US ILC Test Beams

DOE/NSF ILC Detector R&D Review
June 19 – 20, 2007

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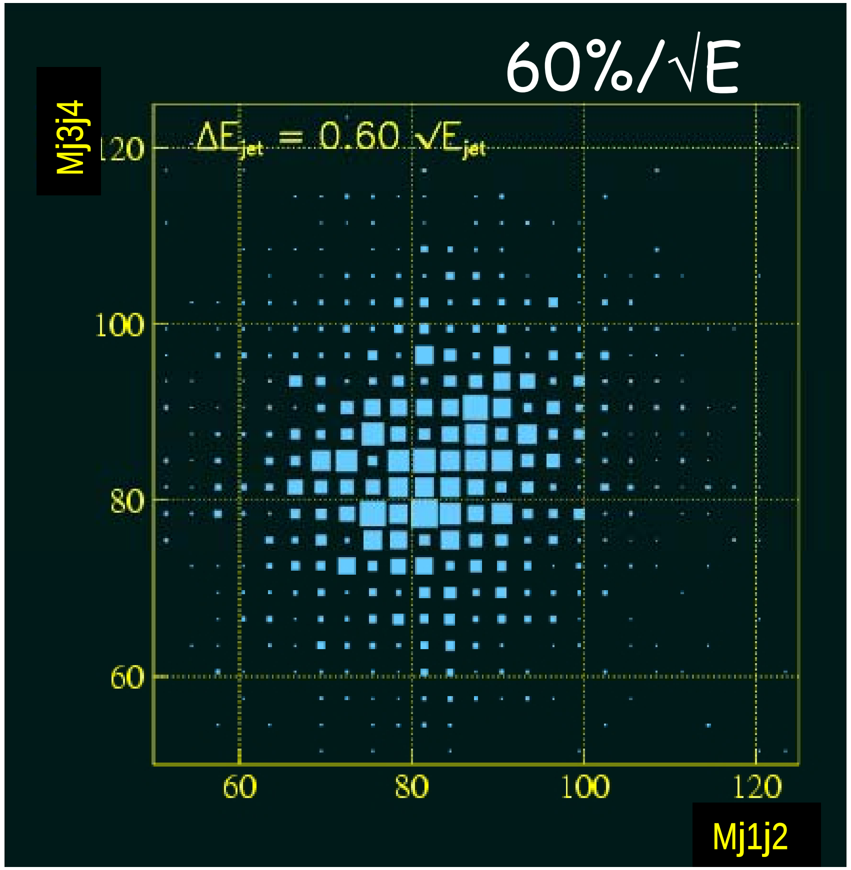
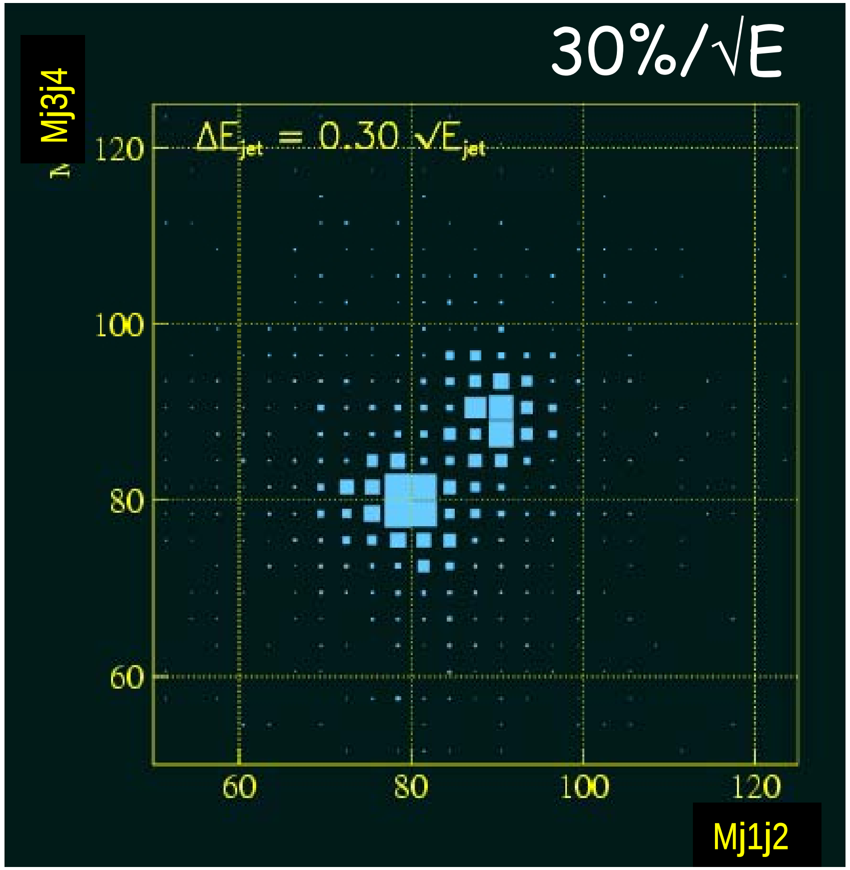
- Introduction
- Existing Facilities and Their Availabilities
- Notable Detector R&D Groups' Requests
- US Beam Test Activities and Plans
- Conclusions

