NP Direct Searches at ILC

Group: "Zaterdag and friends"

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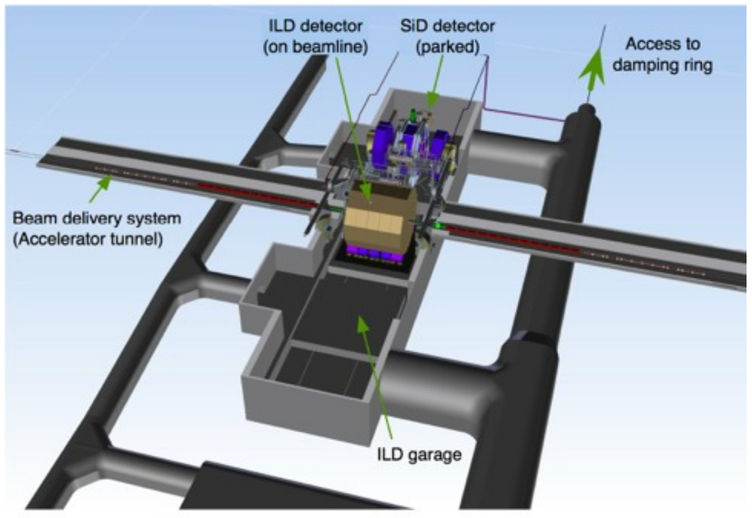
International Linear Collider

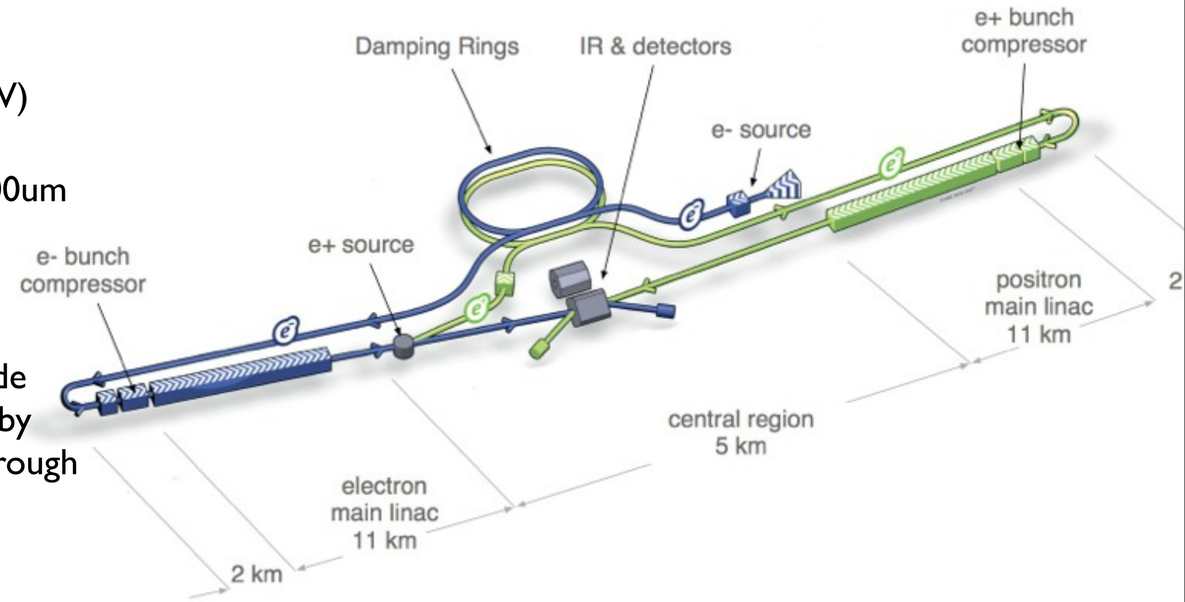
Structure

- 31km long, high-$\mathcal{L}$ e^+e^- collider utilizing 1.3GHz SCRFs
- Two 11km LINACs ($\nabla = 31MV/m$)
- Two beam delivery systems 2.2km long (collisions at 14mrad crossing angle)
- Single-point IP occupied by 2 detectors using "push-pull" mechanism



