Signatures and Benchmarking

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New Format: Signature Sessions

- Missing Energy
- Jets and Photons
- Flavour and Tau Tagging
- Charged Particles

- **Organizers wanted to make an experiment**
- New ground half way from theory to detector
  - Look at things at different angle
  - Are we missing something?

- Worked well – many came to check it out!

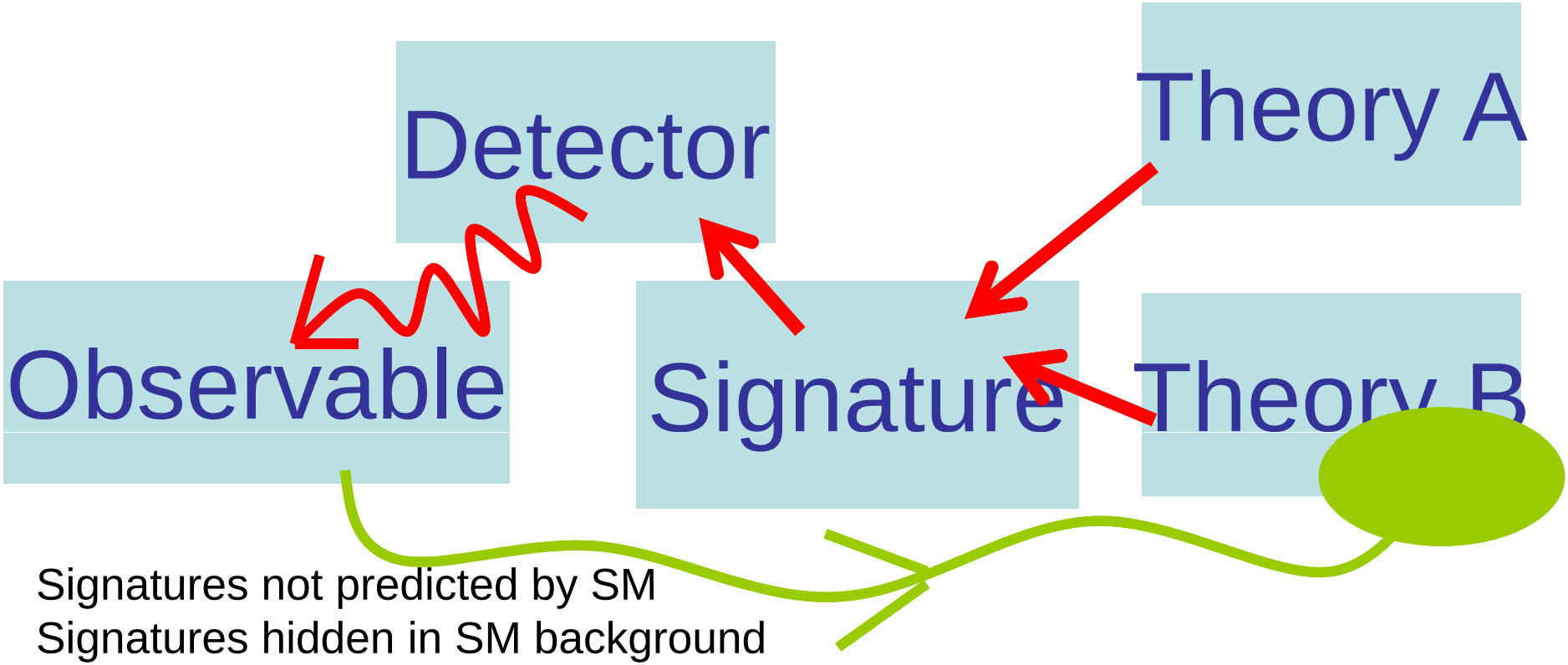
Signatures : Sociology

- Usually experimentalists go to Detector sessions
- Theorists go to Theory sessions

- Many felt Signatures was a good alternative that indeed broke segregation of theorists and brought them together again with experimentalists

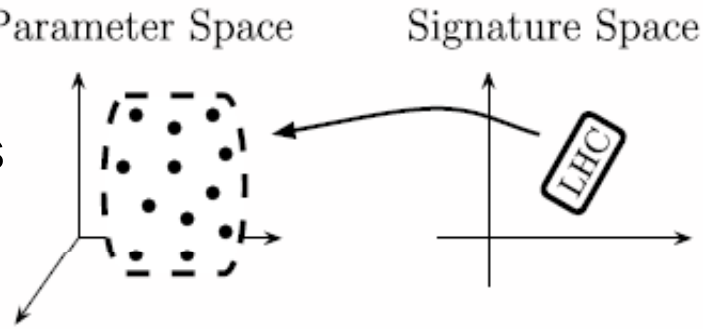
- There was some redundancy (as usual)
- Analyses do not diagonalize along separate objects

From Theory to Observable



- Signatures not predicted by SM
- Signatures hidden in SM background
- Precise measurement of SM signatures

- Multiple theories map into same signatures
- Detector distorts signatures into observables
- Observables map back into theories