Introduction

- International Linear Collider is the next generation machine for precision measurement at high $\sqrt{\hat{s}}$
- Critical physics measurements
  - Higgs production e.g. $e^+ e^- \rightarrow Zh \rightarrow qqbb$
    - separate from WW, ZZ (in all jet modes)
  - Precision higgs coupling measurements
    - g_{tth} from $e^+ e^- \rightarrow tth \rightarrow WWbbbb \rightarrow qqqqbbbb$
    - g_{zhh} from $e^+ e^- \rightarrow Zhh \rightarrow qqbbbb$
  - Higgs branching ratios $h \rightarrow bb$, WW^*, cc, gg, $\tau\tau$
  - etc
- All of these physics goals demand
  - Excellent jet mass resolution, sufficient for separation of W and Z
  - High efficiency and high purity flavor tagging capability
  - Excellent track momentum resolution
  - High precision LEP measurements

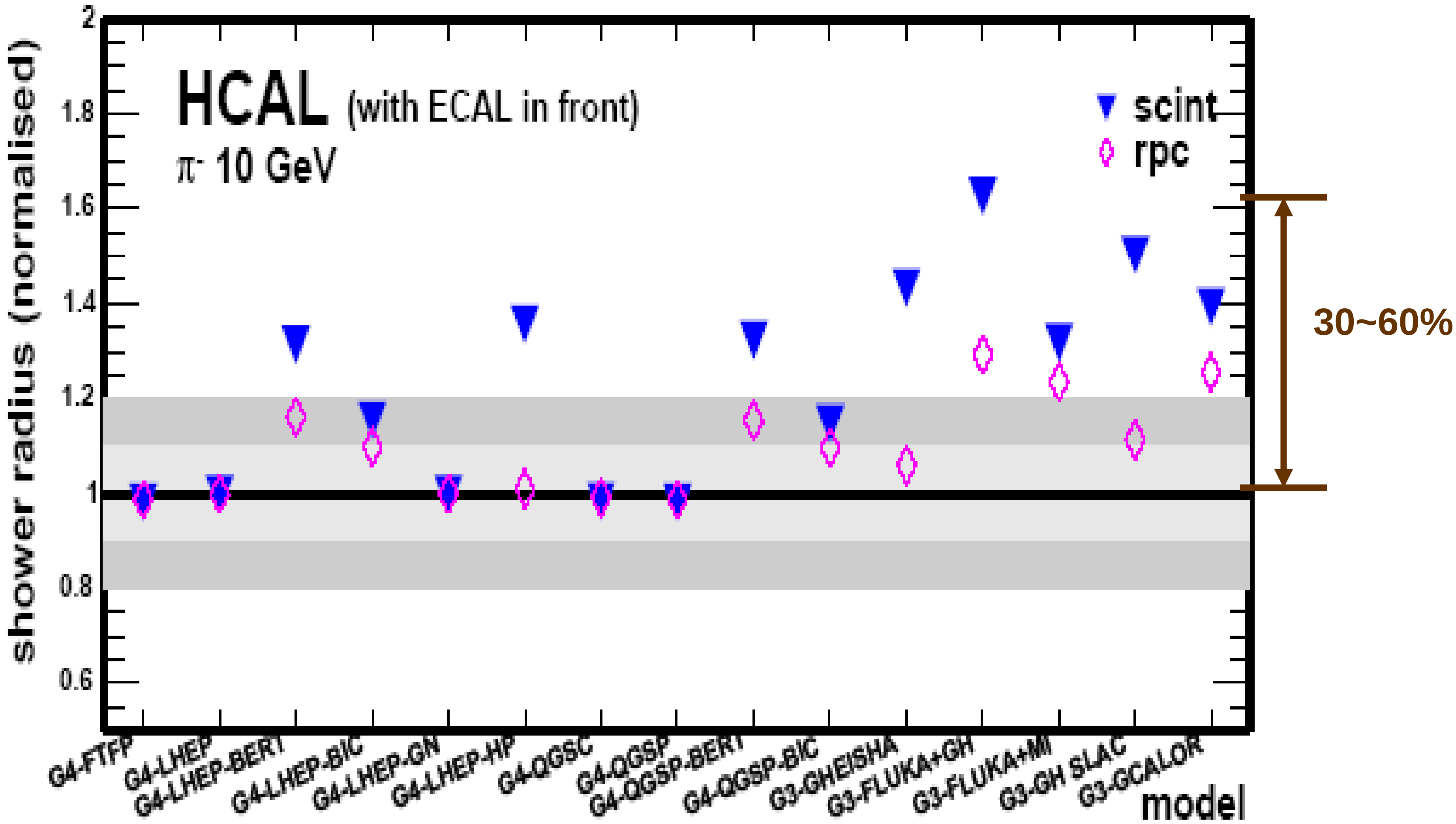
Can Traditional Calorimeter Meet the Requirements?





