Detector Requirements: The BSM Perspective

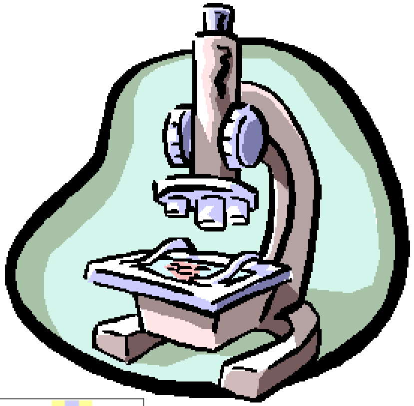
ILD Workshop, Krakow
September 25, 2013
J.List, DESY

ILC New Physics Goals

1. find things missed by LHC

   A) if LHC finds nothing

   B) if LHC finds some,
   but not ALL new states

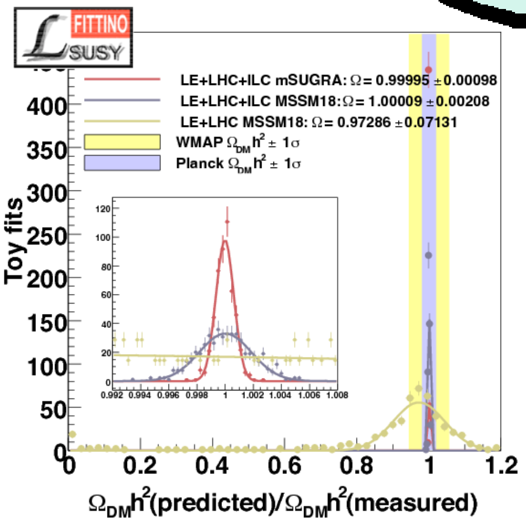


2. do precision measurements of stuff found

   A) by LHC

   B) at the ILC

3. figure out underlying theory,
   determine its parameters,
   show consistency with
   cosmology, flavour, neutrino ….



What could escape the LHC?

- ***not*** the famous plain-vanilla SUSY: strong production, large MET, high ET jets / leptons,...
- but these might be hiding:
  - **small mass differences** (co-annihilation, higgsinos,...)
  - **fully hadronic final states** with low MET (RPV!)
  - **low cross-sections** and **diverse decay modes**
  - signatures with **large irreducible backgrounds** -> systematic uncertainties!

Low energy particles

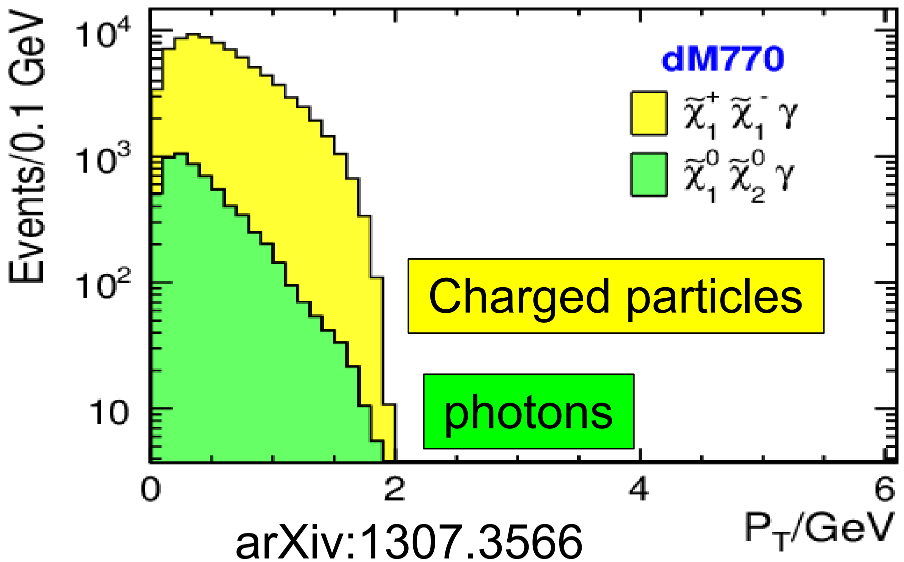
- States with **small mass differences** impossible to resolve at LHC (even if *some* deviation from SM can be discovered!)

