Linear Collider Detector R&D: Opportunities & Resources

Why do we need detector R&D?

What R&D?

Why at Fermilab?

Who?

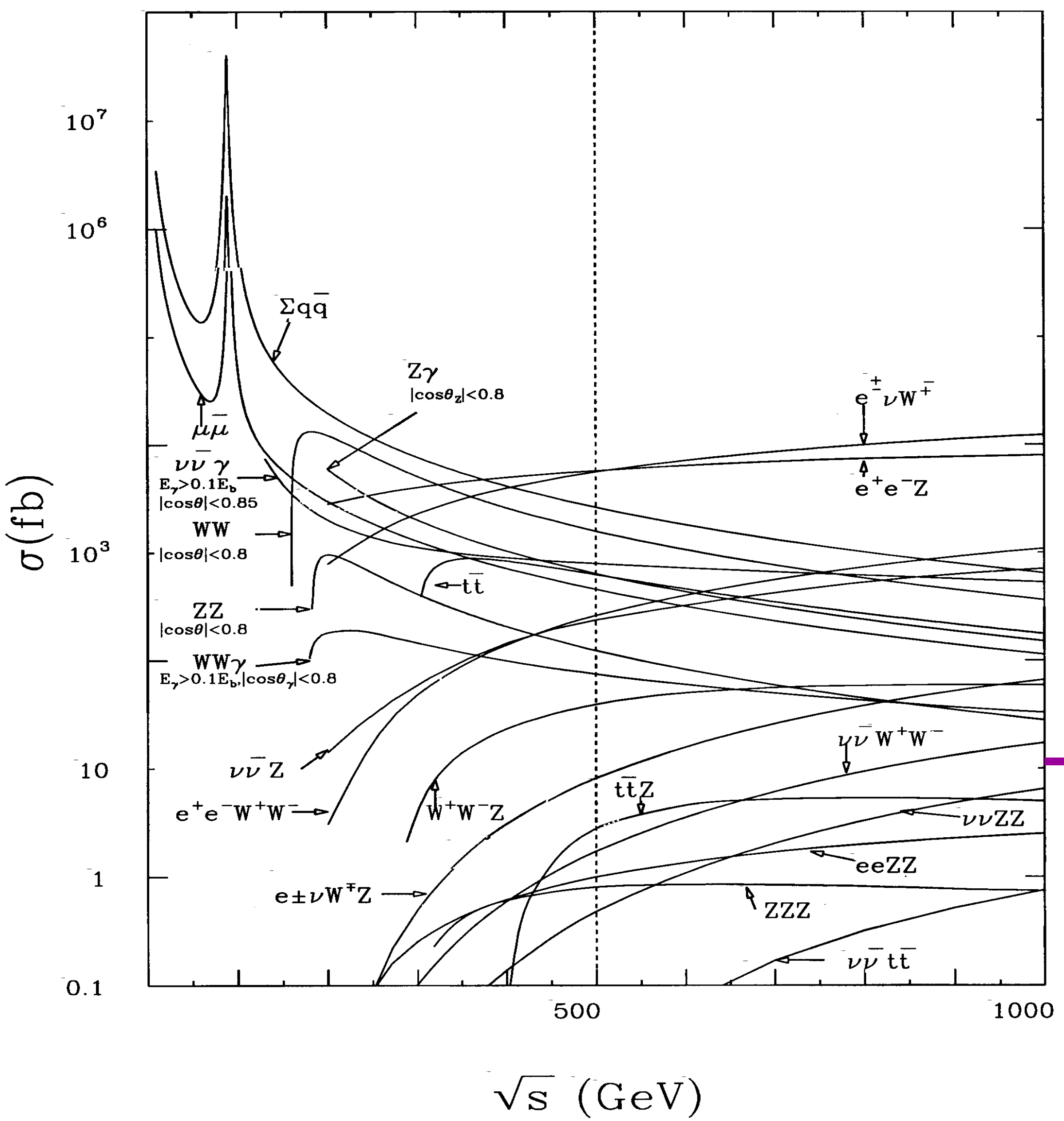
At what cost?

Why do we need detector R&D?

Precision physics measurements w/small σ's

- Low mass Higgs BR requires separation of b's & c's
  => excellent tagging - spatial resolution; vtx det.
  => mass resol'n - precise $\Delta p/p$; tracking; e, μ, τ id.
- High mass Higgs
  => jet mass resolution - separate W/Z => jet + jet;
  Energy flow algorithm - calorimetry, B = 4 - 5 T
- What kind of Higgs? MSSM, SUGRA, …
- SUSY? => hermetic detector
- Detector design is $\cap$ physics and the machine!