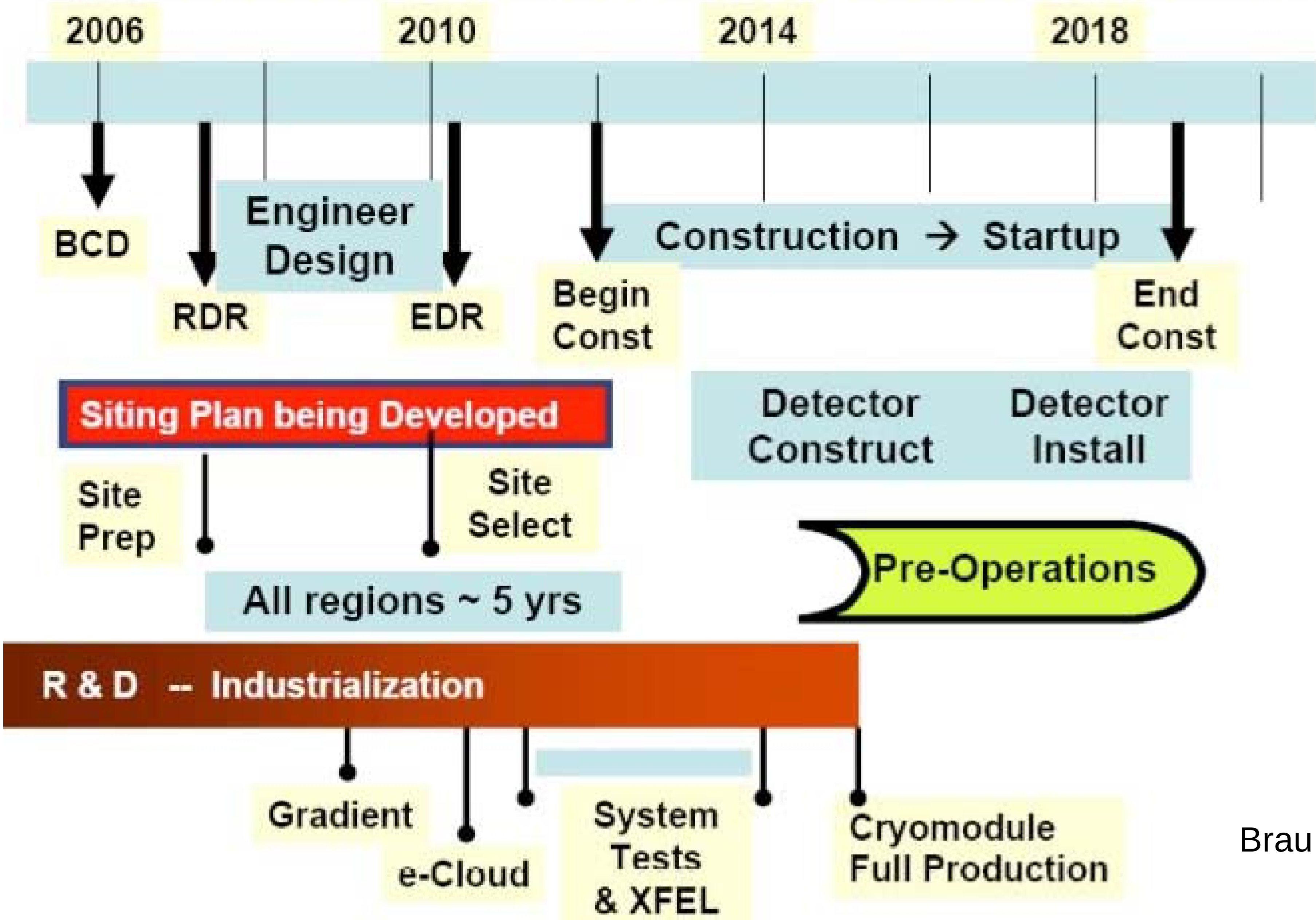
- ILC Physics demands unprecedented precision in detectors
- GDE schedule and WWSC/ILCSC recommendations strongly encourage two detectors by the end of 2008
- Many detector R&D activities reaching to the point of prototype beam tests
  - Need performance testing at the sufficient level
  - Gain information on practical issues of constructing and operating detectors
- Much progress made in understanding and developing PFAs and tools needed for detector designs
  - Hadronic shower behaviors need to be better understood
  - Models should be validated
- ILC Detector designs should be “in synch” with accelerator EDR
  - Most ideal if detector EDRs contain technologies that are <u>performance tested in beam</u> and <u>understood beyond simulations</u> for informed decisions

A Lateral Shower Widths Comparison



G. Mavromanolakis *et al.*

Technically Driven Timeline



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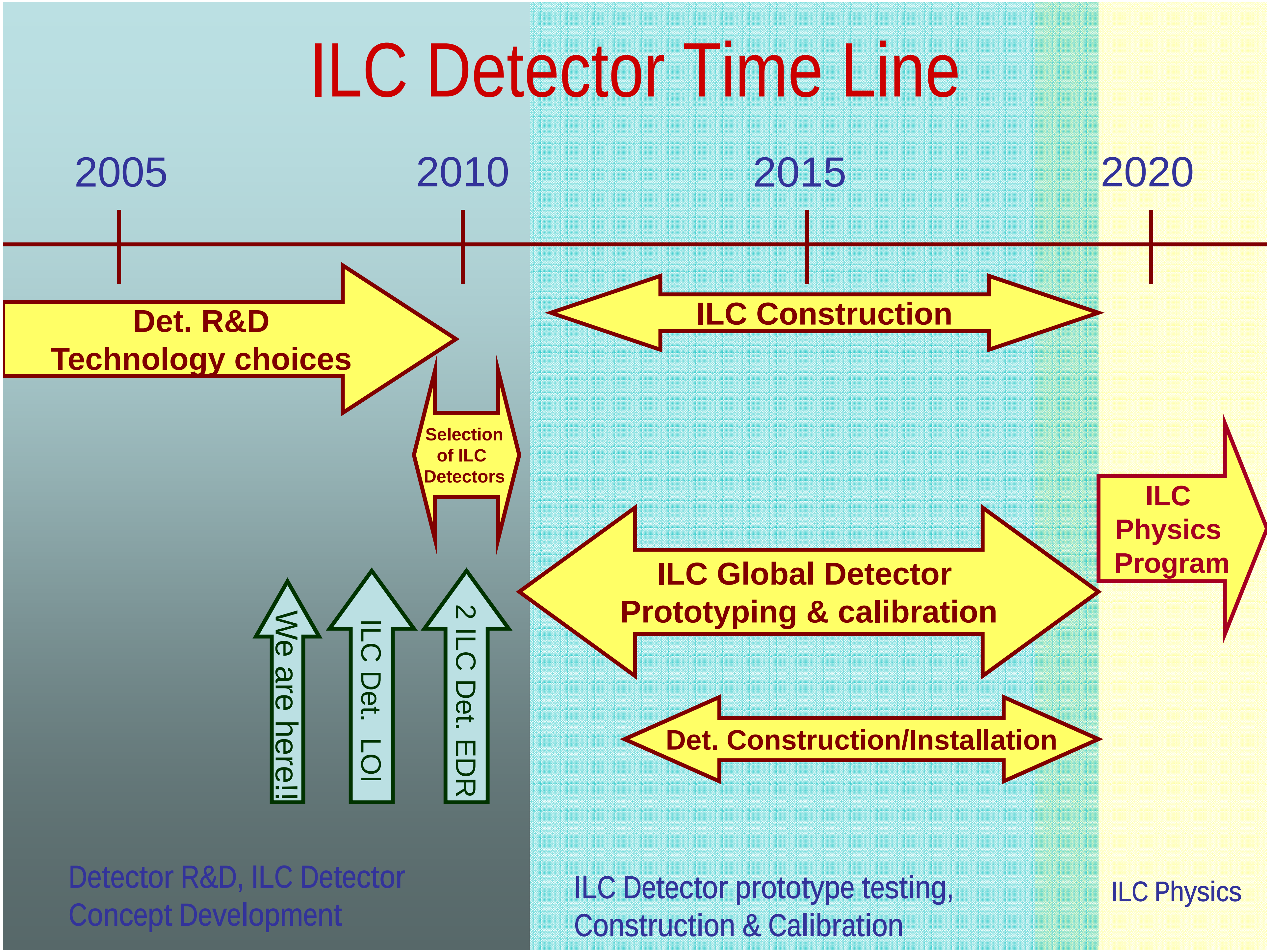