Specs

- $\sqrt{s} = 200 - 500GeV$ (ext. to 1TeV)
- Beam size @ IP 6nm x 500nm x 300um
- $\mathcal{L} \approx 2 \times 10^{34}\ cm^{-2}$
- polarized e^- source (photocathode DC gun) and polarized e^+ source by converting high-p_T e^+e^- pairs through and undulator



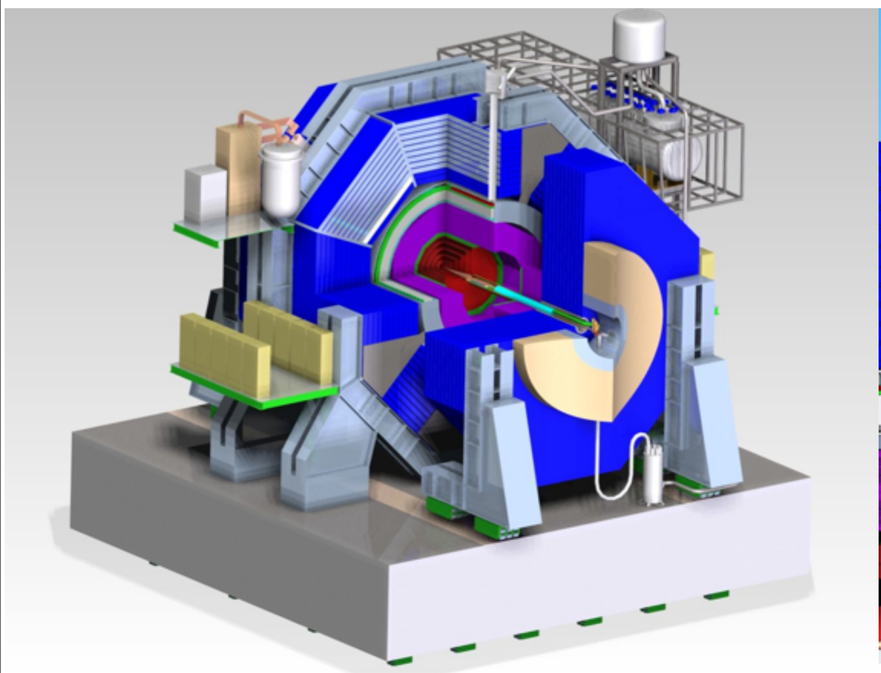
Features

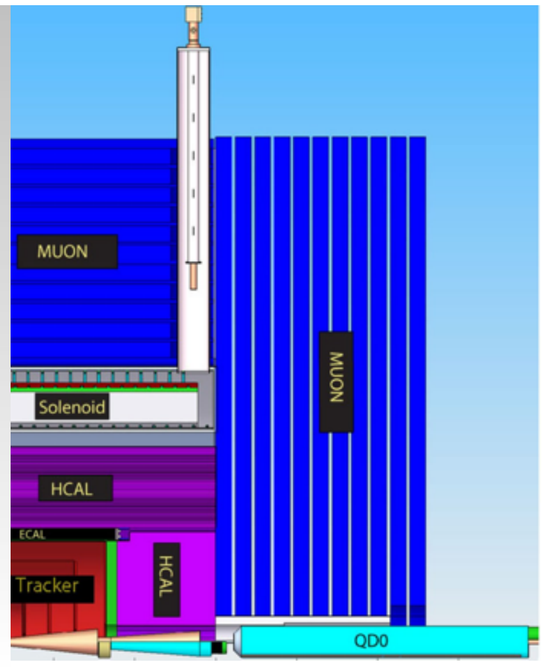
- *Discovery of Higgs :*
  - fine-tuning problem of the SM became real
  - problem of missing DM in SM became acute

LHC may improve systematics
ILC may improve analysis methods

- *ILC offers:*
  - Clean signal without much noise
  - Trigger-less data taking
  - Theoretically clean analysis
  - Initial state well defined
  - Polarization is specified
  - JER two times better than LHC