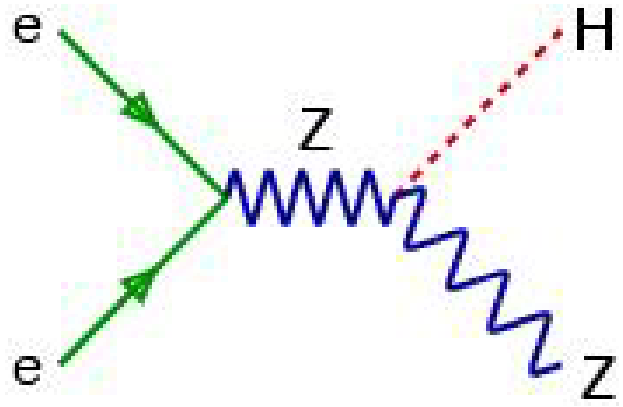


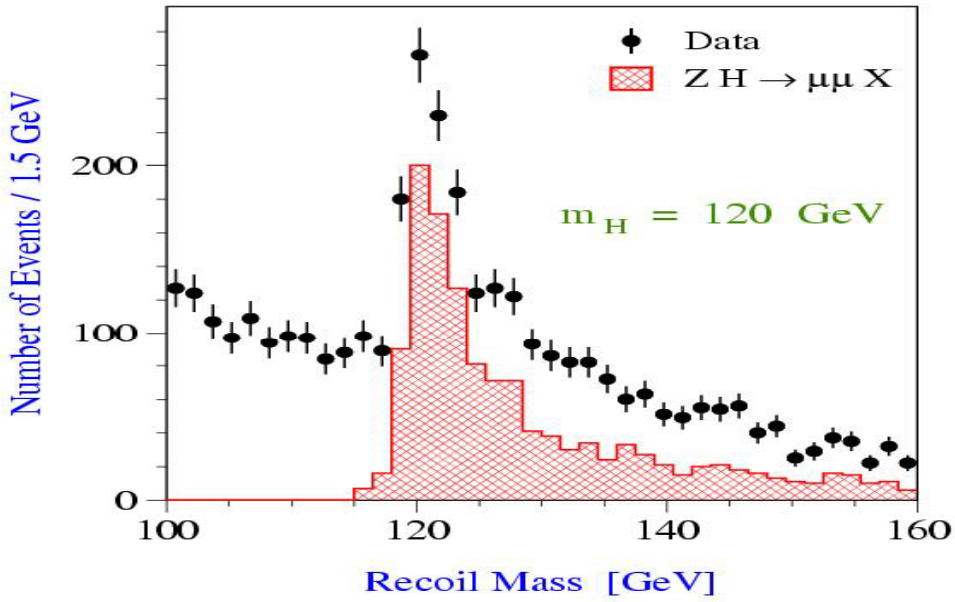
Processes

- Requirements
  - Highlight physics case for ILC
  - Be generic so more physics scenarios are covered → signature oriented
  - Be sensitive to detector parameters
- Choices
  - Higgs
  - SUSY
  - Precision measurements

ZH

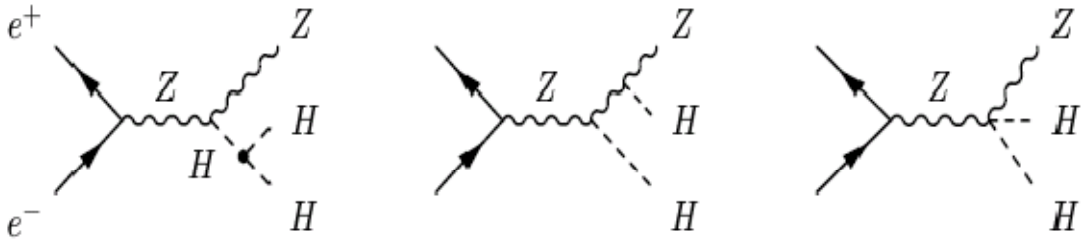
- Higgs:
  - Higgs can be reconstructed through recoil mass independently of its decay channel
  - Even for invisible decays



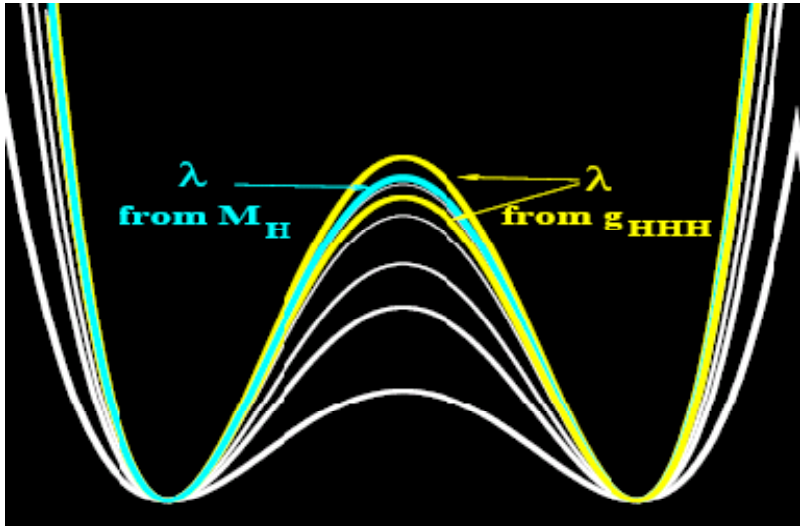


ZHH

Double Higgstrahlung: $e^+e^- \to H^0 H^0 Z^0$

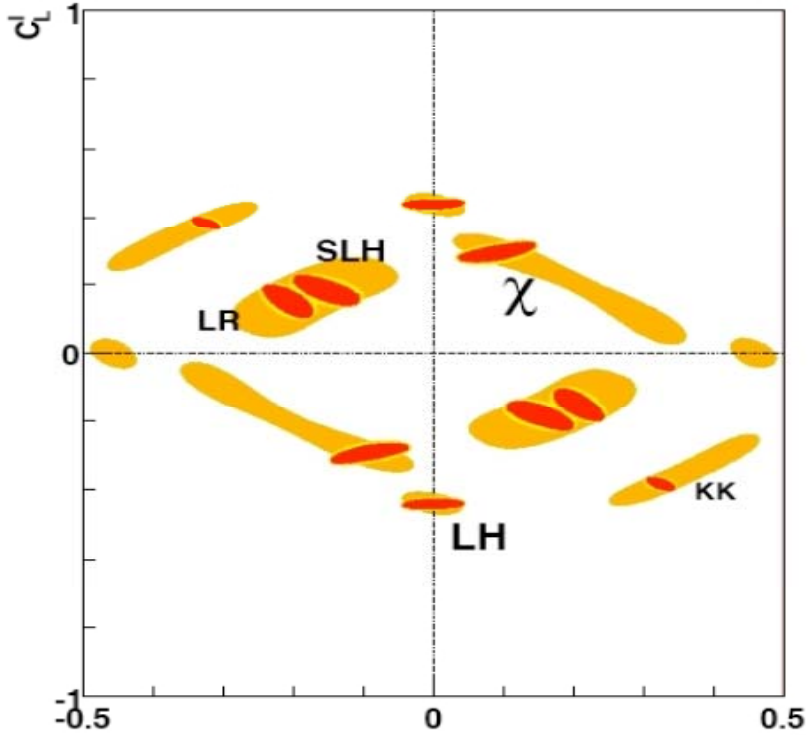


- Key to understanding of Higgs potential – mechanism of symmetry breaking
- Low xsection/ Large SM backgrounds
  - 0.2 fb HZZ vs 500 fb tt
- 4 b-jets in final state
  - b/c tagging and quark charge tagging are crucial