ILC Detector Time Line
2005
2010
2015
2020
Det. R&D
Technology choices
ILC Construction
Selection of ILC Detectors
ILC Physics Program
ILC Global Detector Prototyping & calibration
We are here!!
ILC Det. LOI
2 ILC Det. EDR
Det. Construction/Installation
Detector R&D, ILC Detector Concept Development
ILC Detector prototype testing, Construction & Calibration
ILC Physics

To prepare the community and facilities ...

- IDTB07 workshop at FNAL on Jan. 19 – 21, 2007
  - Over 120 participants
- Goals
  - Assess the current status, capabilities and plans of facilities
  - Assess the current and planned detector test beam activities
  - Identify requirements for test beams to meet adequately the detector R&D needs
  - Plan and discuss for the future beam test activities
  - Feedback information to facilities and ILC detector and physics leadership
- Outcome: ILC Detector Test Beam Roadmap Document
  - Draft released at LCWS07 in DESY
  - Final version targeted to be released on July 1, 2007

Test Beam Facilities and Availabilities

Facilities	Momentum Range	# Beamlines	Particles	Availability and plans
CERN PS	1 - 15 GeV	4	e, h, μ	LHC absolute priority, no TB starting Nov. 2007
CERN SPS	10 - 400 GeV	4	e, h, μ	LHC absolute priority, no TB starting Nov. 2007
DESY	1 - 6.5 GeV	3	e^-	> 3 months per year
Fermilab	1-120 GeV	1	e, π, K, p; μ	continuous (@5% duty factor), except summer shutdown
Frascati	25-750 MeV	1	e	6 months per year
IHEP Beijing	1.1-1.5 GeV (primary) 0.4-1.2 GeV (secondary)	3	$e^\pm$ $e^\pm$, $\pi^\pm$, p	Continuous after March 2008 (unavailable before then)
IHEP Protvino	1-45 GeV	4	e, π, K, p; μ	one month, twice per year
J-PARC	Up to 3GeV		????	Available in 2009 earliest
KEK Fuji	0.5 - 3.4 GeV	1	e	Available fall 2007, 240 days/year
LBNL	1.5 GeV < 55 MeV < 30 MeV	1	e p n	Continuous
SLAC	28.5 GeV (primary) 1.0 - 20 GeV (secondary)	1	e $e^\pm$, $p^\pm$, p	Parasitic to Pep II, non-concurrent with LCLS

Demarteau

Facilities Summary

- Six low energy (<10GeV), electron facilities available at various time periods
- One med energy (<28GeV) available up to 2008 but uncertain beyond 2008 – SLAC ESA
- Two med to low E (<45GeV) hadron facilities
  - Limited availabilities once LHC turns on till the operation stabilizes
- Two high E hadron facilities
  - Required by most detector R&D groups
  - SPS limited once LHC turns on till the operation stabilizes