  => **unique ILC opportunity!**

- Requires:
  - **ability to reconstruct low momentum particles** → sub-GeV tracks, photons
  - **particle ID**: identify exclusive decay modes of (near-)degenerate states
  - **non-pointing signatures**: photons, kinks, …
  - **modelling of pair and γγ backgrounds** incl. overlay

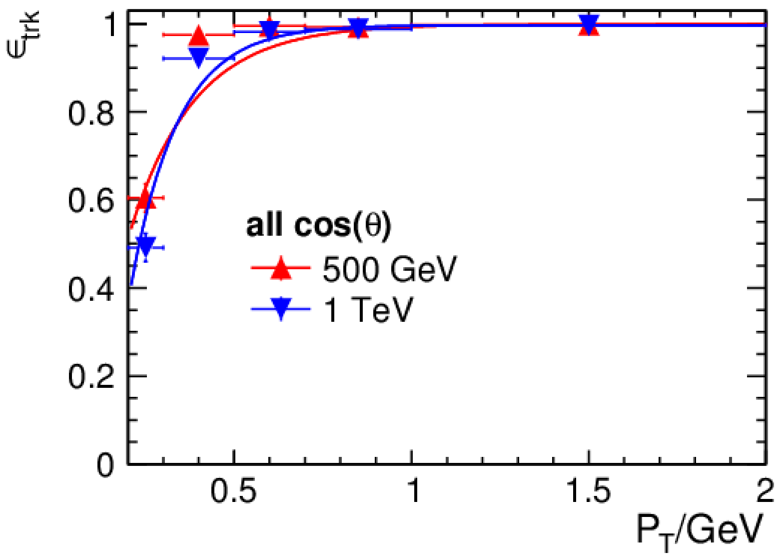
Tracking for sub-GeV particles

- P_T spectrum of **Higgsino decays - ΔM = 770 MeV (!)**



arXiv:1307.3566

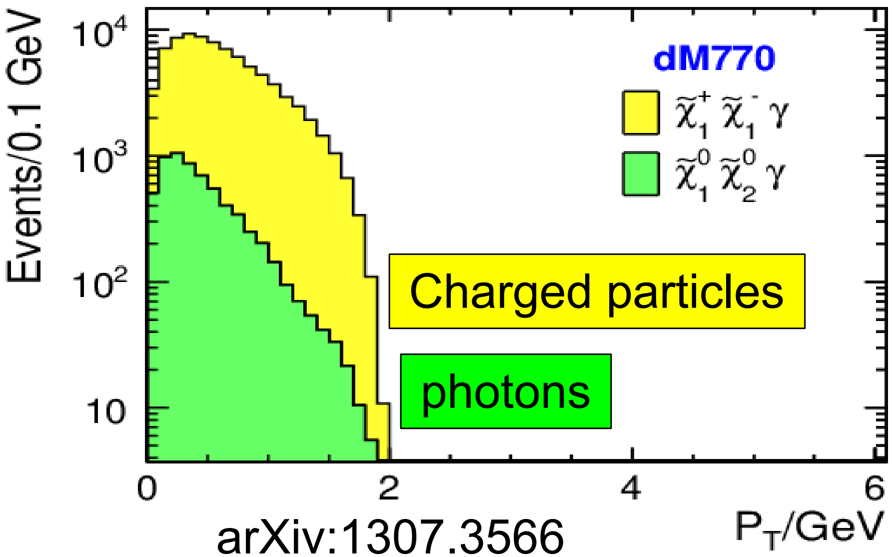
- **Tracking efficiency** in DBD: ttbar + pair background



- Not yet studied: corresponding **fake rate**!
- Can efficiency be improved for < 0.5 GeV?
- Stand-alone Si tracking?