SiD





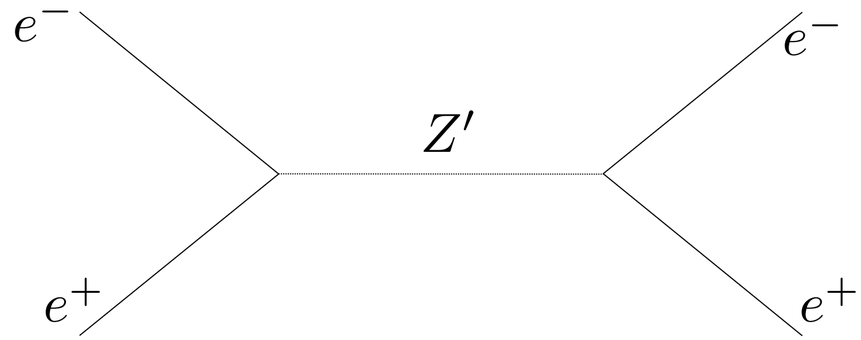
- *Silicon Detector - A compact, low cost, PFA, "power-less" design*
  - Si-based tracking
    - Vertex ($20 \times 20\ \mu m$ 5 layers Si-pixel)
    - Main Tracker (5 cylinders of Si-Strip Sensors)
  - ECAL ($5 \times 5mm^2$ active Si layers + tungsten - 30 total)
  - DHCAL ($1 \times 1cm^2$ active glass-RPC + steel)
  - Magnetic Coil (5T central field, 6.8 outter diameter x 5m long, superconducting 600G DID)
  - Muon (flux-retun yoke with Scintillator)

- *Best SiD Features*
  - Vertex: $\delta(\frac{1}{p_T}) \approx 2 - 5 \times 10^{-5}\ GeV/c$, 3D point resolution, $\approx 300 - 700$ns time resolution (Chronopixel), "live" only at bunch crossings ($< 130\mu W/mm^2$) so triggerless data taking!
  - Main tracker: Finds particles at ± 5 cm of IP travelling at least 5cm, $\delta(1/p_T) < 5 \times 10^{-5}$
  - ECAL: Imaging capability, 26 X_0 and 1 nuclear, 30 layers (20+10)
  - DHCAL: Imaging capability, operational in strong magnetic field, 4.5 nuclear interaction lengths, $4 \times 10^5/m^3$ RO channels.
  - Muons: Spatial resolution ~cm, SiPMs (muon filter & trail catcher)

Physics Programs at ILC

- Higgs precision measurements
  - *decoupling limit, new states, branching ratios, H-self coupling, top quark Yukawa coupling, Composite Higgs, Inclusive cross sections...*
- Two fermion processes
  - *Systematics of eeff, Z' physics, quark/lepton compositeness, Extra dimensions...*
- W & Z Boson Physics
  - *BSM W/Z sector, VB pair prod., triple vector boson prod. WW/ZZ scattering, Giga-Z...*
- Top quark
  - *top properties, eett threshold, top vertices...*
- Extended Higgs Sector
  - *2HDM, H-Singlets/Triplets, neutral/charged Higg, tanβ...*
- Supersymmetry
  - *(in)direct constraints, impact of higgs, neutralino/chargino sector, gravitino...*
- Cosmological Connections
  - *Baryogenesis in EW scale, DM (WIMPs)...*

From a huge variety of Physics programs we choose to probe NP through Z'!