SLAC Test Beam Facilities

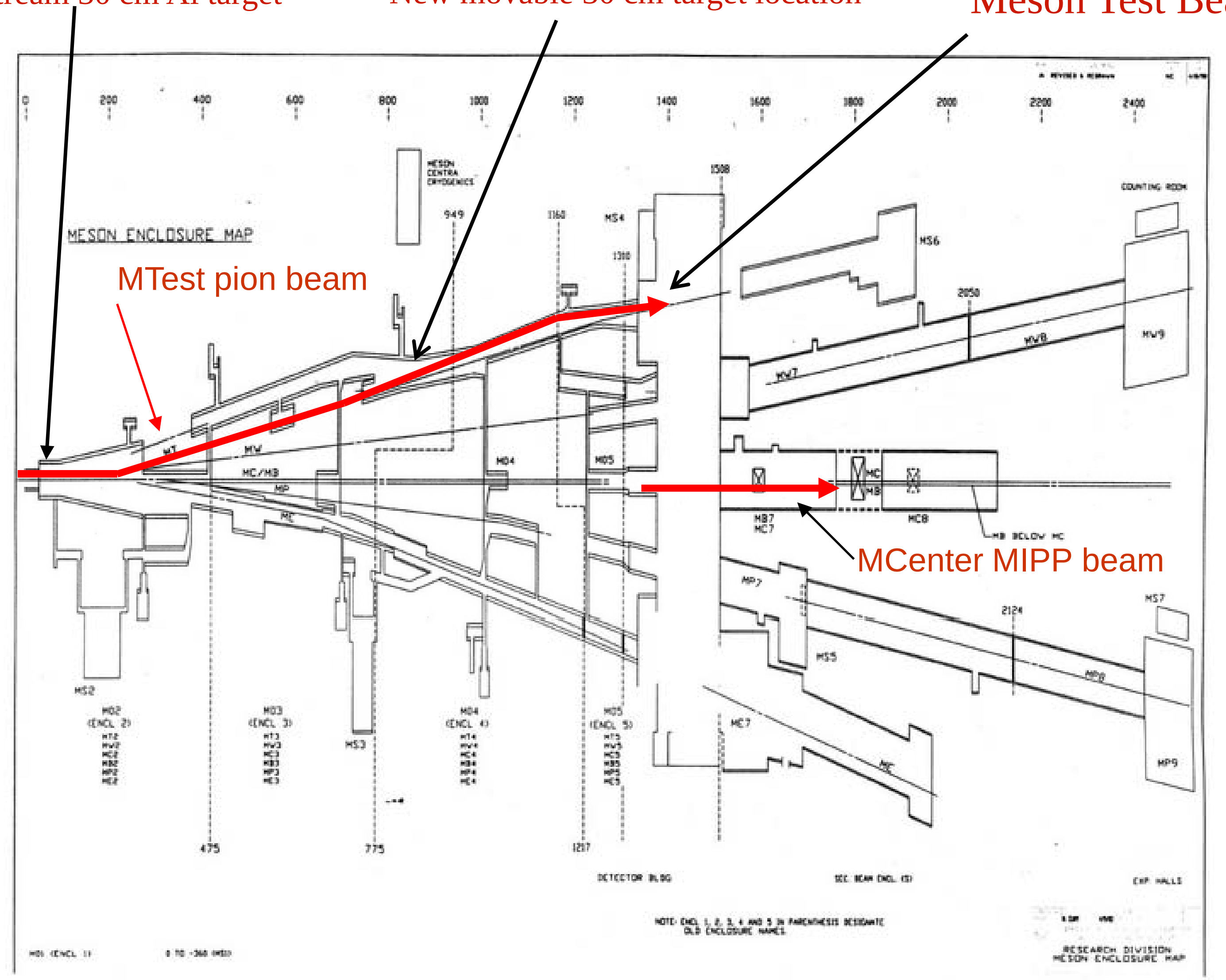
- ESA available through the end of 2008 w/ 28.5GeV e
  - a key facility used primarily for BI and MDI beam tests
  - No promise of operation beyond 2008 but a study group is working with directorate for concurrent ESA operation with LCLS
  - A good change to get LCLS halo down to ESA in 2009
  - Recent effort to extend ESA TB program awaits decisions
- LCLS commissioning to begin soon
  - Fully operational with secondary beam in 2009
- SABER
  - If approved some minimal running in 2007 and some accelerator testing in 2008
  - Primary electrons and positrons can be available but no hadrons
  - A bypass line planned to allow concurrent operation of SABER with LCLS

FNAL Facility

- Upgraded beam line in operation since Jan. 2007
  - Much improved rates at low energies (<6 GeV)
- Upgraded instrumentation
  - High precision particle ID
  - Precision position detectors
- Flexibility in spill structure within the 5% duty factor guideline
- Further extension of possibilities under discussion
  - Tagged neutrals
  - ILC-like spill structure
  - Large bore, high field magnet

MTest Beam Layout and Modes

Eric Ramberg



Proton Mode: 120 GeV protons transmitted through upstream target

Pion Mode: 8-66 GeV beam tuned for secondaries from upstream target

Low Energy Pion Mode: 1-32 GeV beam tuned for secondaries from new downstream target

Upstream target will be installed on a motion platform to improve rates x10

Some measured rates in the MTBF beamline

Tune (GeV)	Rate in MT6/spill*	e^- fraction	Resolution
120	800,000	0	-
66**	90,000	0	-
33	40,000	0.7 %	1.0 %
16	14,000	10 %	1.2 %
8	5,000	30 %	-
4	500	60 %	2.4 %
16***	72,000	20 %	5 %
8	44,000	30 %	5 %
4	27,000	80 %	5 %
2	7,000	>90 %	5 %
1	7,000	>90 %	10 %

Pion prediction 1%

*(Rates are normalized to 2.4E12 protons in Main Injector)

**(Rates in green are for pion mode)

***(Rates in red are for low energy pion mode. These rates can improve x10 with upstream target removal.)

Notable requests at IDTB07 workshop

- Virtually all detector R&D groups need e, μ and hadrons in wide momentum range at various stages of R&D
- ILC beam time structure (1ms beam + 199ms blank)
  – VTX, TRK and CAL electronics
- Large bore, high field magnet (up to 5T)
  – VTX and tracking groups
- Mimicking hadron jets
  – VTX, TRK and CAL
- Tagged neutron beams
- Common DAQ hardware and software
- Common online and offline software
  – Reconstruction and analysis software