Sub-GeV photons / π^0

- P_T spectrum of **Higgsino decays - ΔM = 770 MeV (!)**



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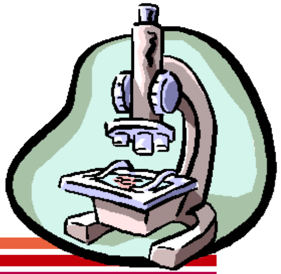
- **Reconstruction efficiency, fake rate, resolution, ...**

?

Once there is a new particle..



- … precision measurements!
- Statistical precisions can reach:
  - O(10 MeV) for masses
  - O(1%) for cross-section x BR

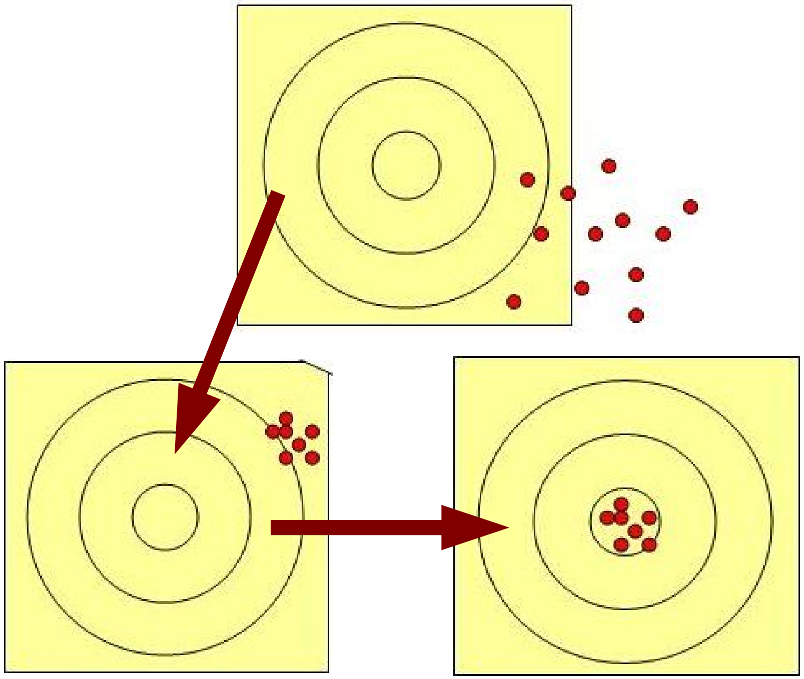
… or better

=> better seriously study also potential systematics -

Or: precision vs accuracy

Precision Measurements

- **Precision** (detector resolution):
  - separate close-by states
  - separate decay modes
- **Accuracy** (detector calibration):
  - momentum / energy scale
  - beam energy spectrum etc

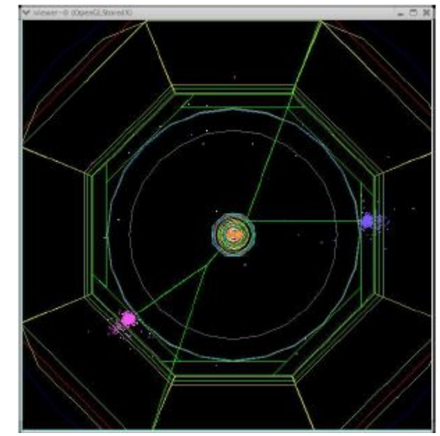


- **Modelling** ("Standard model" calibration):
  - fragmentation / hadronisation corrections
  - γγ background: photon structure functions, modelling of γ-hadron interactions

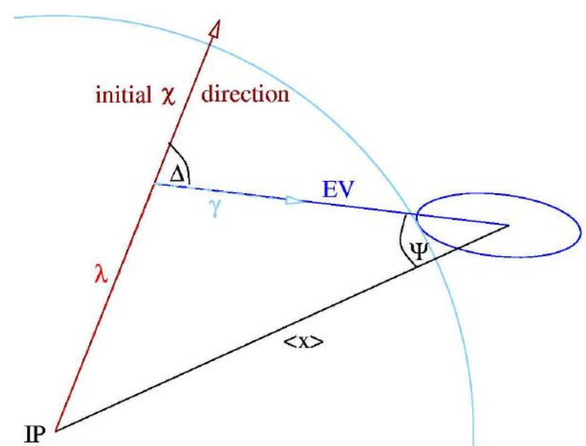
=> needs SM precision measurements!

