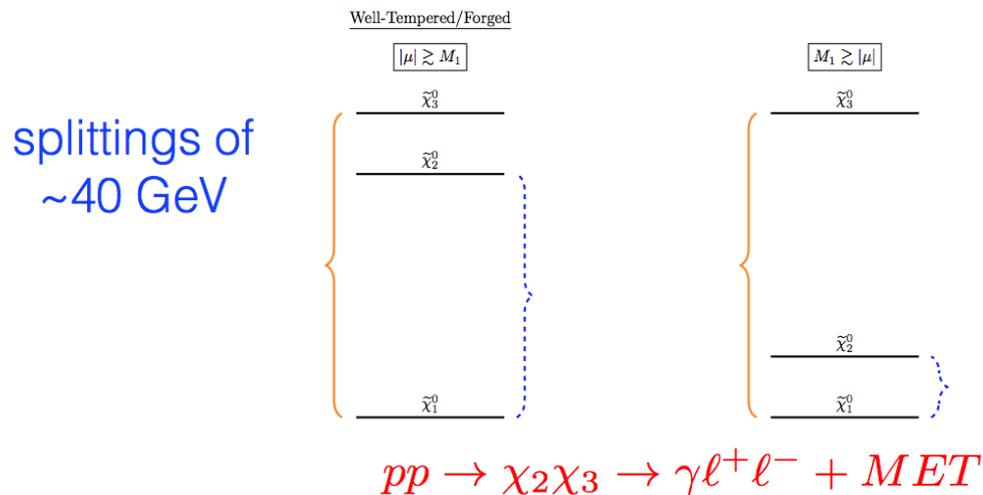
- DM particle + more than a mediator
- Degenerate Higgsino

Final state :
Mono-X



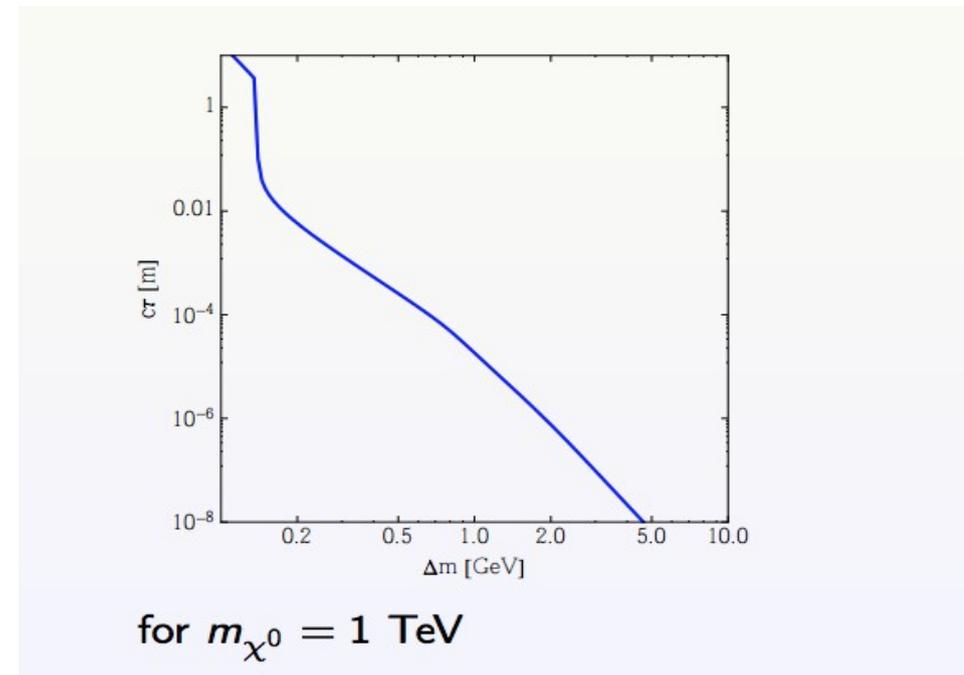
Section 5

- DM particle + more than a mediator
- Compressed spectra/Alternative final states scenarios are motivated by DM.



<http://indico.cern.ch/event/345676/contribution/6/attachments/681336/935979/FCC-Delgado.pdf>

Benchmark points	Point A	Point B	Point C	Point D
μ	-150 GeV	-180 GeV	-145 GeV	150 GeV
M_1	125 GeV	160 GeV	120 GeV	125 GeV
$\tan \beta$	2	2	10	10
$m_{\tilde{\chi}_1^0}$	124.0 GeV	157 GeV	105 GeV	103 GeV
$m_{\tilde{\chi}_2^0}$	156.9 GeV	186 GeV	150 GeV	153 GeV
$m_{\tilde{\chi}_3^0}$	157.4 GeV	188 GeV	163 GeV	173 GeV
$\sigma(pp \rightarrow \tilde{\chi}_2^0 \tilde{\chi}_3^0)$	394 fb	200 fb	345 fb	287 fb
$BR(\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 \gamma)$	0.0441	0.0028	0.0017	0.0014
$BR(\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 \ell^+ \ell^-)$	0.0671	0.0712	0.0702	0.0700
$BR(\tilde{\chi}_3^0 \rightarrow \tilde{\chi}_1^0 \gamma)$	0.0024	0.0767	0.0115	0.0102
$BR(\tilde{\chi}_3^0 \rightarrow \tilde{\chi}_1^0 \ell^+ \ell^-)$	0.0714	0.0613	0.0447	0.0304
$\sigma(pp \rightarrow \tilde{\chi}_2^0 \tilde{\chi}_3^0 \rightarrow \gamma \ell^+ \ell^- \tilde{\chi}_1^0 \tilde{\chi}_1^0)$	1.297 fb	1.125 fb	0.279 fb	0.205 fb



<http://indico.cern.ch/event/345676/contribution/1/attachments/681329/935972/Mahubani-HinoDM.pdf>

Final state :
Disappearing tracks

Section 6

- Beyond WIMP DM
- Axions?/Asymmetric dark matter/Dark QCD
 - References to added (each is a section)
- **Are we missing anything else?**
 - If so it will go here

Section 7

- Detector bounds
 - Summarize the final states that drive the results
 - A table of which final state is needed for which search
- Discussion on the detector design limitations
 - Review of each final states and detector bounds
 - Discussion of where improvements can be added
 - Section is a conclusion directed at detector design
- List of potential weaknesses in the current design

Summary

- We have presented a brief outline
- Two general ideas are implicit :
 - What are **all dark matter models** on the market?
 - What does FCC cover that **other experiments can't**?
 - Can we collect no-lose theorems?
- Next weeks
 - You/your friends will be contacted about contributions
 - We welcome any suggestions