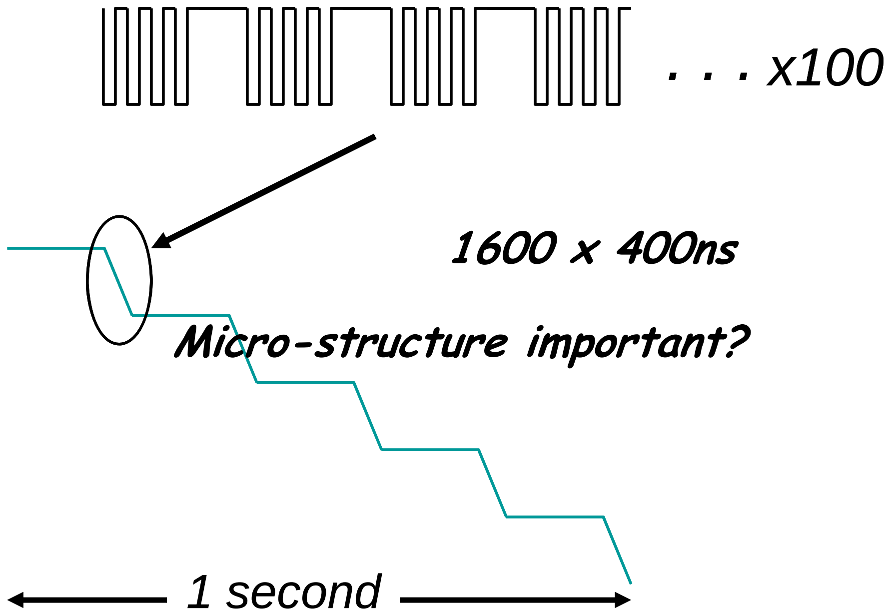
Mimicking ILC Beam Time Structure

- ILC-like macro-structure: 1ms beam + 199ms blank
- Important to perform testing in as realistic a condition as possible
- Requests have been made by
  - For ECAL electronics testing
  - Vertexing and tracking community @ IDTB07
  - Tracking R&D review report recommendations
- SLAC can provide this
  - But 3 consecutive pulses
- Fermilab contacted for a possibility
  - Neutrino beams had such a short pulse structure but from TeV

Can Fermilab Test Beam simulate ILC structure?

Possible path to ILC beam structure:

- Fill Main Injector with 4 Booster batches, with 19 nsec RF structure.
- Turn on already existing 2.5 MHz coalescing cavities. This results in a 400 nsec particle bunch spacing, with gap after 4 buckets.
- Implement a shorter - 1msec? - partial extraction cycle ('ping') using current quadrupole resonance magnet.
- Fit 5 of these pings in a 1 second spill



How important is keeping the micro structure?
How closely does the macro structure have to be kept?

Large Bore, High Field Magnet

- The tacking R&D review report encourages strongly on the need for a tracking & vertexing common test facility
  - Tests under magnetic field – as close a field strength to the real thing - necessary to demonstrate performance of detectors and electronics
- Some CAL Technology testing
- Some solutions are being looked into
  - TRIUMPH: B=2T, ID=1m ID, L= 2.2m
  - AMY Solenoid: B=3T, ID=2.2m, L= 1.6m
  - Purchasing a new split coil solenoid to allow normal beam incidence: B=3 – 5T, ID=0.25 m, L=0.4m
- Discussion on-going to define the specification of the magnet
  - Will probably have to wait till better coordinating structure implemented

Improving Simulation

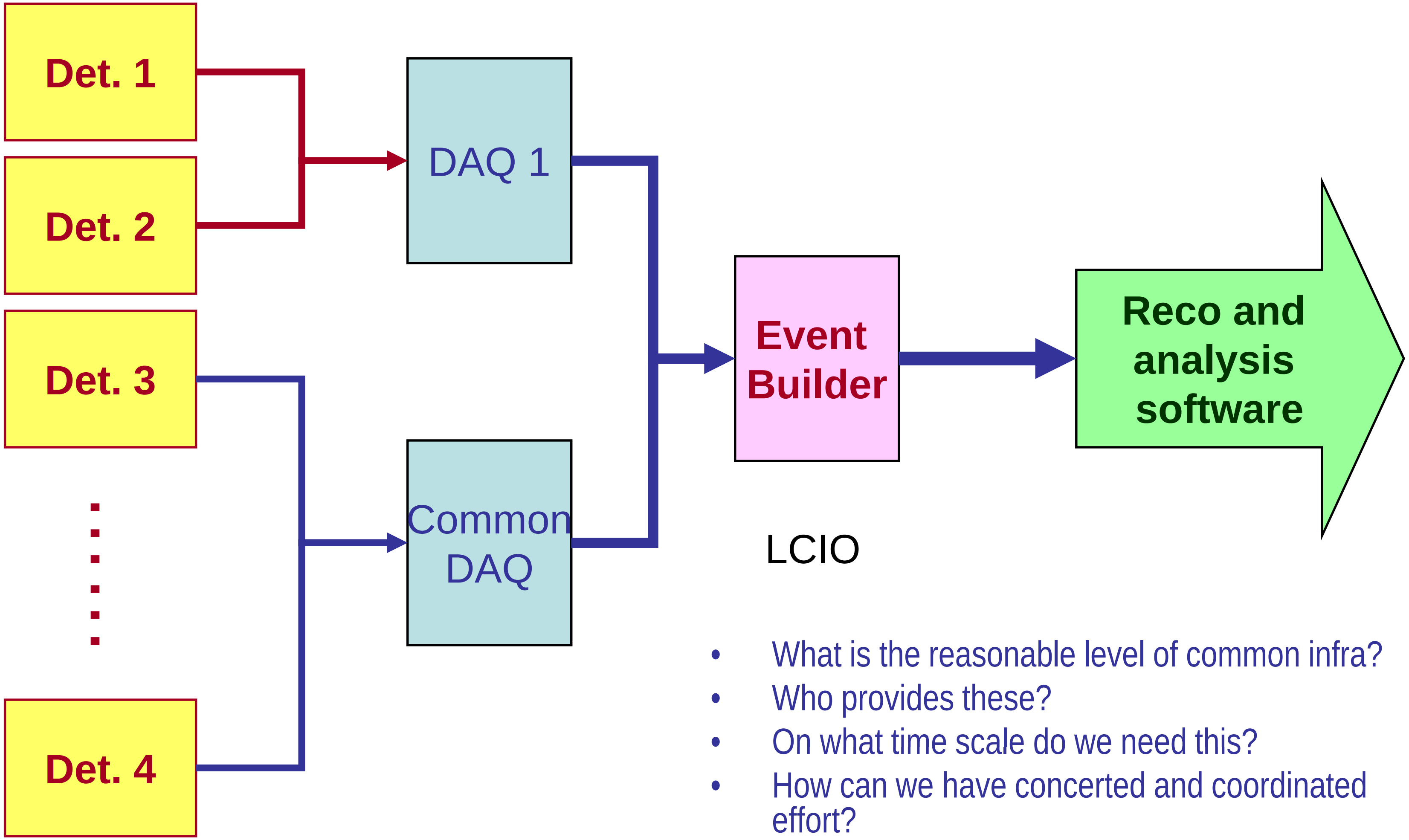
- Critical for ILC detector R&D, especially for PFA development
- Current models do not describe data too well, not just shower shapes
- Data incorporated into the models are from 70s
  - Work ongoing to incorporate data after 70s
- Turn around time seems to be quite long (typically over a decade??)
  - How can this turn around time be shortened to be useful for ILC?
- Do fresh new x-sec data help?
- What kind of data do we need?
  - Will neutral hadrons in a prototype detector helpful?