Non-pointing Photons

- Generic BSM signature: invisible → photon + invisible
- Often in connection with lifetime
  => non-pointing photons!
- Measure photon angle from cluster main axis in Ecal

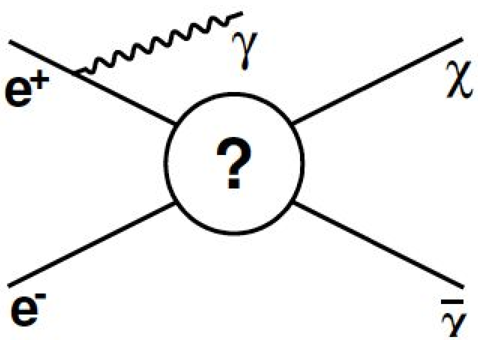


- Reconstruct lifetime and masses of “invisible” particle
- Last studied with LoI detector
- Benchmark Si vs Scintillator vs mixed ECal in terms of photon φ and θ reconstruction: resolution & bias

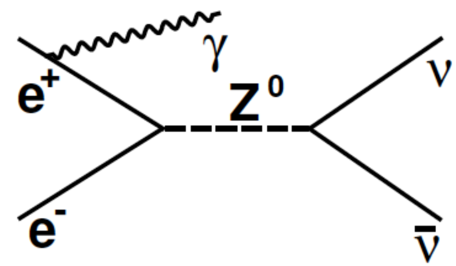


Model-independent WIMPs

- In "invisible + ISR" mode

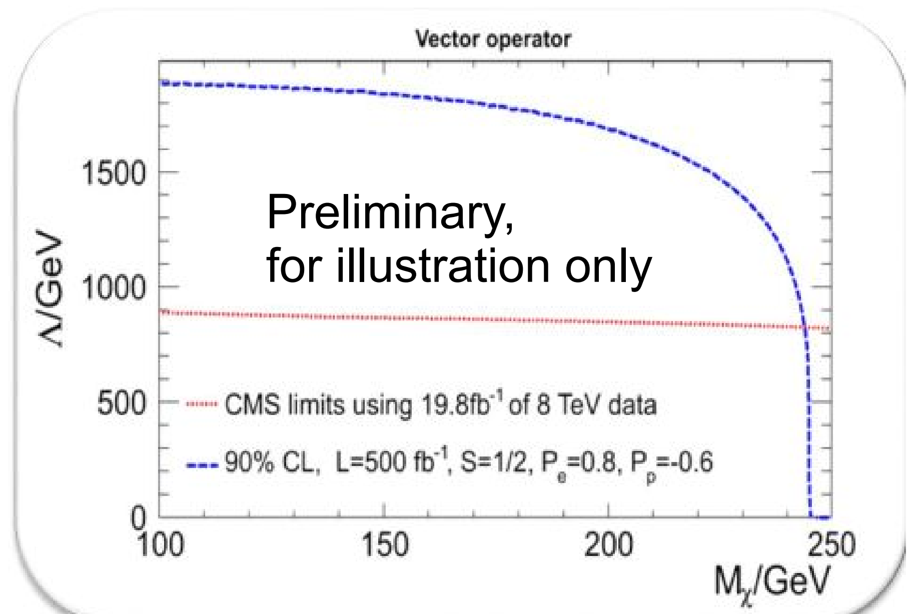


- Huge irreducible background due to



+ t-channel

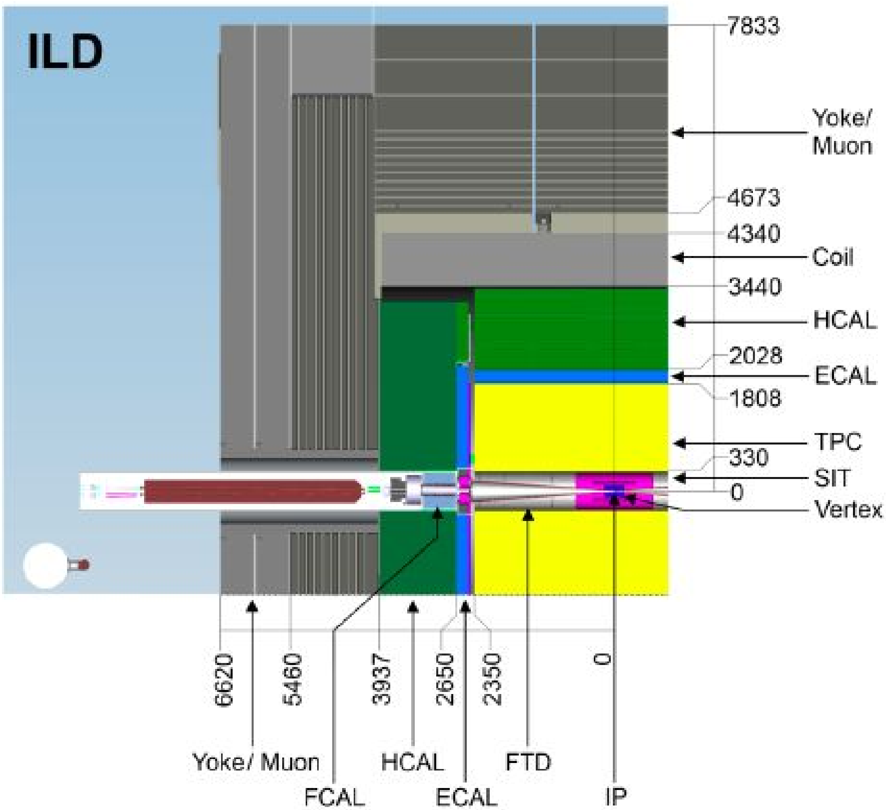
- Sensitivity limited by systematics
- Currently: assume 3% on background prediction