Precision

- Precision measurements of A_{LR} and A_{FB} allows to distinguish between models: Little Higgs, Simplest Little Higgs, E_6, KK excitations, LR-symmetric

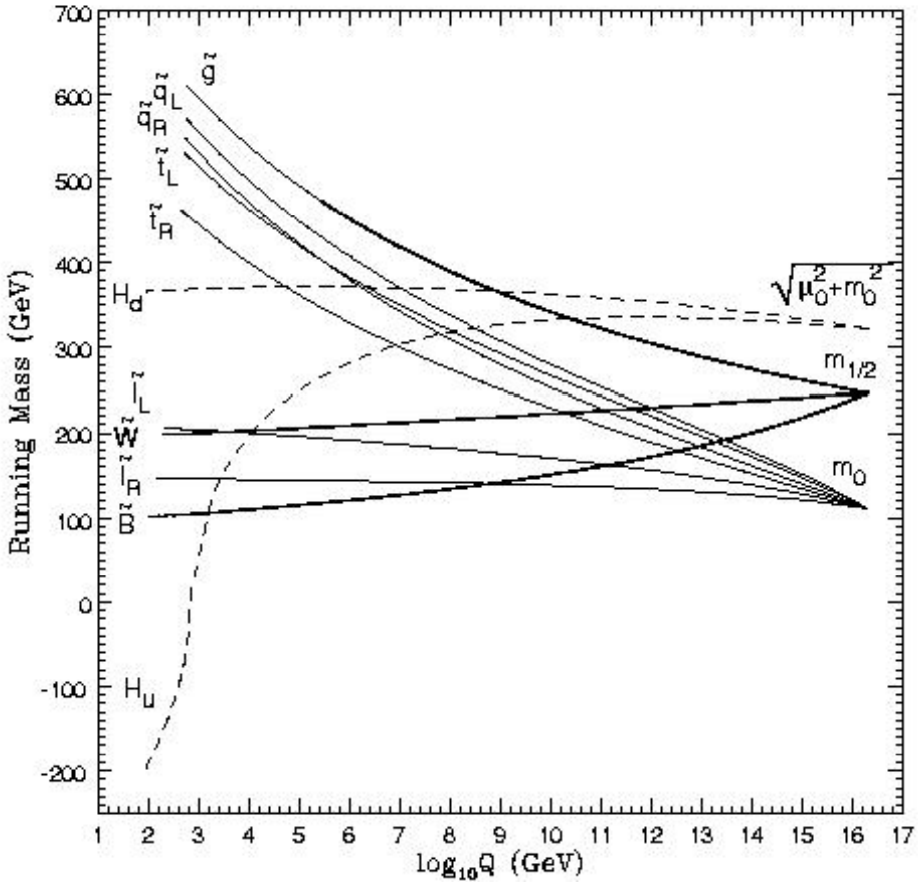


500 GeV, m(Z') = 2 TeV
1 ab-1, $e^+e^- \to \mu^+\mu^-$

Godfrey, Kalyniak, Tomkins

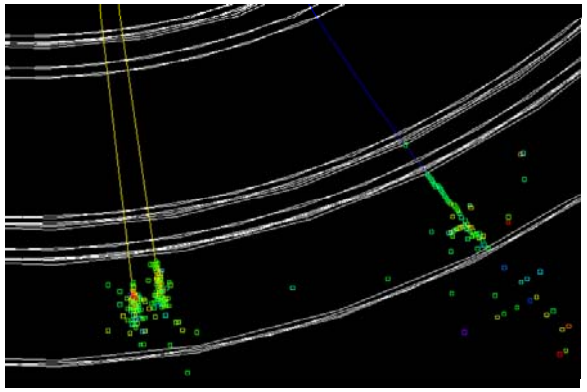
SUSY as Source of Signatures

- Excellent theoretical motivation
- Rich phenomenology
  - Mass spectrum and couplings are determined by several high mass scale parameters
  - Define decay modes of SUSY particles →signatures
- Can produce almost any signature!