Cross sections



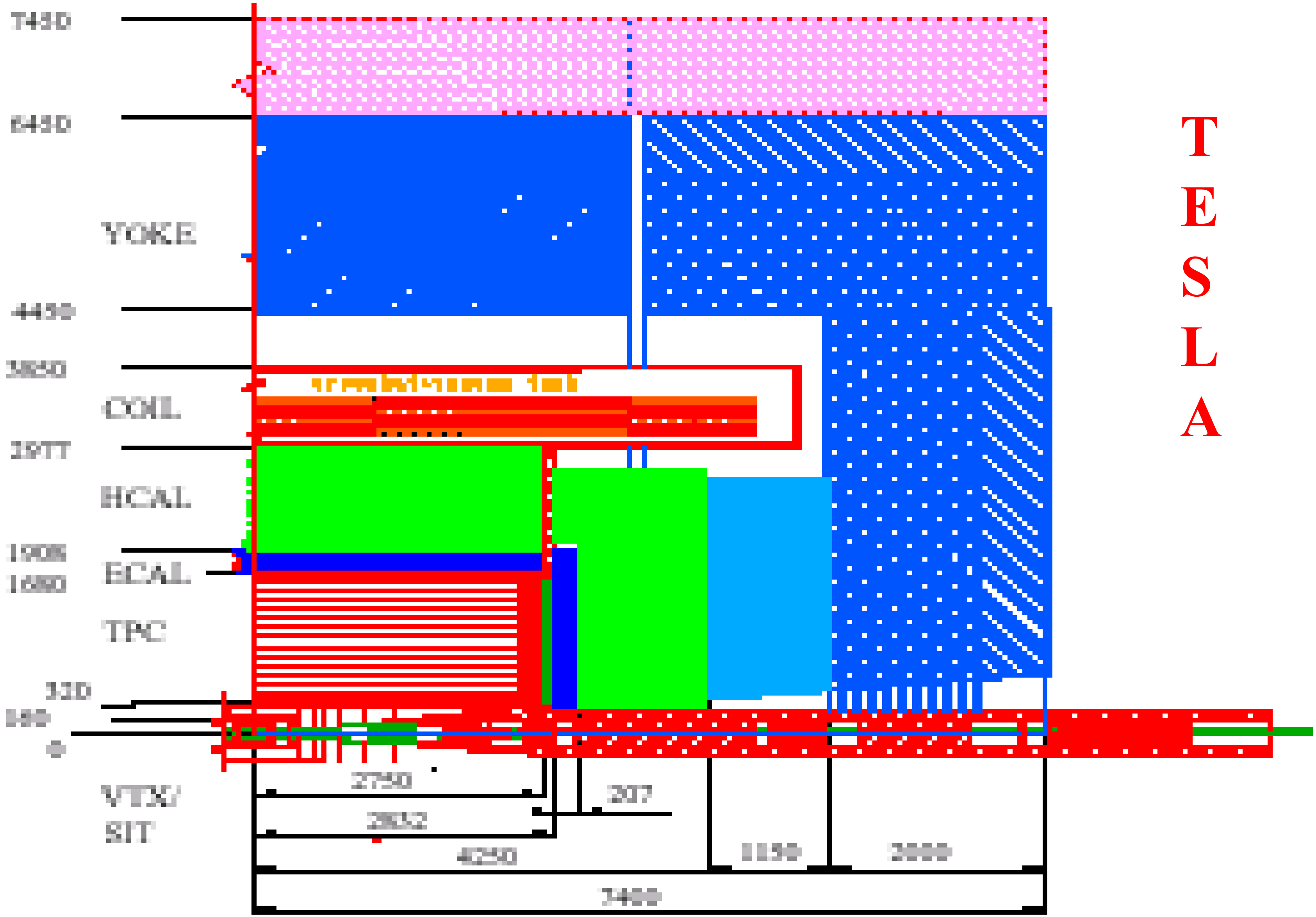
$L \sim 1*10^{34}\ cm^{-2}s^{-1}$

For one year = 10^7 s

$\int Ldt = 10^{41} cm^{-2}$

$= 100\ fb^{-1}$

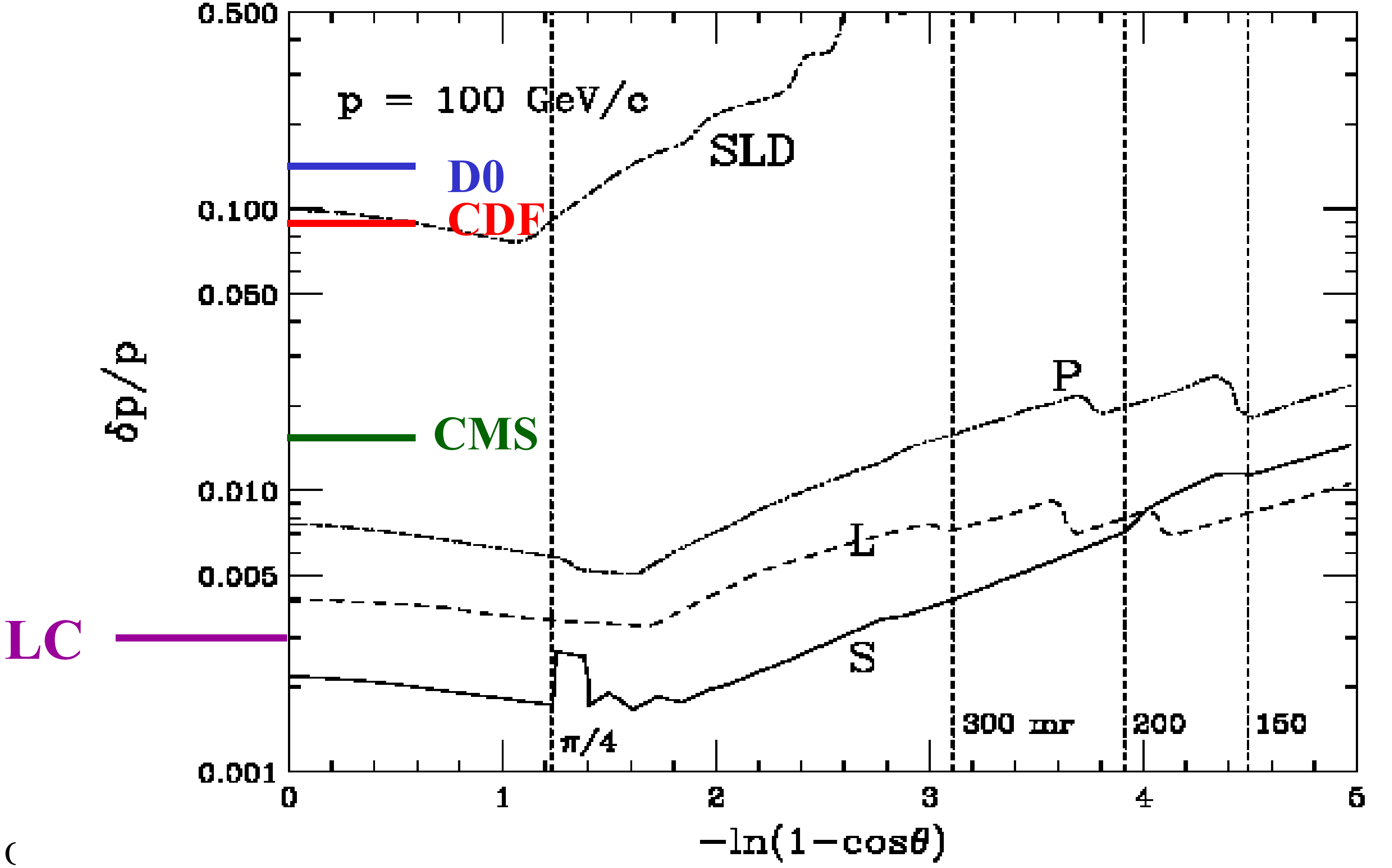
1000 events/yr


7450
6450
YOKE
4450
3850
COIL
2977
HCAL
1908
1680
ECAL
TPC
320
0
VTX/
SIT
2750
2832
207
4250
1150
7400

T E S L A

Momentum Resolution (NLC design)

p = 100 GeV/c



LC Detector Design: Tracking

See http://blueox.uoregon.edu/~lc/randd.pdf

(1) Improved momentum resolution:

$\Delta P_t/P_t^2 \leq 5 \times 10^{-5} \Rightarrow < 0.5\%$ for $P_t = 100$ GeV

for b,c mass separation

(2) Improved space point resolution on charged tracks; ~ 5μ is anticipated with R&D. Vertices.

These improvements will be achieved with small pixels $(20\mu)^3$ and reduced multiple scattering:

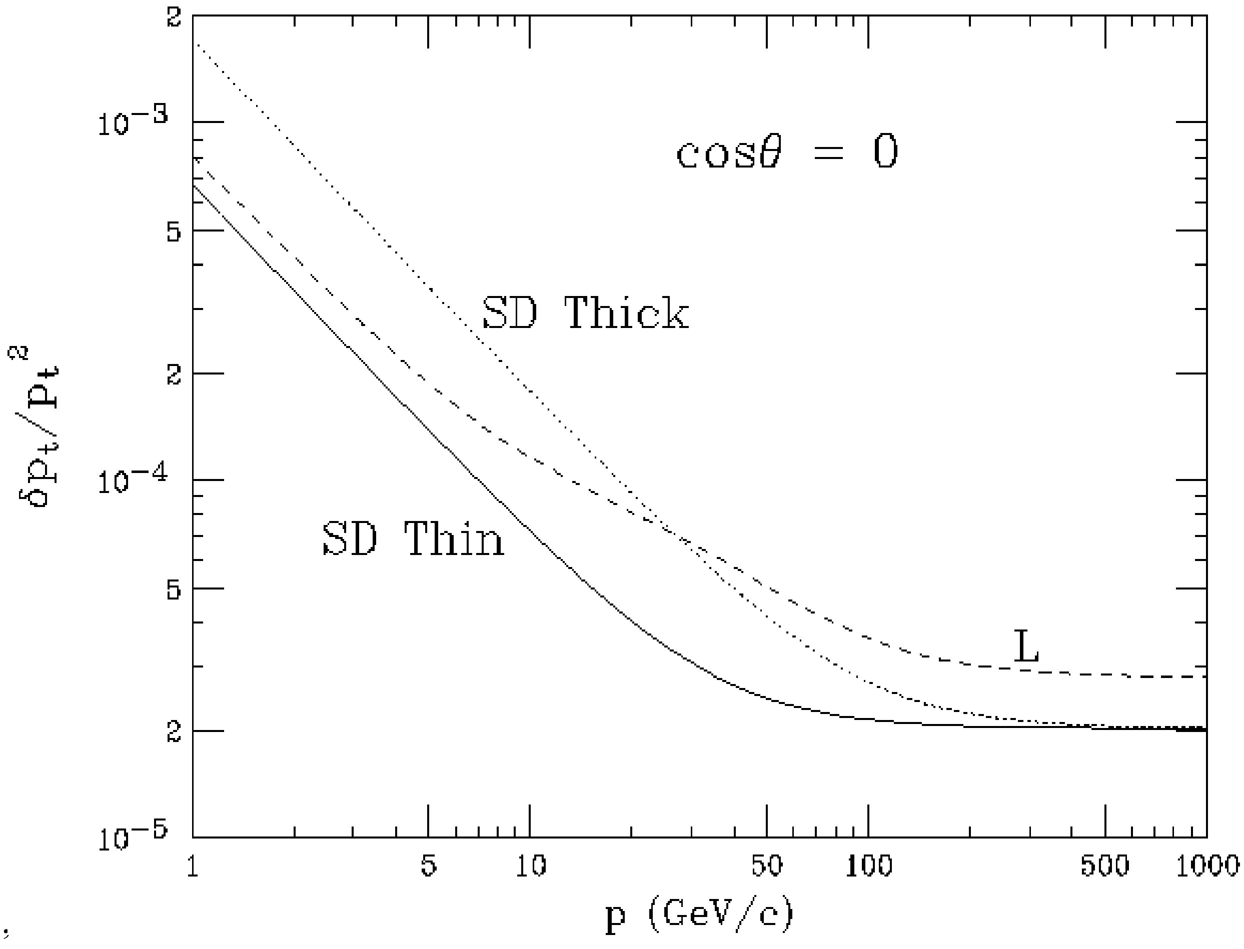
(<0.1 % X_O per ladder - reduced thickness)

Technology ? : Improved CCDs, MAPs, HAPS

What Physics? : Higgs Branching Ratios, etc.

SUSY searches, etc.

NLC Si Detector - Momentum Res.



LC Detector Design: Calorimetry

http://blueox.uoregon.edu/~lc/randd.pdf

- Want to separate W/Z ⇒ j1 + j2
- Energy-flow Algorithm ⇒ E and H Cal highly segmented to separate showers from tracks so that neutrals can be well measured; charged E from tracks.

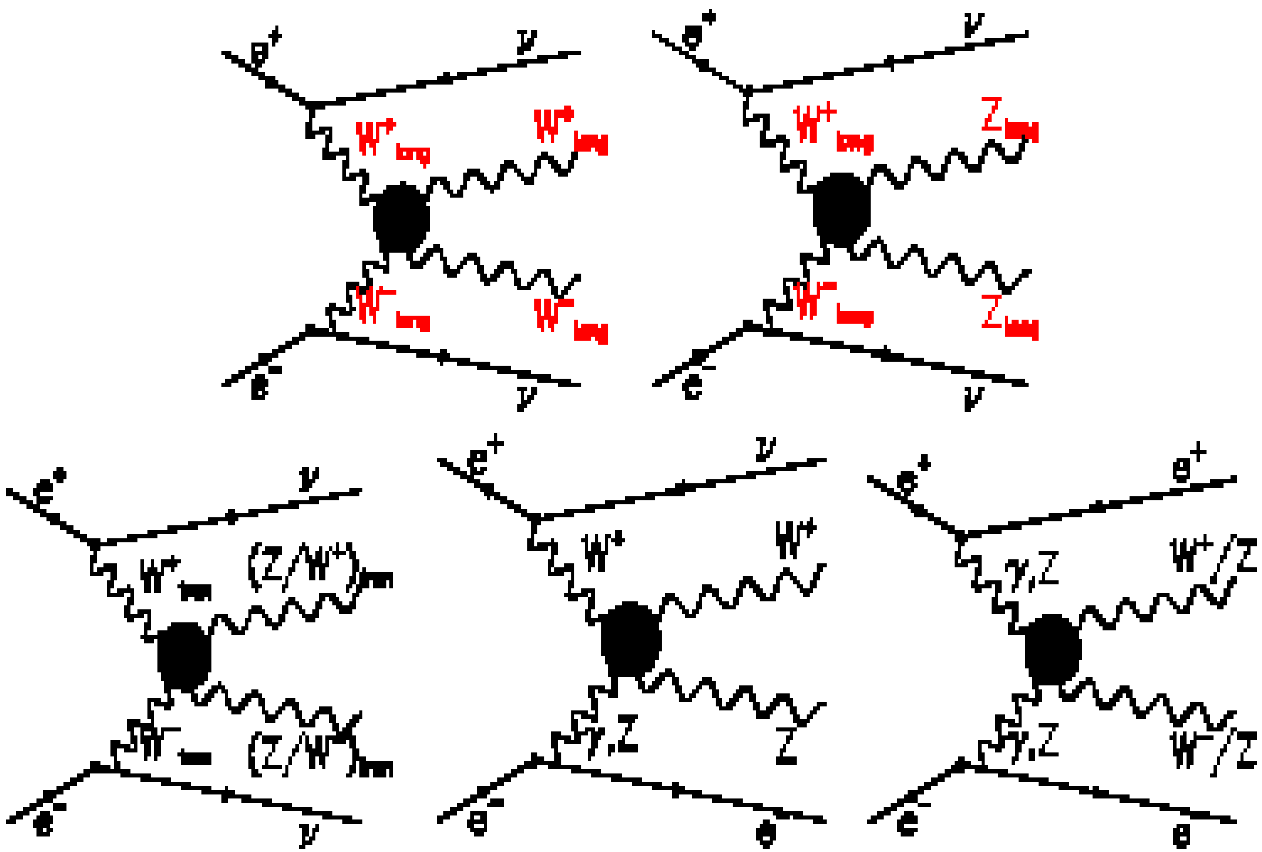
⇒ BR^2/R_M large. => B large; R large; Moliere rad small
W has R_M = 9 mm