D. Wright

Tagged Neutral Hadron Beam Facility

- A new proposal from MiPP gives high possibilities of momentum tagged neutral hadron beams at FNAL
- Do we need beam test with neutral hadrons?
  - Successful PFA means the HCAL measures neutral hadrons well with minimal confusion
  - Simulation models need some low E neutral hadron data, despite isospin symmetry
  - Hadron calorimeter calibration can use momentum tagged neutral hadrons
- Can we trigger effectively?
  - What is the purity?
  - Can detectors and DAQ handle the rates?
- What energy range?
  - Which ones do we need to understand better?

Point of Merge for DAQ Commonality



- What is the reasonable level of common infra?
- Who provides these?
- On what time scale do we need this?
- How can we have concerted and coordinated effort?
- Do we need this at all?

Worldwide Detector R&D Needs

Detectors	N_Groups	Particle Species	P (GeV)	Magnet (Tesla)	N_Weeks/yr	ILC time structure	Note
BI&MDI	2E+8ESA+1F+ 2C+3BC	e	up to 100	Not specified	64		Mostly low E elec
Vertex	10	e, π, p; μ	up to 100	1 – 3	40	Yes	
Tracker	3TPC+ 2Si	e, π, p; μ	up to 100	1.5 - >3	20	Yes	
Cal*	5 ECALs+3 DHCALs + 5 AHCALs	e, n, π, K, p; μ	1 – >=120	Not specified	30 – 60	Yes	
Muon/TCMT	3	e, π, μ	1 – >=120	Not specified	12		

*Note: Most calorimeter R&D activities world-wide are organized under CALICE collaboration.

Some of these can work concurrently, but many can't!

BI and MDI Beam Test Activities

- Very active program with close worldwide collaboration
- Activities
  - 6 approved test beam experiments@ SLAC ESA: T-474, T-475, T- 480, T-487, T-488, T-490 @ SLAC ESA
  - MDI-related Experiments
    - Collimator Wakefield Studies (T-480)
    - Energy spectrometer prototypes (T-474/491 and T-475)
    - IR background studies for IP BPMs (T-488)
    - EMI studies
  - Beam Instrumentation Experiments
    - RF BPM prototypes for ILC Linac (part of T-474)
    - Bunch length diagnostics for ILC and LCLS (includes T-487)
- Plans
  - Continue ESA program, requesting 4 weeks of Beam Tests
  - Beam CAL prototype in 2008
  - Gam CAL prototype in 2008 - 2009

US Beam Test Activities

- Vertex Groups
  - LBNL group performed irradiation tests at LBNL facility
- Calorimeter Groups
  - DREAM @ CERN in 2006
  - RPC chamber tests @ FNAL MTBF in Feb. 2006
  - GEM Chamber tests @ KAERI in 2006 and @FNAL in Mar. – Apr. 2007
- Muon and TCMT
  - NIU TCMT participated in CALICE @ CERN in 2006
  - FNAL Scint-based muon detector beam tested in 2006

CAL Schedule and Plans

- Summer 2007 – Mid 2008
  - Complete Vertical Slice Test @ MTBF (July 2007)
  - Complete 1m^3 prototype RPC (400k channels)
  - Develop large scale GEM unit chambers (30cmx1m)
- Mid – late 2008
  - Complete RPC beam exposure for MC validation together with CALICE Si/W and/or Sc/W ECAL
  - SLAC-Oregon SiW ECAL in e beam in 2008
  - Start GEM 1m^3 prototype stack construction if funding allows
  - Beam test TGEM based prototype as an alternate, cost reducing solution
- Late 2008 – 2009
  - Complete GEM 1m^3 prototype stack
  - Beam exposure of (hopefully) a full 40 layer stack GEM DHCAL
  - SiD Si/W ECAL Testing w/ HCALs in hadron beams
  - Dual readout calorimeter prototype in beams