SUSY Non-SM Signatures

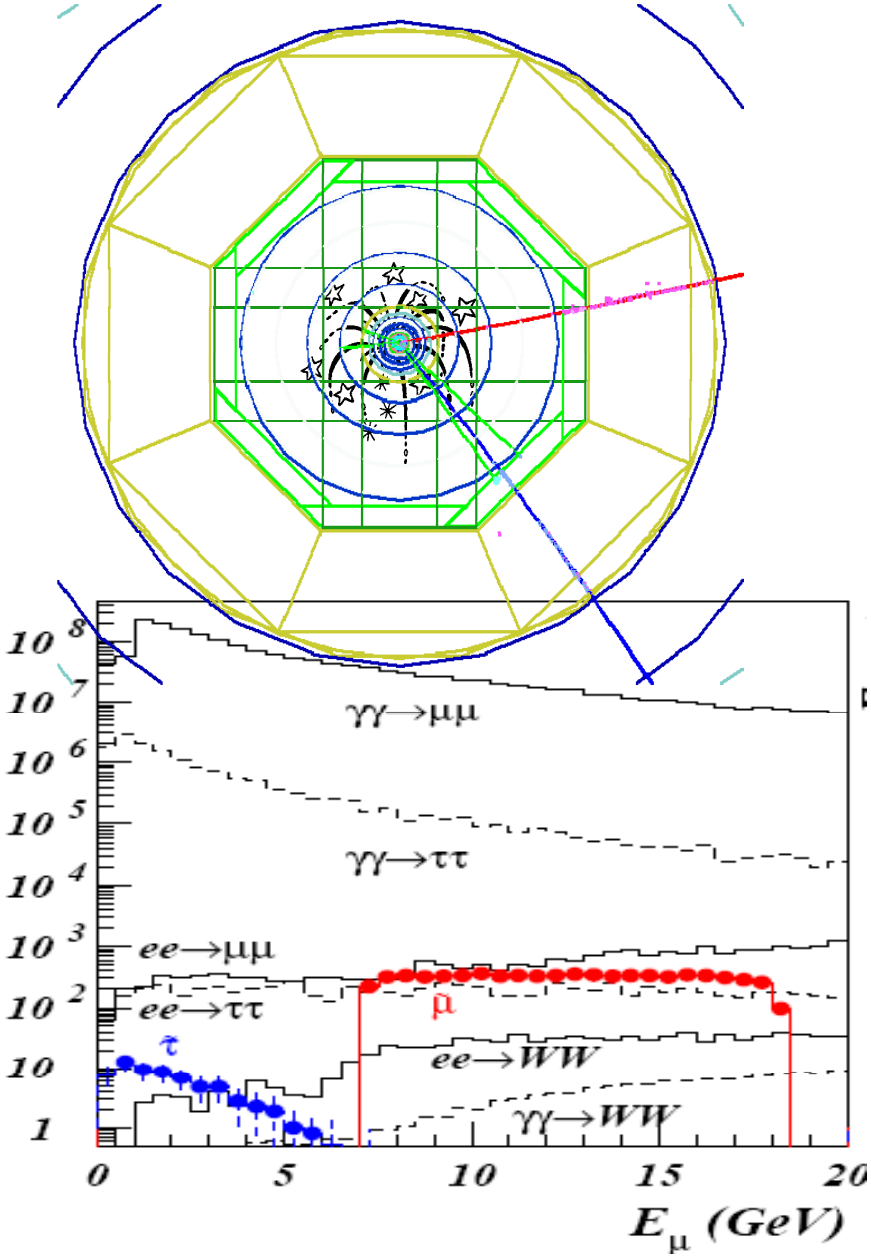
- Heavy neutral or charged objects with long lifetime in SUSY
  - Displaced photons in GMSB SUSY with gravitino LSP



  - Slow charged particles, ex charginos, staus, stops

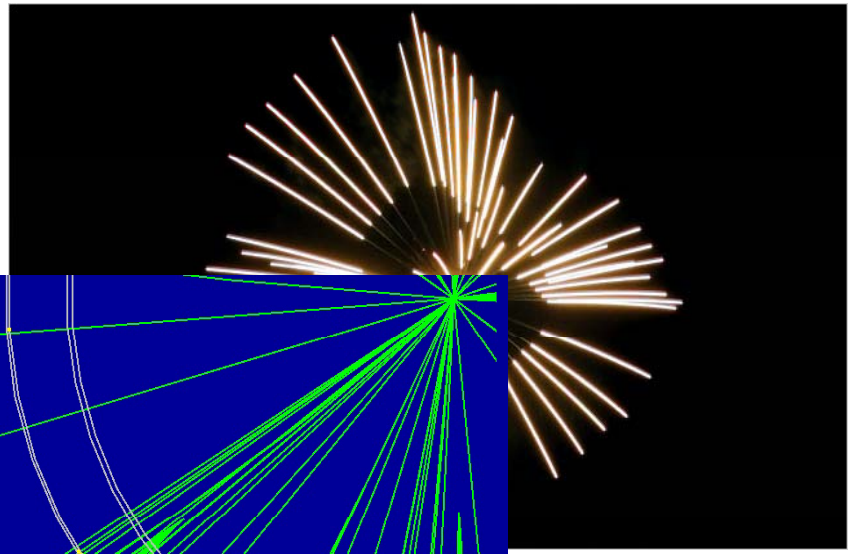
Cosmology Motivated SUSY Scenarios

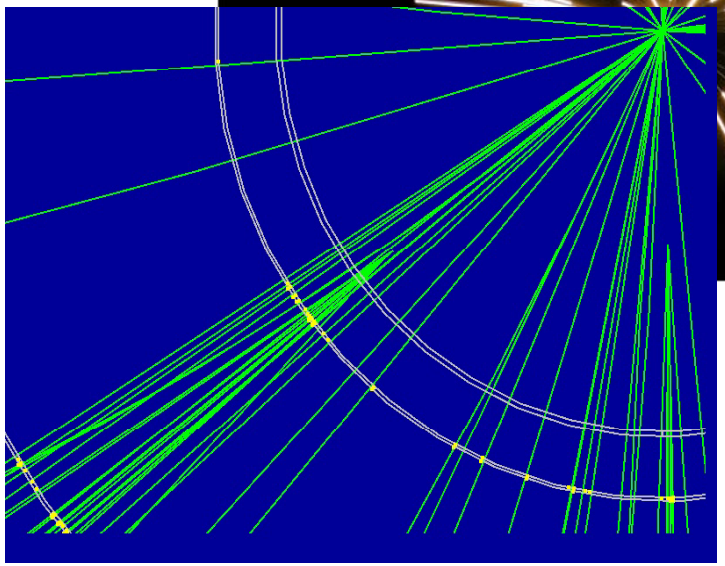
- Dark Matter is 25% of Universe – how to explain?
- In SUSY : small mass split between LSP and NLSP = small visible energy in the detector
  - ee → staus
- Important case to motivate the massless Tracker with zero P_T cutoff
- Large two –photon backgrounds
  - Need to veto electron/positron in forward systems