$\Delta E_j / E_j \sim (0.3 - 0.4)/\sqrt{E_j}$: Brient & Videau Study

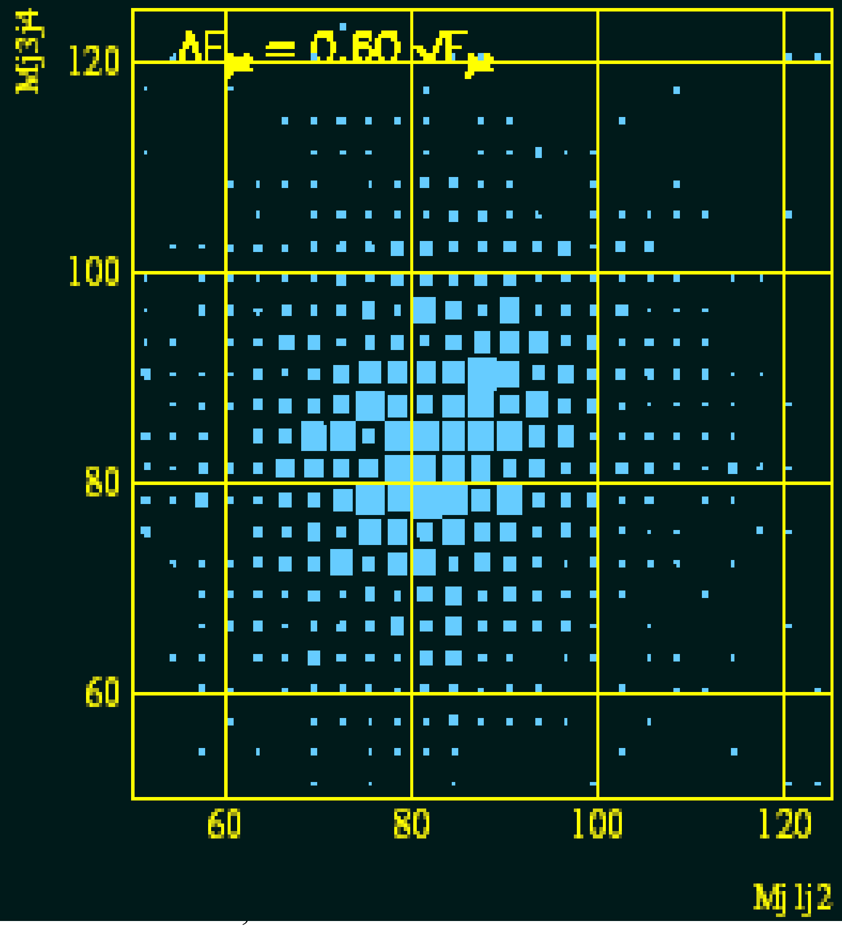
Technology?

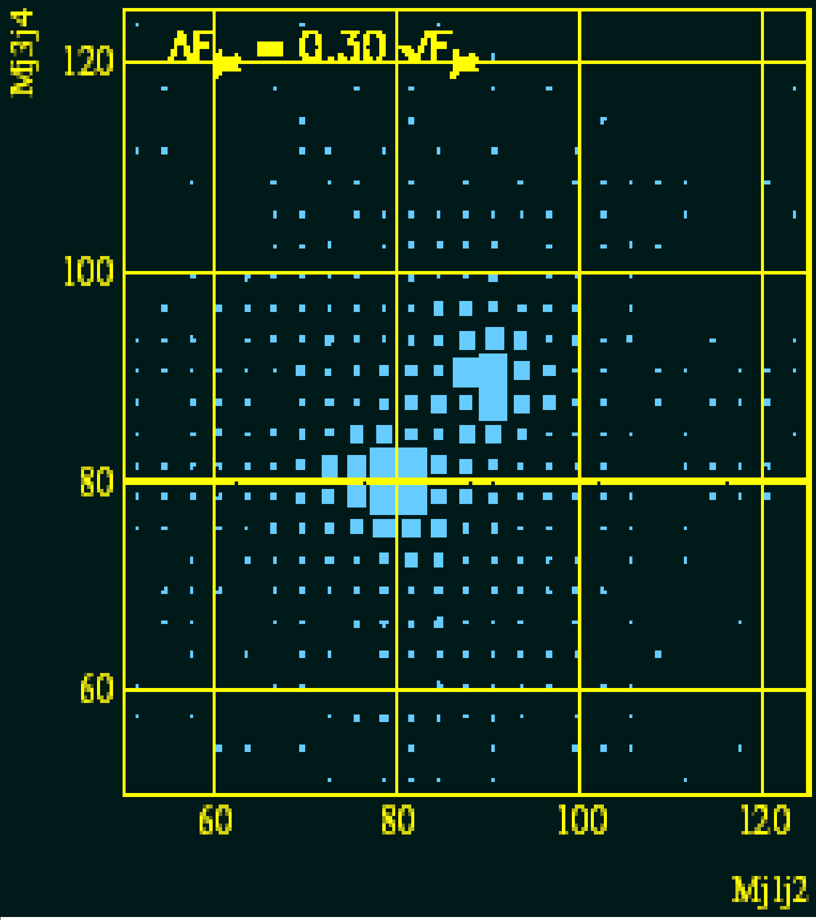
EM	Si-W	Oregon/SLAC
	Pb Scint	KEK
	Si-W	Ecole Polytechnique

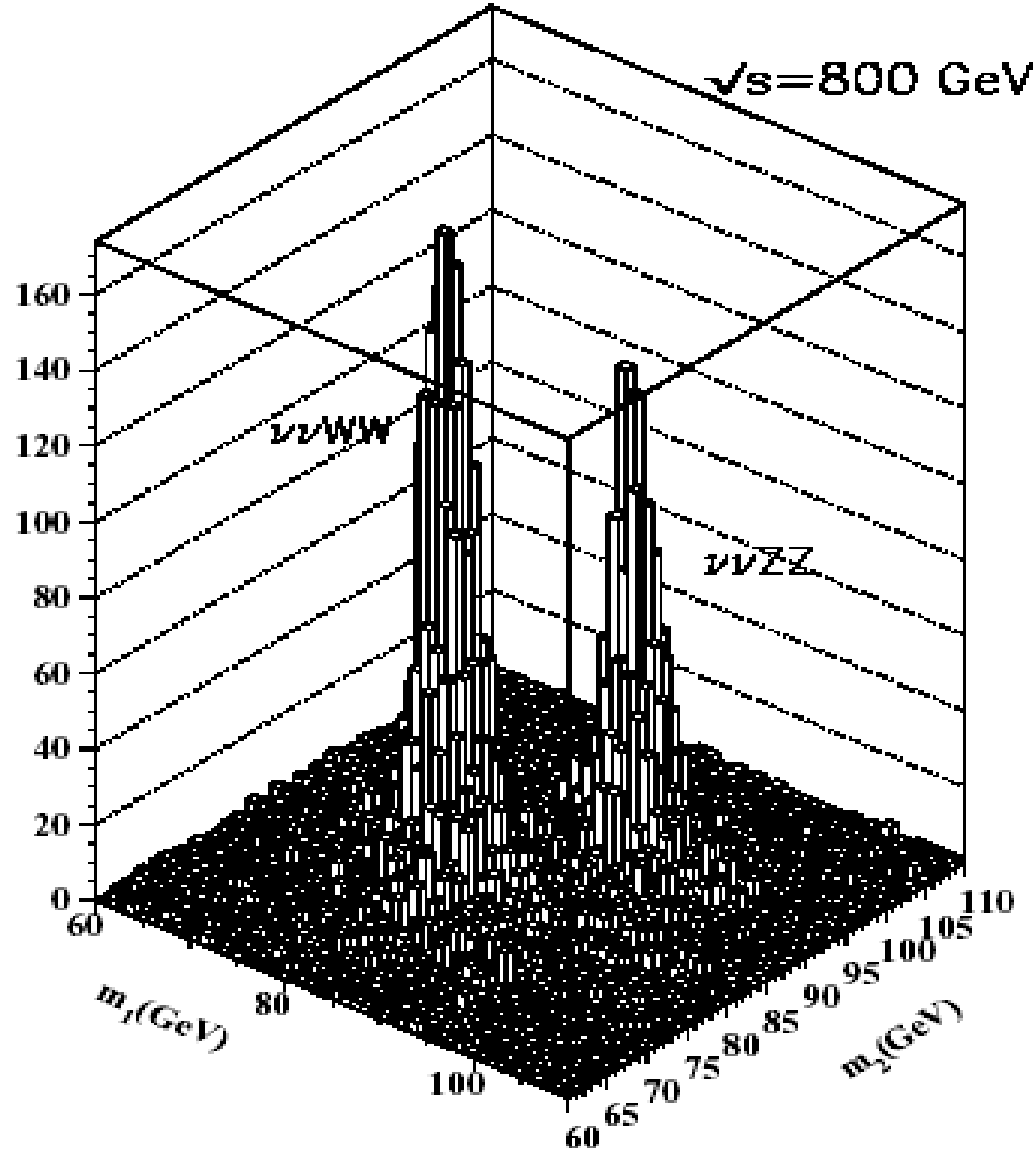
WW Scattering - TESLA
(R. Chierici, S. Rosati & M. Kobel)