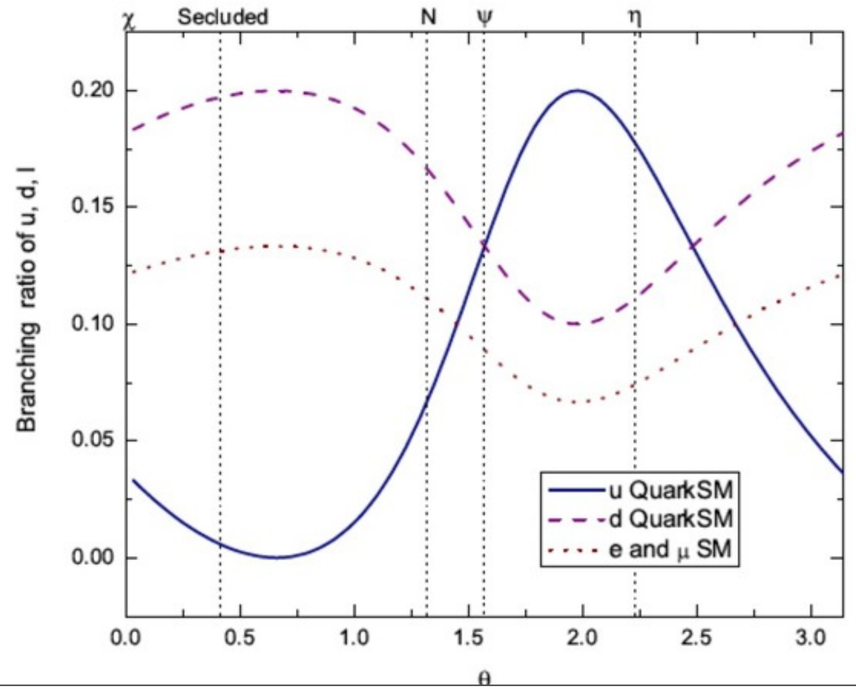


Z' theoretical model

- Sequential model (SSM)
  - Assumes same couplings as SM Z boson
    - Different couplings to exotic fermions
    - Within extra dimensions excited state of Z
    - Useful reference when comparing other models

- New U(1)' gauge symmetry
  - Well motivated extension of SM
  - Models include:
    - Supersymmetry
    - Grand Unified Theories (larger than SU(5): ex E6))

- Benchmark models:
  - Left-right symmetric model (LRS)
  - Alternative LRS (ALR)
    - Same as LRS but embedded in E6
  - Littlest Higgs (LH)
  - Simplest little Higgs (SLH)



Z' at ILC

- Z' couplings conserve Baryon-Lepton number $\longrightarrow m_{Z'} \approx TeV$ scale

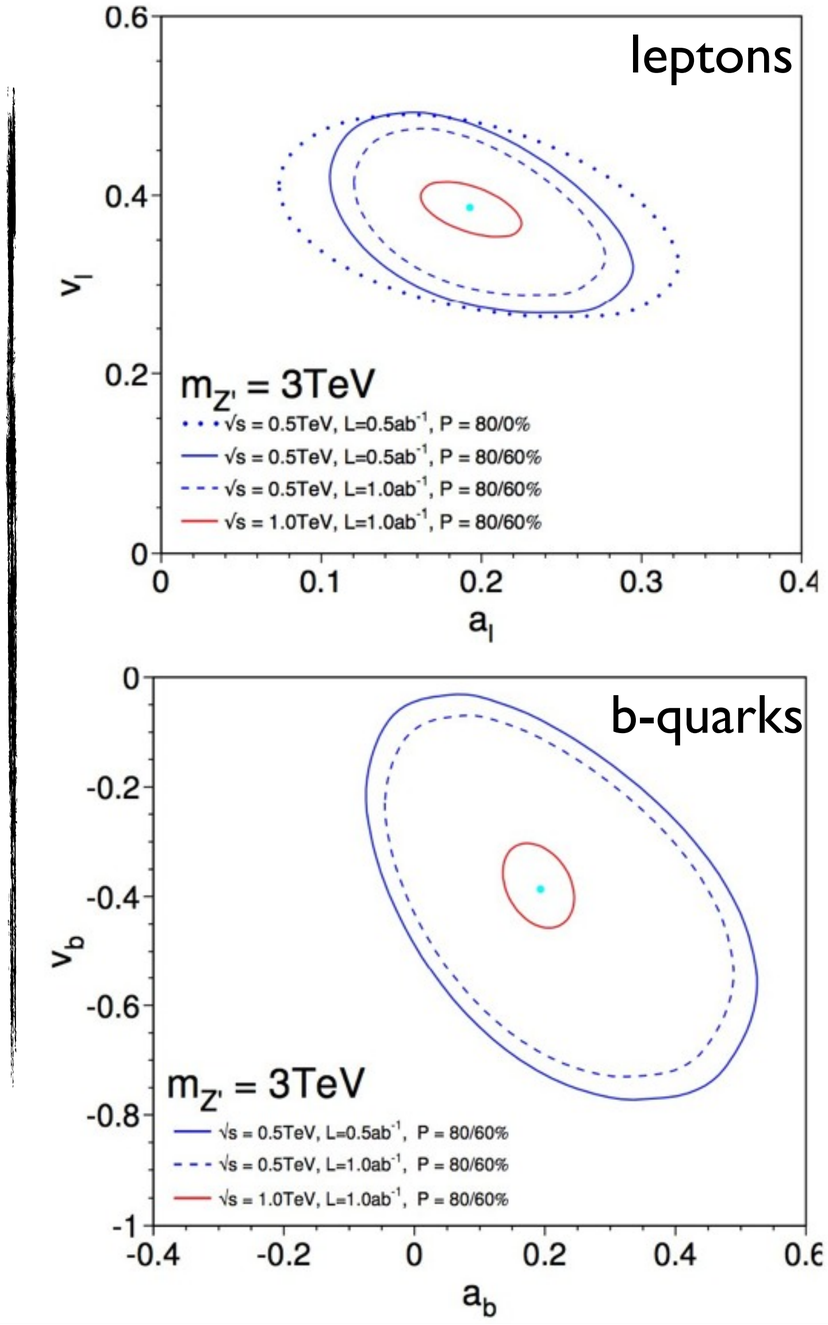
- <u>No results from LEP, Tevatron, LHC:</u>
  No possibilities to discover Z' on-shell at ILC
  LHC searches puts a limit on the Z' mass range (above 3 TeV for $\ell\ell$ collider):