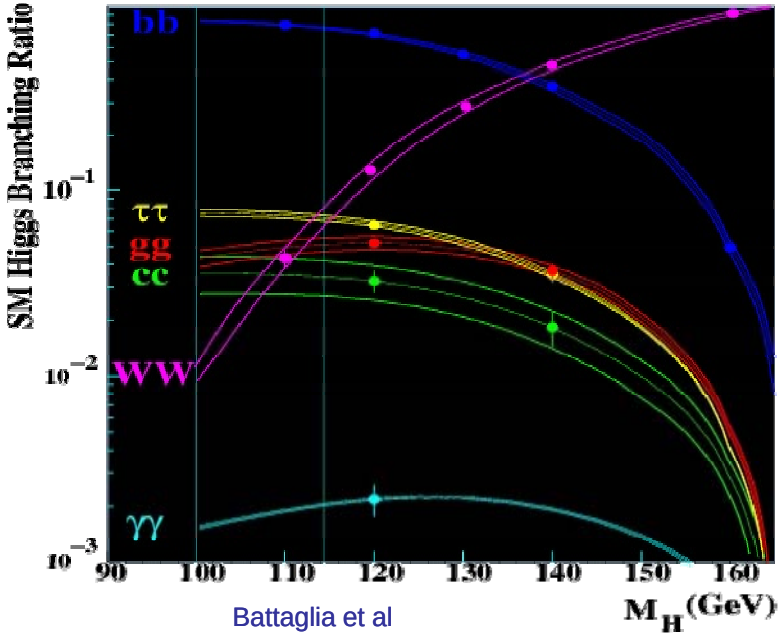


Benchmarking Vertexing

- New physics couples to mass – heavy objects like b and c quarks will accompany new phenomena
- Highly efficient b/c tagging, determination of quark charge
- ee→ZH →Z cc



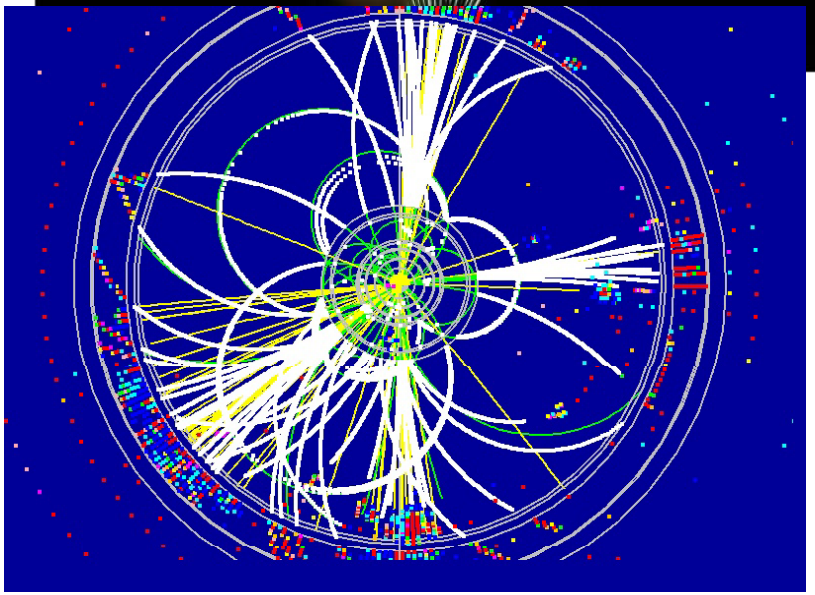




Battaglia et al

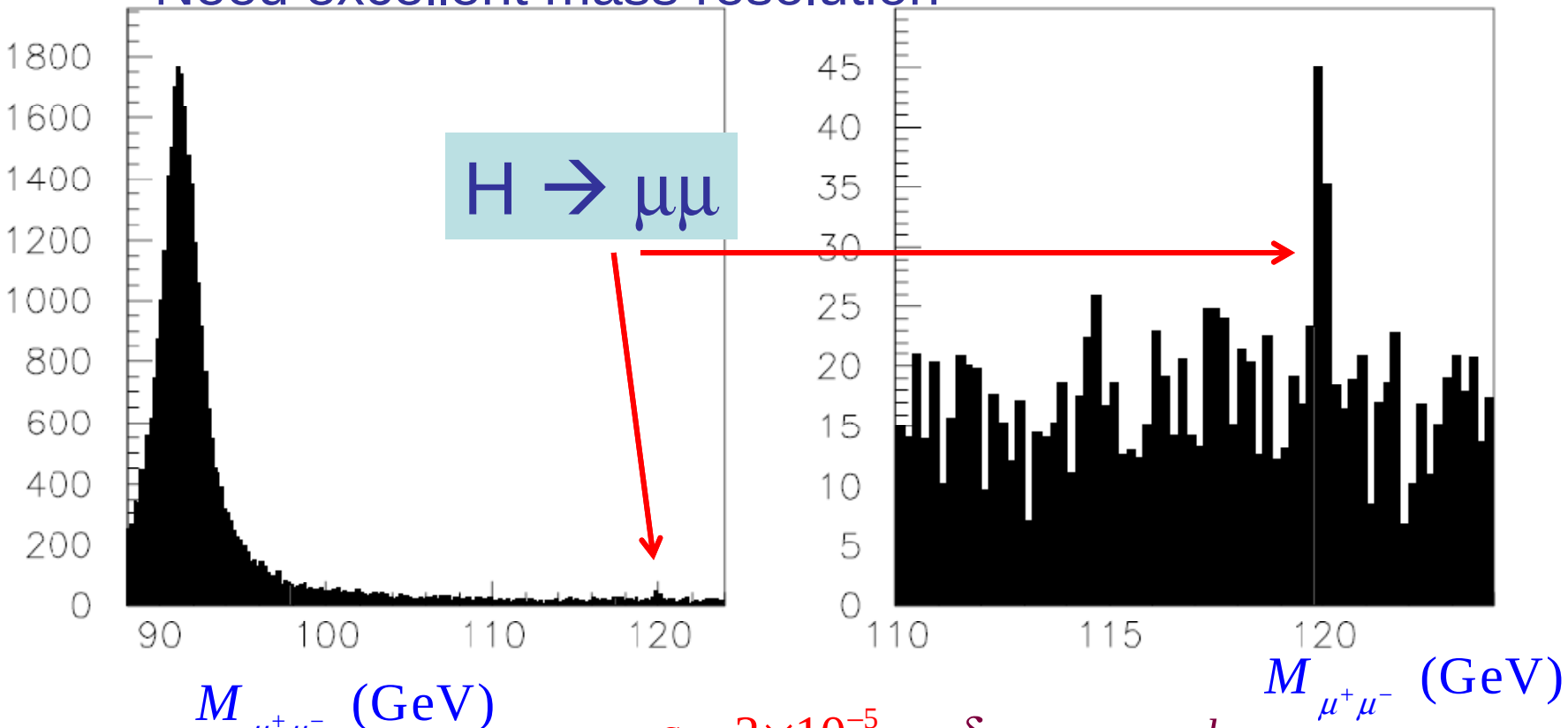
Benchmarking Tracking

- Main issues
  - Momentum resolution
  - Pattern recognition in dense jets
  - V0 reconstruction
  - ALGORITHMS
  - Forward tracking