Brient/Videau ZZνν, WWνν






√s=800 GeV
ννWW
ννZZ
0
20
40
60
80
100
120
140
160
60
80
100
m1(GeV)
60
65
70
75
80
85
90
95
100
105
110
m2(GeV)

LC Detector Design: Muons

http://blueox.uoregon.edu/~lc/randd.pdf

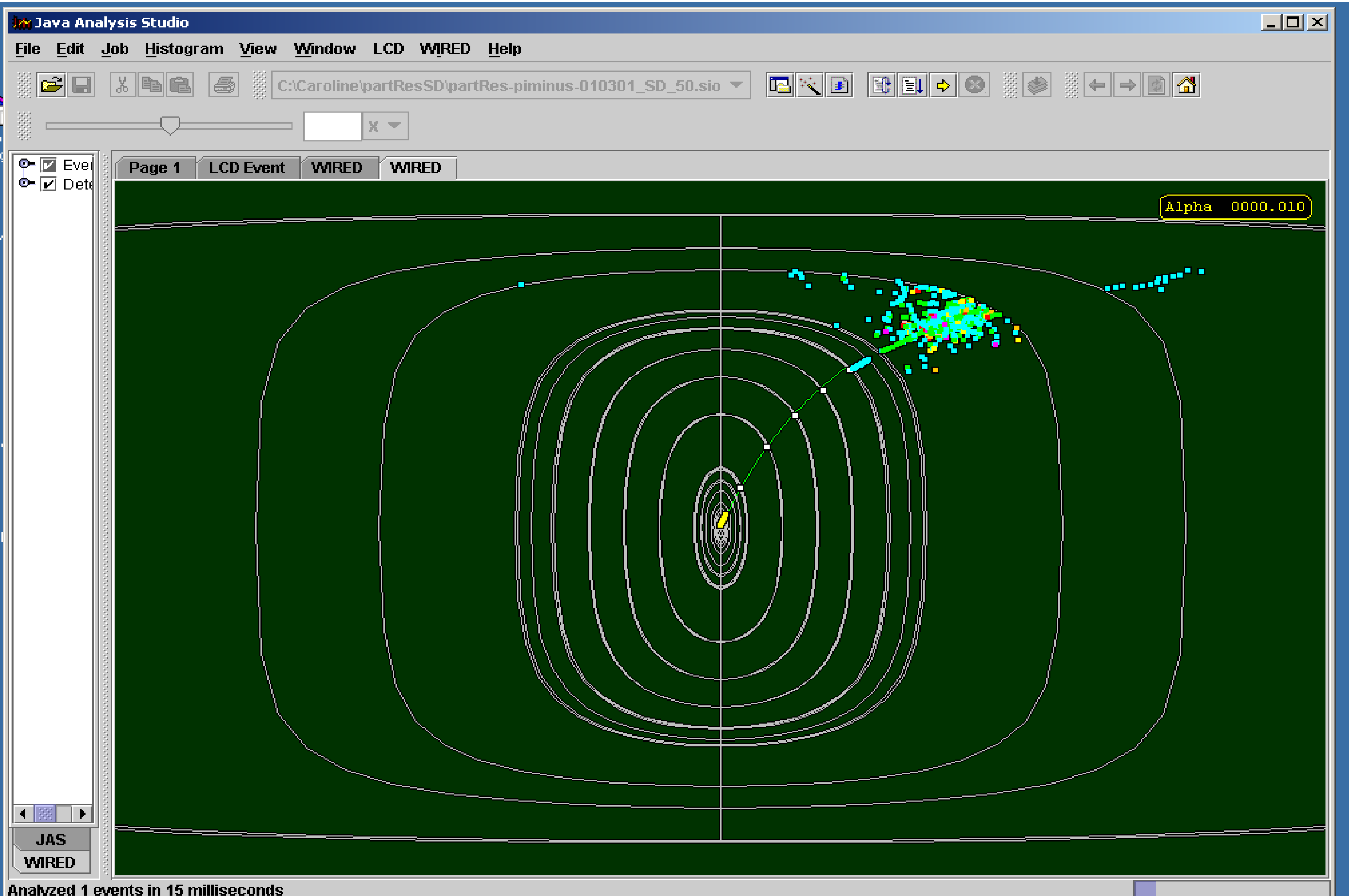
- Identify muons via their penetration through the solenoid Fe return yoke (traditional technique). Include hadron calorimetry measurement capability in μ detector design, since the calorimeters are thin:

  4.5 - 6.7λ in depth,

  due to cal segmentation and solenoid volume.

  What technology? Wire chambers; Resistive plate chambers; Scintillator; etc.