- 1% would give factor ~2 gain in suppression scale Λ



Physics Benchmarks

- Light Higgsinos/Winos:
  - very small mass differences
  - Exclusive decay modes: displaced vertices, particle ID
- WIMPs:
  - Invisible + ISR
  - High irreducible background from SM $\nu\nu\gamma$: control of systematics
- Light Gravitinos:
  - non-pointing photons
  - Ecal performance in cluster angle reconstruction
- Light staus:
  - small mass differences
  - $\gamma\gamma$ background suppression
  - tau reconstruction

What does this mean for ILD?



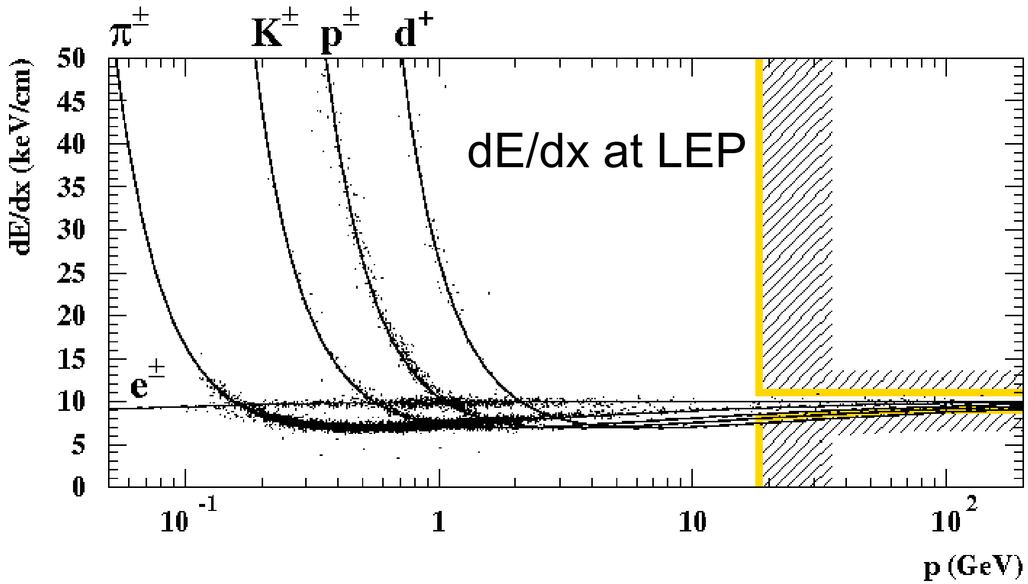
- Go through aspects **unique** to BSM
- Aspects for SM / Higgs also good for BSM ;-)
- Will comment on
  - Vertex / inner Si
  - TPC
  - Ecal
  - Fcal