H→μμ

- One of important Higgs Br
- $M_{\mu\mu}$ distributions for NN>0.95 for signal and background summed
  - Need excellent mass resolution



$$a = 2\times10^{-5}$$

$$b = 1\times10^{-3}$$

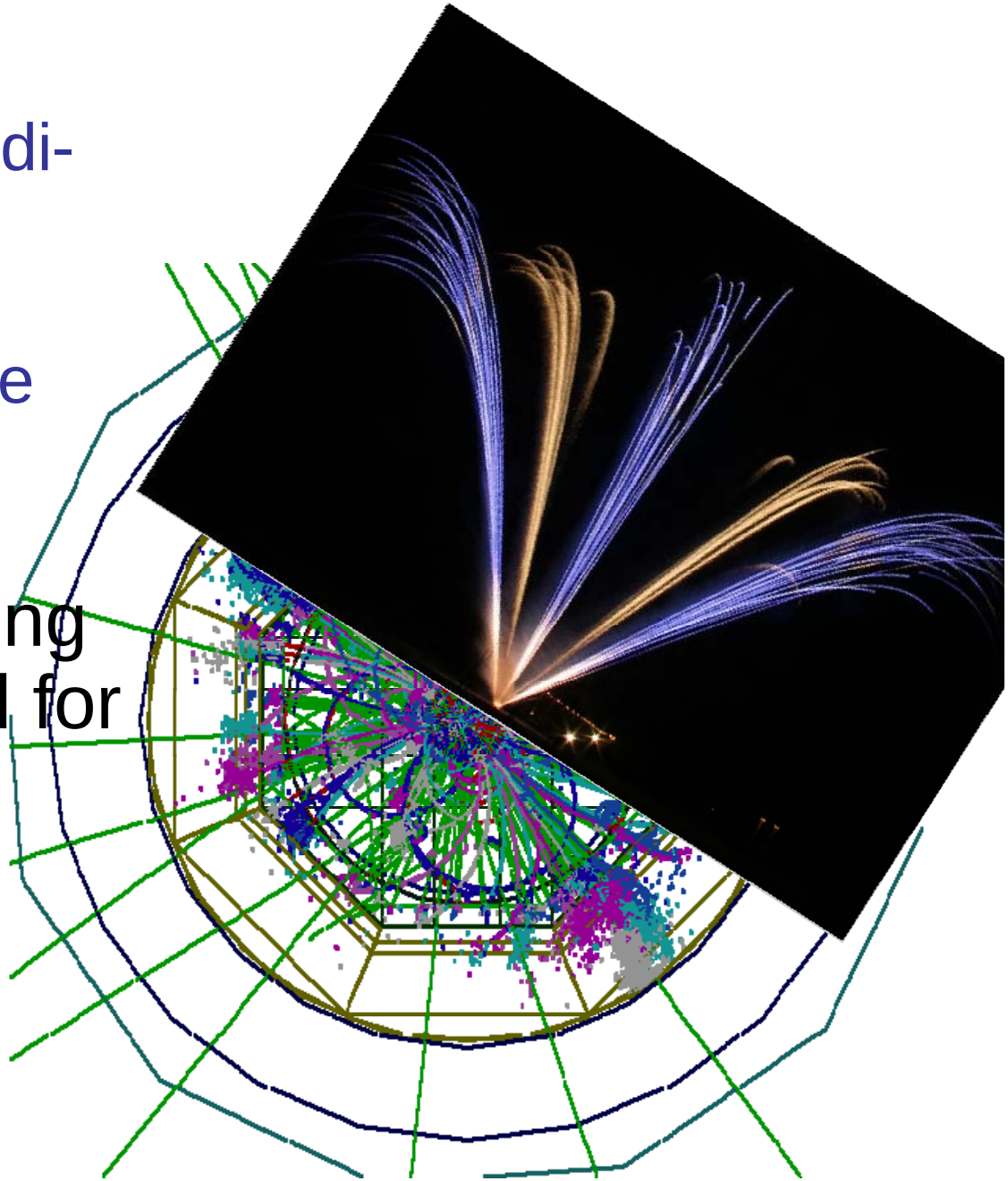
$$\frac{\delta p_t}{p_t^2} = a \oplus \frac{b}{p_t \sin\theta}$$

Benchmarking Jets

- Main issues
  - Energy resolution, di-jet mass resolution
  - **Algorithms** are probably even more important than in tracking
- W/Z separation using di-jet mass needed for example in