50 GeV π- event 11 run 0 EyeFish View-18 hits in Muon Detector



Univ/Fermilab LC Detector R&D - I

- Vertex Detector & Tracker:

CCD ASIC readout chip: (UCLC Proposal)
w/U Okla., Boston Univ. & Fermilab
P. Skubic, U. Heintz, W. Wester/R. Yarema
Other CCD R&D: Oregon Yale LCFI-Europe
Brau Baltay Damerell
Monolithic Active Pixel Sensors, HybridAPS
M. Winter, Strasbourg, et al
Scint Fiber Int.Tracker (LCRD Proposal)
Fermilab-Bross, Indiana-VanKooten, Notre Dame-Hildreth,Ruchti,Wayne

+10 other UCLC & LCRD proposals

Univ/Fermilab LC Detector R&D-II

- **Calorimeter:**

1. Digital HCAL at NIU (UCLC Proposal)
   NIU Chicago Colorado Kansas NotreDame
   Zutshi-Oreglia-Nauenberg-Wilson-Karmgard
2. Development of E-flow Algorithms (UCLC Proposal)
   NIU - D. Chakraborty
3. Scint. Strip Cal-Fiber Readout w/ High Spatial Resol'n (LCRD) Colorado – Nauenberg (FNAL ?)
4. Digital HCAL w/GEM Readout (LCRD Proposal)
   U Texas/Arlington -A. White (FNAL ASIC dev)
5. Study of RPCs as the Active Medium for HCAL (LCRD) ANL – Repond, Boston – Butler/Narain, Chicago – Oreglia, U Ill - Thaler

Univ/Fermilab LC Detector R&D-III

- Muons:

1. Scintillator-based Muon Syst (UCLC proposal)

NIU	Notre Dame	Fermilab
A. Maciel	M. Wayne	A. Para, Fisk, Milstene,

2. Scintillator-based Muon Syst (LCRD proposal)

UC Davis	Wayne State	Fermilab
M. Tripathi	P. Karchin	

Simulation software (NIU), Scintillator Devl (NIU) MAPMTs/Calib (Wayne St), Fibers (Notre Dame/ Fermilab), Readout (UC Davis), Mechanical Engr. (Fermilab)

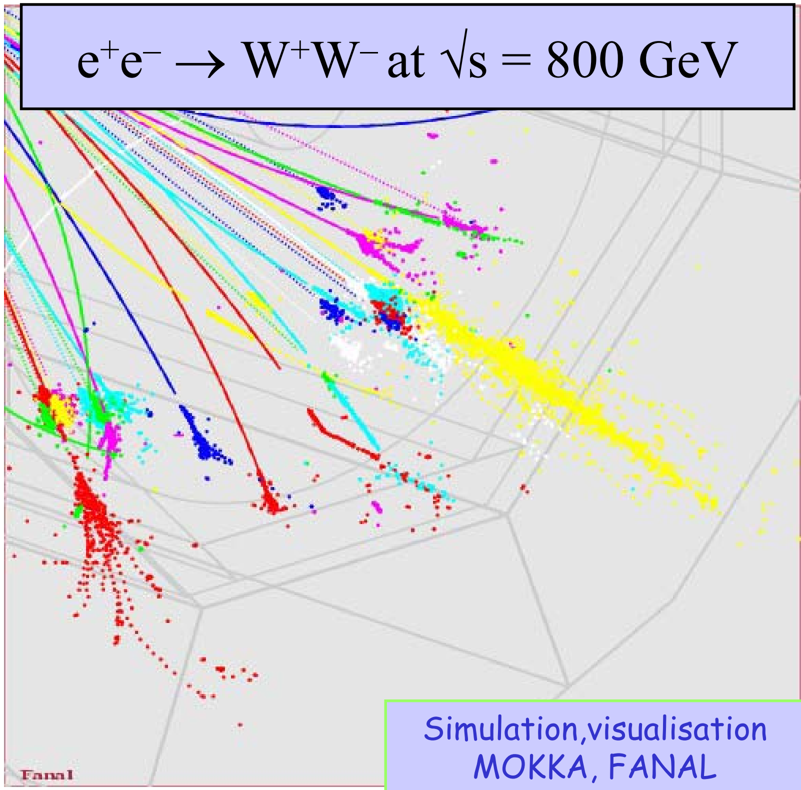
LC Detector R&D/Fermilab Facilities

- Computing & Software Development: Simulations, PREP Electronics, On-line systems support, Data Analysis.
- ASICs Design, PPD EE and ME support.
- Lab 8 Gerber, polishing, coating, etc.,
- Lab 6 Scintillator R&D,
- Lab 5 Scint Extrusion Fac'ty (bought by NIU)
- Mtest Test Beam – Heavy Future Use

Fermilab LC R&D: The next 6 yrs.

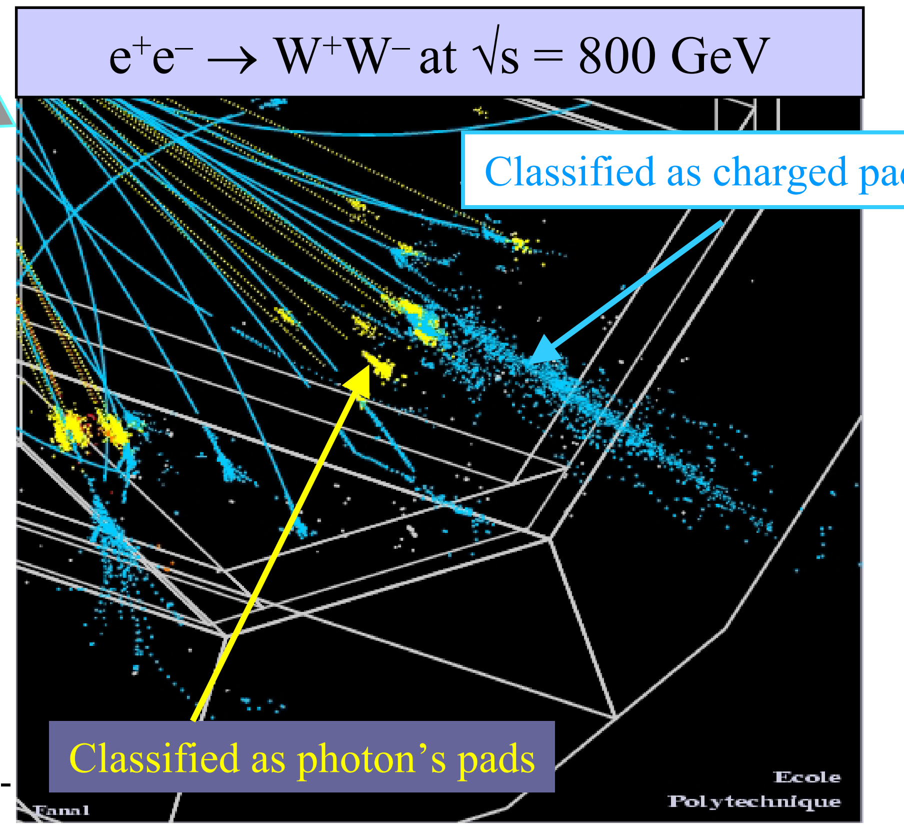
1. Detector & Physics Simulation Software
2. Vertex Detector Pixel R&D
3. Calorimeter: Electronics/Readout ASICs
4. Scintillator R&D – applied to Cal & Muon
5. SC Solenoid: 4T or 5T? Int'l Collaboration
6. Prototype Detector Beam Tests

1. Detector & Physics Sim. Software



- Int'l LC simulation and analysis software development.