- Potential discovery for $\sqrt{s} << M_{Z'}$:
  Measure contact interaction corrections to 2-fermion processes

- Tool for discovery: $e^+e^- \rightarrow Z'^* \rightarrow f\,\bar{f}$

- $\sigma(ee \longrightarrow ff) \longrightarrow v_f$ and a_f couplings for leptons and quarks: *Well known for SM Z Any deviation evidence of Z' !*

Even if LHC discovers Z'
ILC will perform the <u>precise</u> measurements!



Asymmetry Measurements

- *Asymmetry measurements:*

<u>A_{FB} (forward-backward)</u>

$$A_{\mathrm{FB}}^{f} = \frac{N_{\mathrm{F}} - N_{\mathrm{B}}}{N_{\mathrm{F}} + N_{\mathrm{B}}} = \frac{3}{4}\mathcal{A}_e\mathcal{A}_f$$

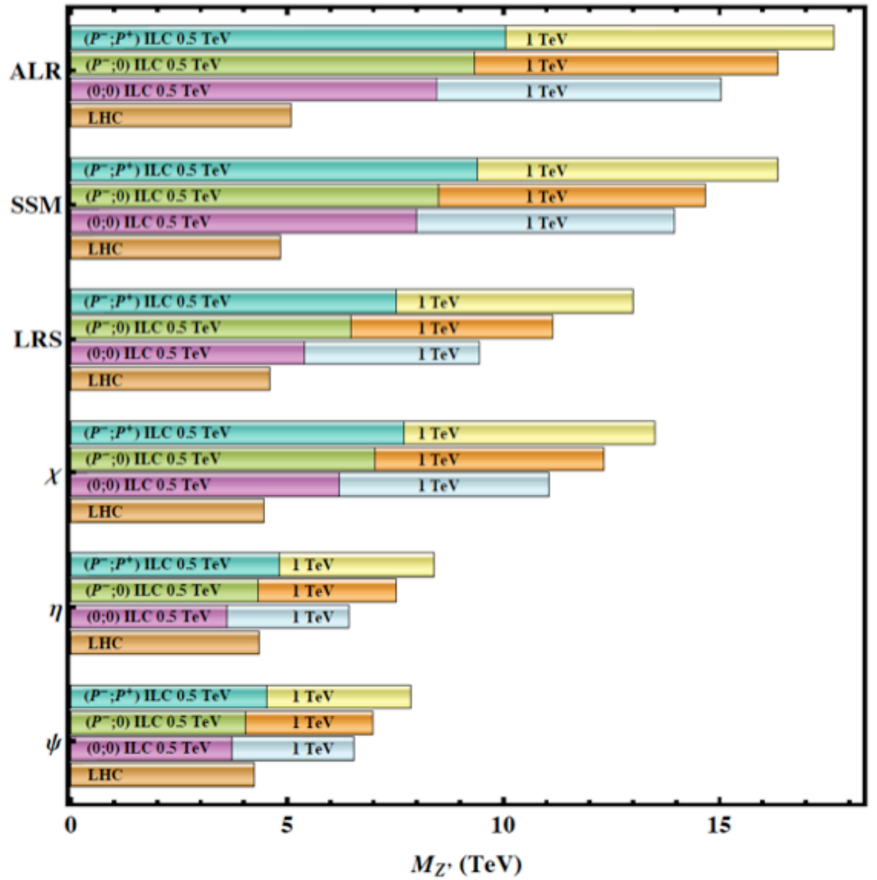
<u>A_{LR} (left-right)</u>

$$A_{\mathrm{LR}} = \frac{1}{\mathcal{P}}\frac{N_{\mathrm{L}} - N_{\mathrm{R}}}{N_{\mathrm{L}} + N_{\mathrm{R}}} = \mathcal{A}_e$$

- *Left-Right polarization:*
  ILC provides polarized beam!

- Higher precision coupling constant measurement

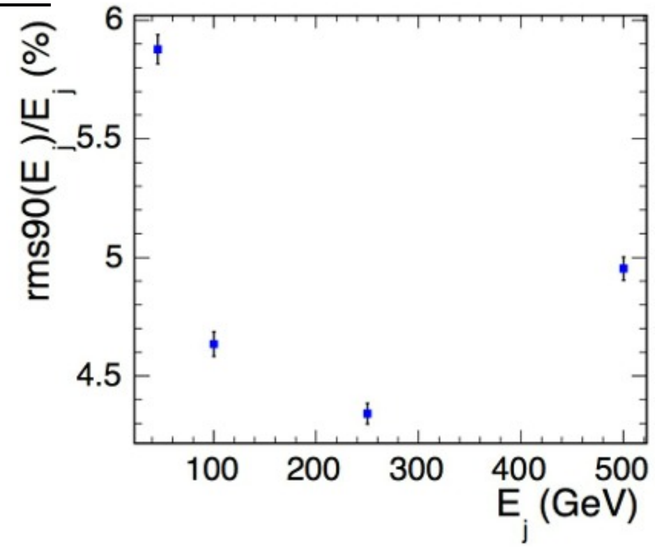
- Even with 500 GeV ILC will be more sensitive than LHC.