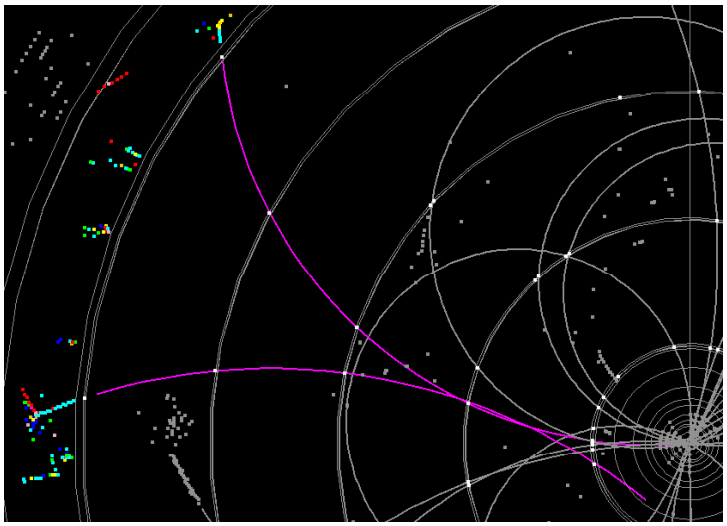
$$e^+e^- \to \tilde{\chi}_1^+ \tilde{\chi}_1^-$$

$$e^+e^- \to \tilde{\chi}_2^0 \tilde{\chi}_2^0$$



Integrated Approach

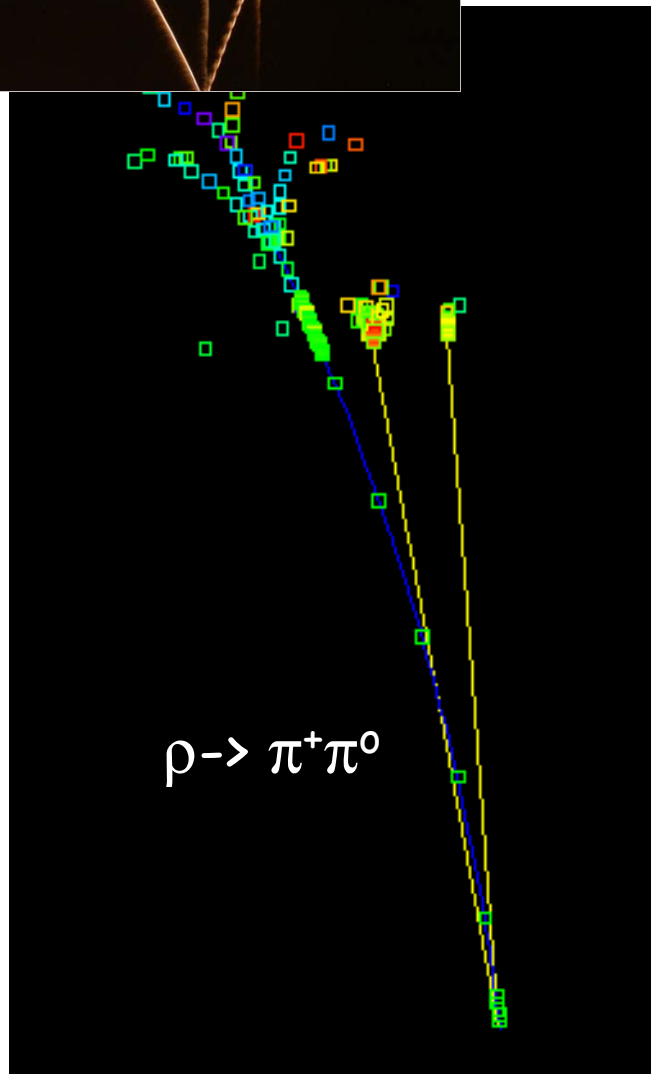
- PFA
  - Tracking helps Calorimetry



- Calorimetry helps tracking
  - Calorimetry assisted tracking, take seeds from calorimeter
  - Using π^0 to constrain the vertex mass → improvements in b-tagging
  - Tau ID

Importance of π^0

- Polarization of tau can be measured through decay products
- For ex: H→ττ process
  - Tau polarization (from τ →ρν → $\pi^+\pi^o\nu$) allows to determine CP properties of Higgs
- Or separation of W→τν and H^+→ τν
- Or determination of tan beta in stau→tau LPS using tau polarization
- Separation of clusters and reconstruction of π^o requires excellent segmentation of EMCAL



From Physics Studies to Benchmarking

- Entering a new phase: LoI in 2008 and EDR in 2010
- Emphasis of physics studies will shift towards
  - Evaluation and comparison of detector choices
  - Realities required by engineering: material
  - Realities required by reconstruction algorithms
- Matured tools
  - Pandora and other PFA
  - Tracking algorithms
  - LCFI vertexing package

Benchmarking Processes

reduced list recommended by Snowmass 2005 report hep-ex/0603010

0. Single $e^{\pm}$, $\mu^{\pm}$, $\pi^{\pm}$, π^0, $K^{\pm}$, K^0_S, γ, $0 < |\cos\theta| < 1$, $0 < p < 500$ GeV
1. $e^+e^- \to f\bar{f}$, $f = e, \tau, u, s, c, b$ at $\sqrt{s}$=0.091, 0.35, 0.5 and 1.0 TeV;
2. $e^+e^- \to Z^0h^0 \to \ell^+\ell^- X$, $M_h = 120$ GeV at $\sqrt{s}$=0.35 TeV;
3. $e^+e^- \to Z^0h^0$, $h^0 \to c\bar{c}, \tau^+\tau^-, WW^*$, $M_h = 120$ GeV at $\sqrt{s}$=0.35 TeV;
4. $e^+e^- \to Z^0h^0h^0$, $M_h = 120$ GeV at $\sqrt{s}$=0.5 TeV;
5. $e^+e^- \to \tilde{e}^+_R\tilde{e}^-_R$ at Point 1 at $\sqrt{s}$=0.5 TeV;
6. $e^+e^- \to \tilde{\tau}^+_1\tilde{\tau}^-_1$, at Point 3 at $\sqrt{s}$=0.5 TeV;
7. $e^+e^- \to \tilde{\chi}^+_1\tilde{\chi}^-_1/\tilde{\chi}^0_2\tilde{\chi}^0_2$ at Point 5 at $\sqrt{s}$=0.5 TeV;