Vertex / SIT / FTD

- Unique ILC BSM opportunity: small mass differences
  => sub-GeV particles => don't reach TPC!
- **Stand-alone pattern recognition** & track fit in Si detectors!
- Currently: seems challenging ….if integrating 80...100 BX worth of pair background! → Where's the limit?
- => Optimise point resolution vs read out speed
  (cf talk by Marc Winter yesterday!)
- Geometric combinations: alternating layers for time / point res.?
- At which point resolution does flavour tag start to suffer?
- Dependence on ECM:
  - 250 GeV: less pairs → focus on point resolution (Higgs!)
  - 500 GeV/1TeV: timing more important?

TPC: dE/dx

- One of the selling points of a TPC!
- Easy: anomalous dE/dx from exotic particles
  → basically ruled out by LHC (even visible with Si)
- Interesting: pi vs p vs K separation
  - Improve jet energy resolution (and scale?) by taking correct masses – for a 45 GeV jet, m_p = 1 GeV is 2%
  - Reduce uncertainties due to fragmentation
  - Identify exclusive decay modes of new particles
    → some completely background free
    – discovery with very few events!



Ecal: Photons

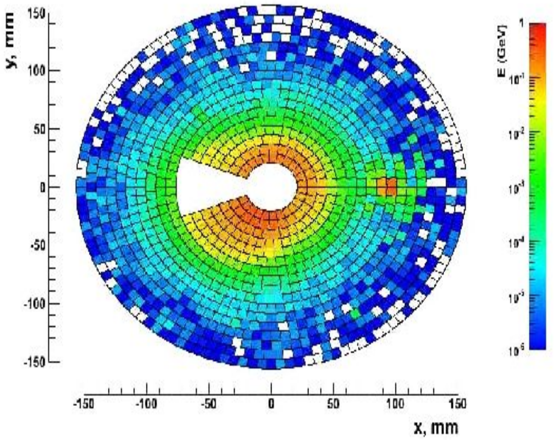
- Major cost driver – will have to justify the costs!
- SiW factor 2 more expensive than scintillator strips
- Jet energy resolution looks comparable (?)
- Interesting for New Physics:
  - Photon energy resolution
    - high energy up to ECM/2: WIMPs!
    - low energy: eg Higgsinos
  - Photon angle reconstruction (cluster shape)
  - Pi0 reconstruction (eg Higgsinos, WInos)

=> any of these better or worse for one of the options?

FCal: Hermeticity

- High energy electrons / photons (✔)

  BeamCal acceptance:
  limited by beam background rather than intrinsic detector properties !?



Low angle muons & hadrons ?

  - Sensitivity of BeamCal, LumiCal to MIPs, hadrons?
    → important to suppress certain γγ backgrounds

- LHCal – design?
  - Performance?
  - **LHCal is essential** for hermeticity
    → NP with small mass differences !

Conclusions

- We have to continue to make the physics case
- In particular for BSM:
  have to ensure ILD's sensitivity to LHC “loop-holes”
- Once something is found:
  the full precision program – control of **systematics**
- Wish-list for ILD:
  - **SiTracking**: Sub-GeV particles → stand-alone Si tracking in presence of beam background ?!
  - **Ecal** options: benchmark photon angle reconstruction
  - **TPC**: investigate benefit of dE/dx particle ID
  - **Fcal**: design for LHCal, MIP/hadron hermeticity