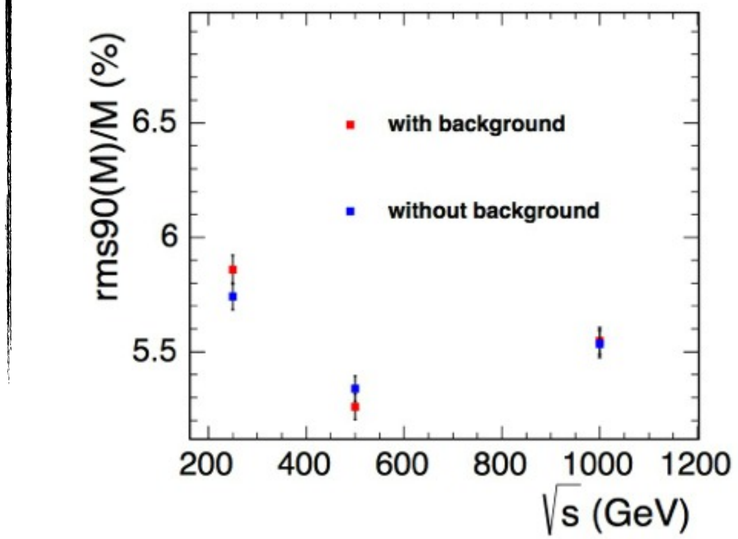
R&D Contributions

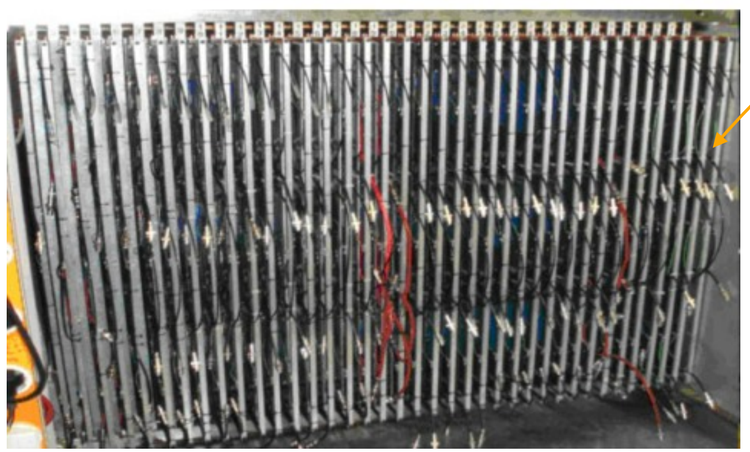
- Plans to start ILC operation at best <u>2026</u>. *What up to then?*
- Since it's closely related to our analysis a great plan would be to work at the SiD calorimetry:
  - While most of the R&D has already started two main projects are still pending: HV distribution and gas recirculation system
  - These two projects can be divided into 3 phases :
    - Development (HW & SlowControl) & Testbeams & Collab. Meetings *(Interesting also for industrial applications!)*
    - Commissioning
    - Long-term support & Monitoring → *<u>Long term contribution to the collab.</u>*

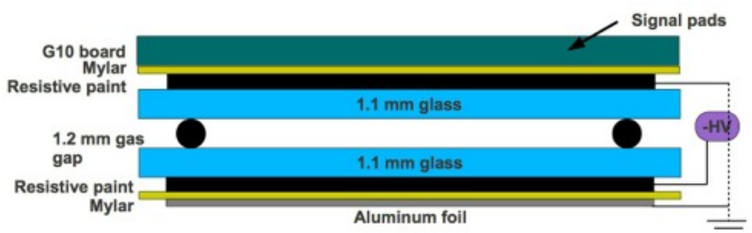
$E_{reso} : Z' \to q\bar{q}$

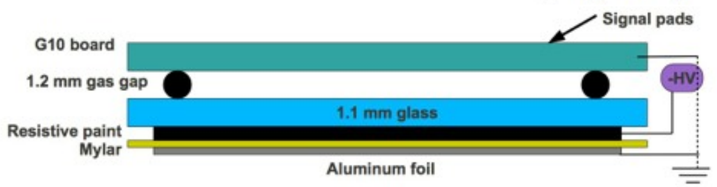


$m_{reso} : ZZ^* \to X_k X_l jj$









Back to the future: Linear Lepton Collider

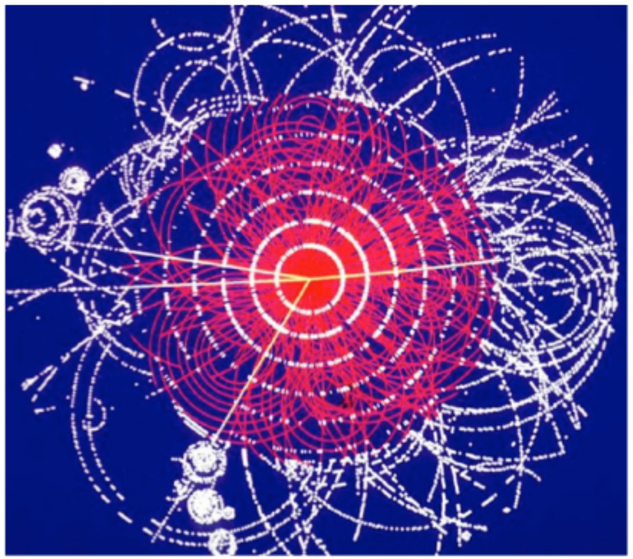
- The new generation of Linear Collider brings more capabilities to exciting studies!
- The cleaner signal of ILC with respect to LHC makes the collaboration a leading force of the upcoming results.
- SiD provides all the tools our analysis requires.
- Joining forces with the SiD collaboration for the R&D, monitoring and maintenance of the detector will also make us a long lasting member of it.
- The know-how and the technologies that will be assimilated, would also have *industrial* applications.
- Our analysis is the *"next big thing"*, and our channel would be the golden channel for this analysis.
- At the moment the only thing missing is the initial funding...

BACKUP

International Linear Collider

Comparison of LHC/LC

LHC



LC