Benchmarking Processes

- Reduced list looks like a good starting point

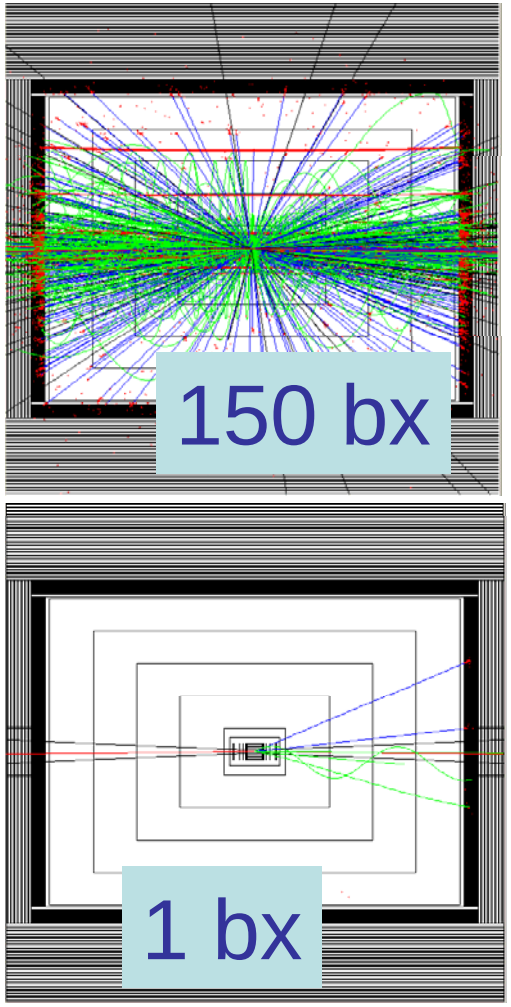
- Compulsory part should be a bit shorter and better defined
  - Better definition of processes
  - ee→ ff : what are the fermions, which new physics to consider?

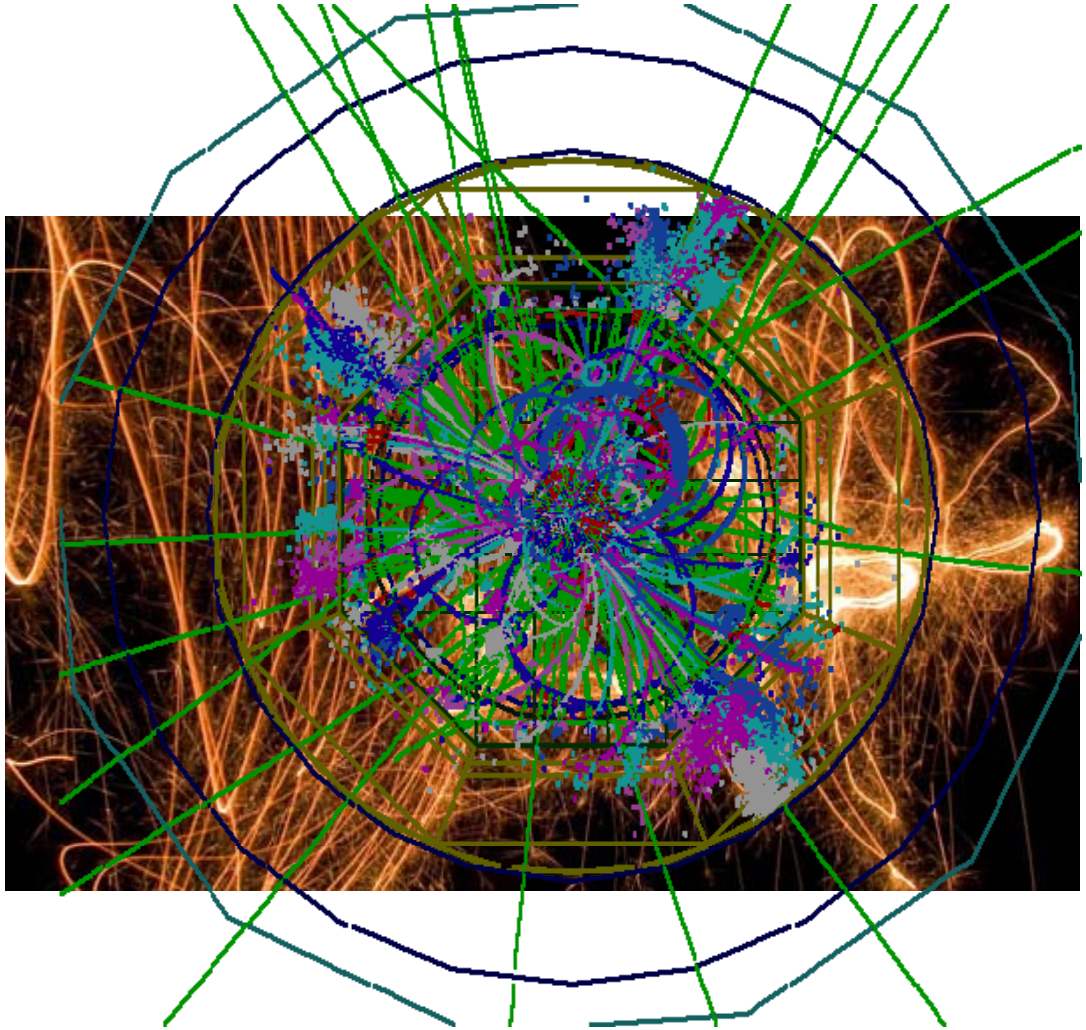
SM Backgrounds

- Define a standard set of SM processes
  - All benchmarking signals can be mixed with SM background
  - Include machine background and polarization
  - Decide how to deal with large and small xsections
- Common to all concepts
  - Use the same machine parameters like energy spread and polarization
  - SLAC generated all SM backgrounds – others are welcome to use

Machine Backgrounds

- Important source of occupancy in Vertex Detector and Tracker





Benchmarking: Anything New?

- Forward region is important
- Taus are important
  - Need dedicated effort to efficiently tag taus combining topology, vertexing and calorimetry
- Objects and Anti-objects
  - Sometimes need to veto objects
  - Different requirements to efficiency/purity operational point

- Soft particles in Tracker : makes the case to be as good as you can = technically limited

Summary

- New format inspired more communications between experimentalists and theorists
- Some lessons leant and few new old things uncovered
- Will we do it again?