After reconstruction

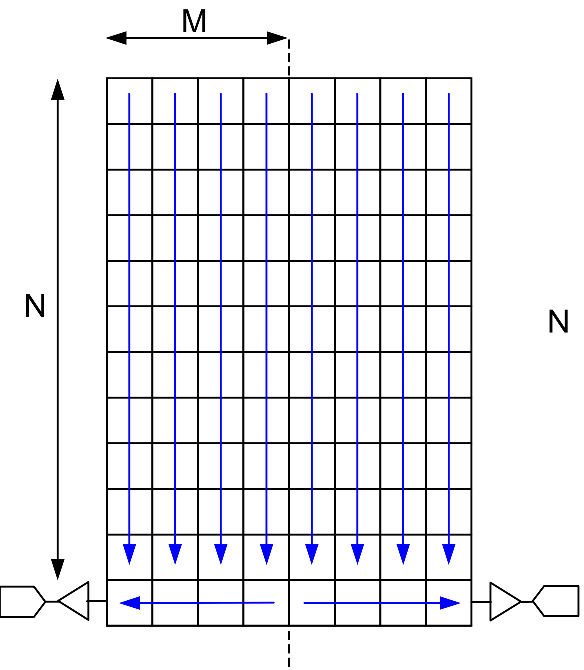


•Calor Mtest beam tests.

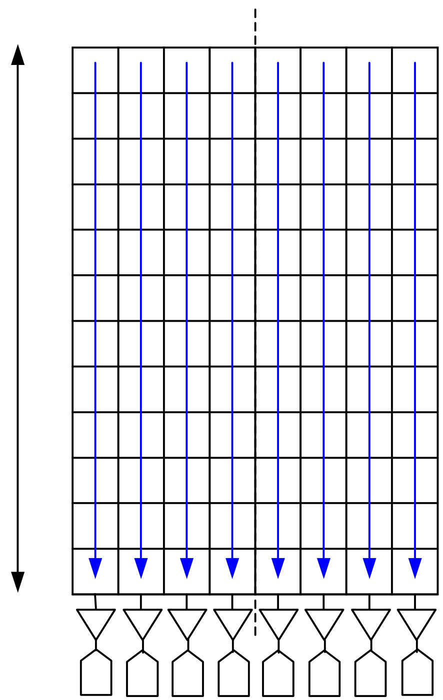
•E-flow algorithm development.

2. Vertex Detector Pixel R&D

CCDs: 800M pixels of size ~ 20 μm



"Classic CCD"
Readout time ≈ $N \times M/F_{out}$



Column Parallel CCD
Readout time = N/F_{out}

LCFI – Damerell et al

- Improved readout w/ column parallel; CCD readout ASICs design: W. Wester, R. Yarema's group; need thinner detectors; 50MHz – 1MHz / TESLA – NLC clocks.
- Other Si pixel R&D is also in progress:
- Monolithic Active Pixels
- DEPFETs
- Hybrid Active Pixels

3. Calorimeter R&D

GEM: Gas Electron Multiplier

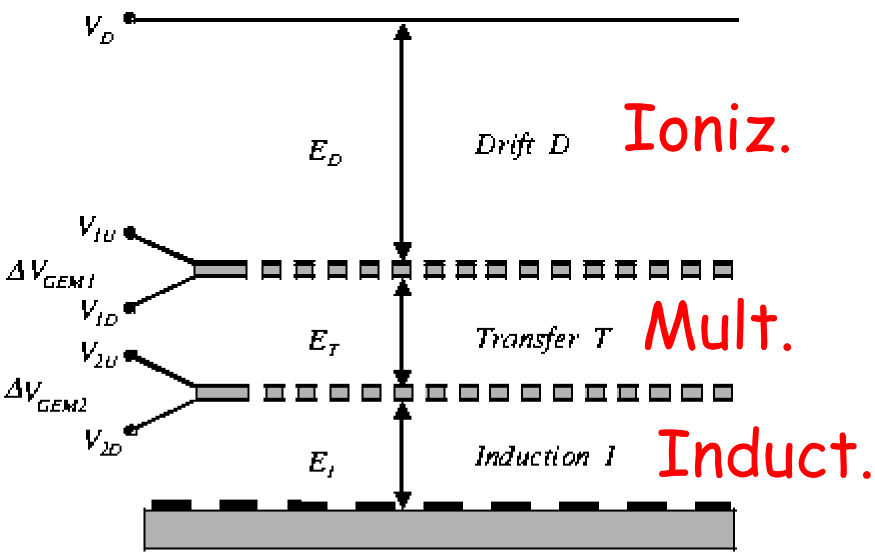


Fig. 1: Schematics of a double-GEM detector.

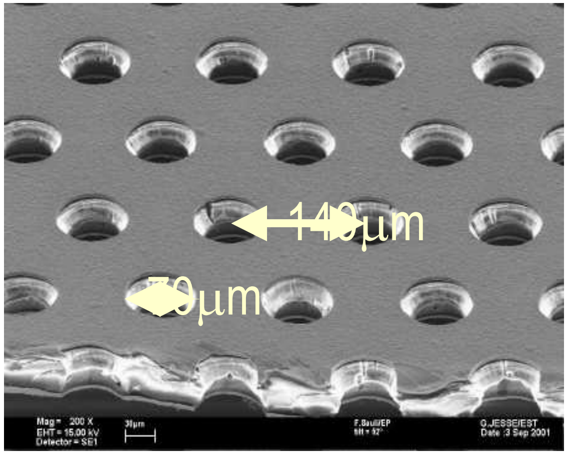
Other CAL R&D:

NIU Scintillator Lab 5

RPC readout at ANL

UTexas-Arlington w/ASICS readout R&D at Fermilab for Digital HCal.

Etched GEM Foil



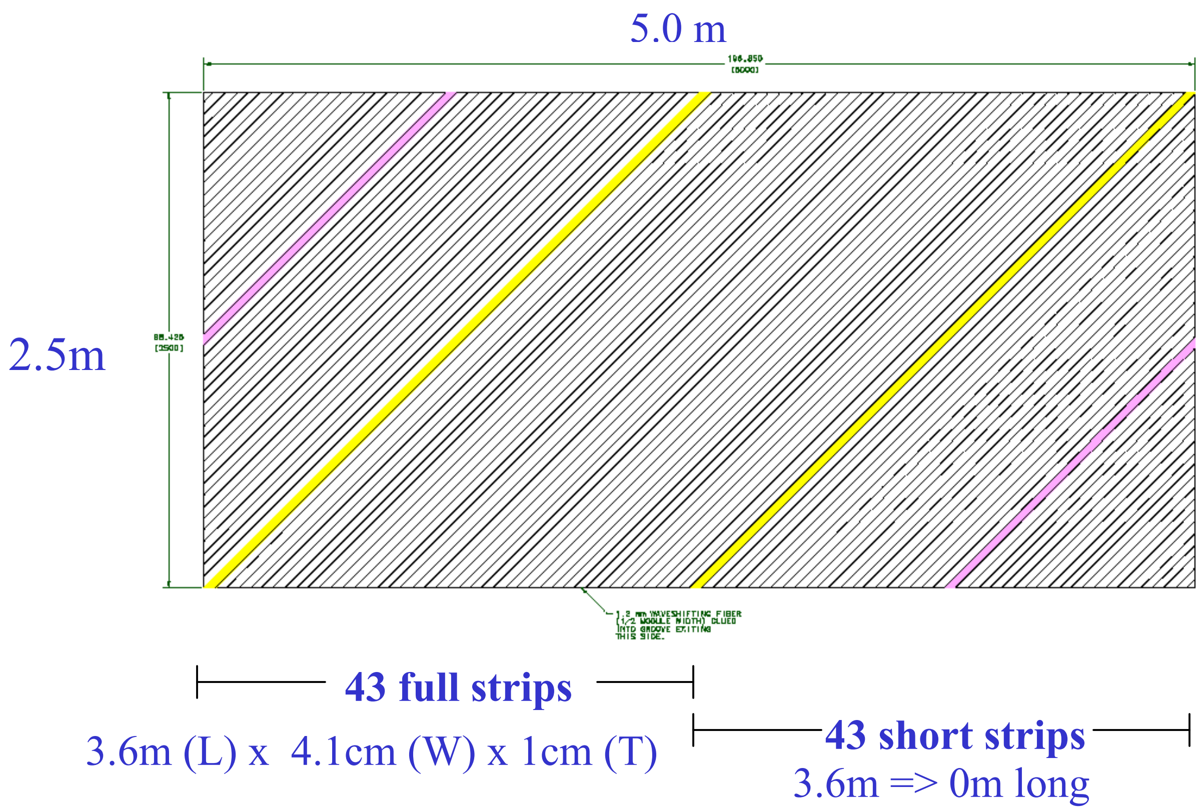
Lab 5 at Fermilab

Berstorff Extrusion Machine
(purchased by NIU); Installed.

First articles of scintillator in June ‘03.

4. Muon System R&D

UC Davis, Fermilab, NIU, Notre Dame & Wayne State



Read out: both ends of full strips; one end of short strips (except the shortest 22).
2*(43 + 21) fibers/side =128 channels = 8 (1.2mm dia) fibers/pix * 16(4 x 4mm^2) pixels
=> Equivalent of One MAPMT/prototype plane

4. Muon System R&D (cont.)

Software Development

- Development of global simulation software - NIU.
- Muon tracking & identification:

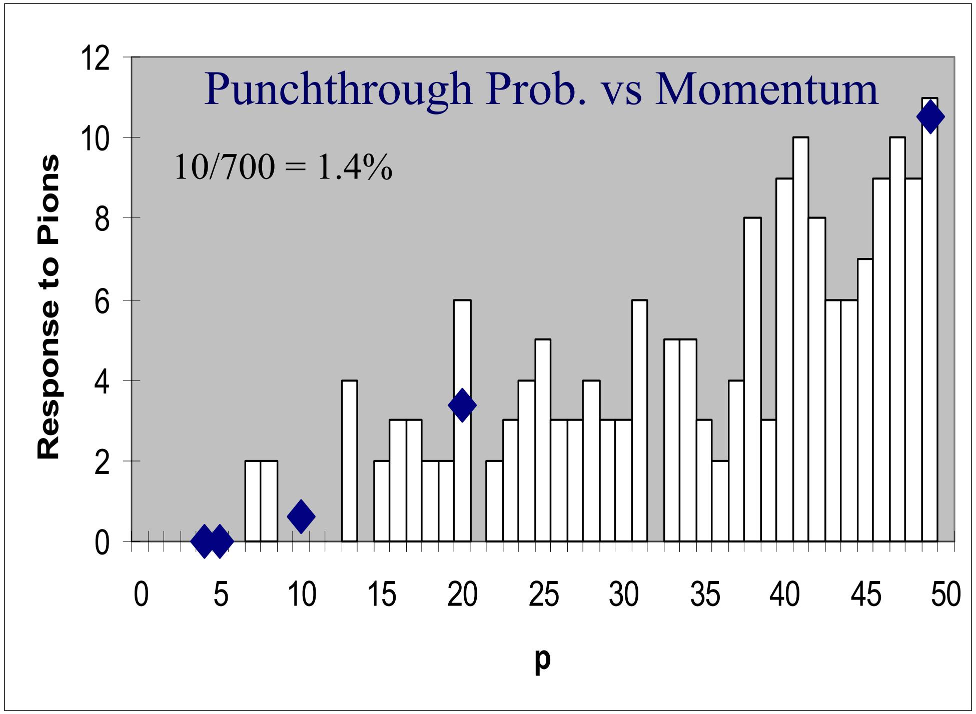
  Single π's , μ's;

  b pairs:

  Efficiency

  Punchthrough

  μ's in jets



5. Test Beams

- CERN – No PS or SPS beams in 2005. West Area test beams will be stopped at the end of 2004. North Area beams may be operated in 2006 if it is financially possible.
- DESY has an electron test beam 1 – 7 GeV/c: Teststrahl 21. OK for start of EMCal tests.
- Frascatti - low energy electron beam: < 750MeV
- KEK JHF Testbeam proposal initiated – 3 GeV
- SLAC End Station A – Beam diagnostic facility?
- Fermilab MTest http://www-ppd.fnal.gov/mtbf-w

Test Beam Needs

	Group	Apparatus	Beam Conditions	When/Where
1	TESLA/CALICE J.-C. Brient/P. Dauncy et al	E_Cal/H_Cal E-flow Tests	e, μ, π, p 5 - 50 GeV	Late 2004 DESY 2005 Fermilab/SLAC?
2	JLC-Cal – Y. Fujii et al	EM & H Cal Prototypes	e, μ, π, p 2 - 200 GeV	KEK/2004; JHF prop. US 2005 - 2008?
3	LC- Cal – R. Frey et al	E_Cal H_Cal Prototypes	e to 10 GeV e, μ, π, p =>120	E_cal at SLAC '04; E & H_Cal @ FNAL
4	Digital H_Cal – Argonne, NIU, UTA, et al	H_Cal Prototypes	e, μ, π, p =>120	Fermilab – 2005 - '06
5	IP Instrumentation Woods/Torrence et al	Gas Č counter/cal Quartz fiber cal Sec. Emission det. W. angle, vis light beamstrahlung Synchrotron rad BPM E spectro	e/γ to 100 GeV; LINX for beamstrahlung; Polarized e's	Various
6	IP Instr and Calorimetry Onel/Winn et al	Compton polar. w/ quartz fiber cal; Sec. Emission det. Č compensated cal	e, π, p =>120 < 20, < 300 GeV	Fermilab CERN PS & SPS
7	Tile/fiber Tests R. Ruchti	Detector prototypes, timing,	e, μ, π 10 – 100 GeV	Fermilab
8	Muon Prototype Detectors TESLA/ALC	RPCs and Scintillator based	e's 50-750 MeV e, μ, π =>120GeV	Frascati 2004 Fermilab 2005

Costs/Schedule

- This is a guess – not an estimate!
- Assume 5 potential areas for detector R&D and a linear ramp-up of personnel to 50 Fermilab people in 4 FYs; physicists, engineers and technicians; no overhead. Assume one person-yr = $100K. So the salary burden is $5M in FY08. Multiply by 2 for overhead, M&S, etc. So the cost in FY08 is $10M and a linear ramp says 2.5M + 5.0M + 7.5M +10M = $25M. Then the R&D would last another 3 years: FY09, FY10, FY11, at which time detector construction would commence and take about 4 years.
- Previous detector cost estimates ~ $300M +

Summary

- LC detector R&D is ramping up. Both DOE and NSF are beginning to fund R&D proposals.
- R&D needs to be completed in about 7 years to pace the machine schedule.
- There is time to do the R&D and choose the best technologies for the proposal and a robust cost estimate.
- Fermilab should be strongly involved in detector R&D. It's important to your future. We have expertise and facilities to join several international detector & accelerator R&D efforts.