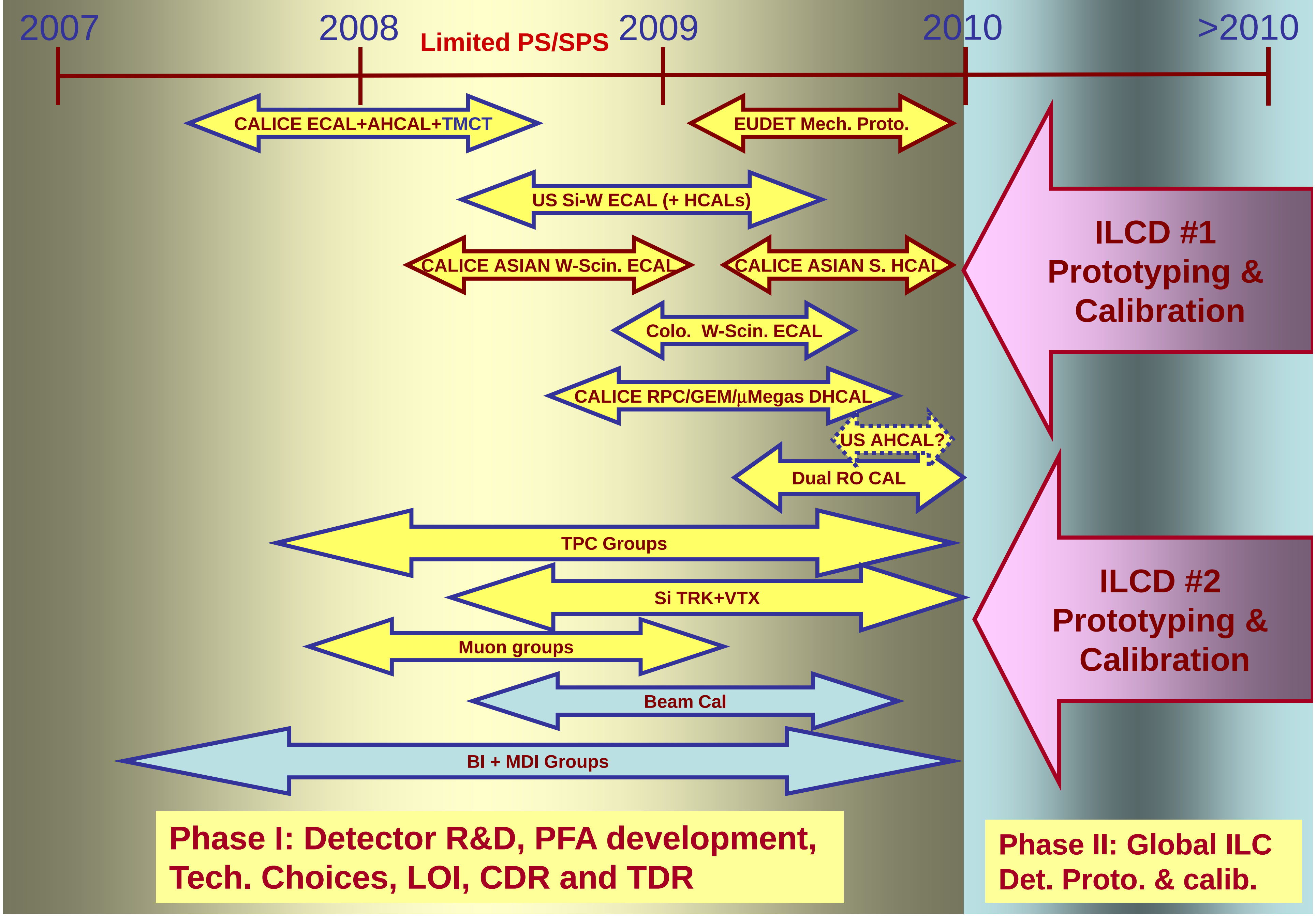
Vertex and Tracking Plans

- Vertex
  - LBNL Thin Pixel Pilot Telescope @ MTBF in 2007 (T966)
  - EMI testing at SLAC
  - Various prototype testing at FNAL
- Tracking
  - Drift Chamber with Cluster Counting (CluCou)
  - Time Projection Chamber (LCTPC)
    - Large TPC prototype testing expected shortly
  - Silicon Strip Tracking
    - As additional tracking with TPC (SiLC)
    - Silicon tracking only (SiD)

Muon and TCMT Plans

- Remaining 2007
  - NIU TCMT to participate in CALICE physics run @ CERN
  - Muon group to test prototype strips and FE electronics/DAQ and existing strip-scint. planes.
- 2008
  - TCMT to be part of CALICE run @ FNAL
  - Add new strip-scintillator plane(s) w/ 100 – 200 strips and prototype electronics: 500 channels
  - Many more scint pixels & electronics channels for tail-catcher.
- Beyond 2008
  - New electronics on existing planes

Upcoming WW ILC Detector R&D Beam Tests



Conclusions

- Beam tests a critical ingredient in making informed decision in designing an ILC detector
  - Most detector R&D groups try to complete beam tests by late 2009
- US Detector Beam Test activities picking up steam
  - Has been trailing European and Asian efforts
  - Rich program planned in the coming few years
  - Many groups are collaborating closely with groups in other regions
- Beam Test Facility becoming scarce
  - SLAC ESA's fate beyond 2008 not clear
  - In FY08 and better part of FY09, FNAL practically the only facility with high energy hadrons
  - FNAL facility needs to be prepared for a large influx of requests
    - Revive fixed target beam lines?
- Continued strong support for US R&D groups' beam tests critical to keep the competitive edge
  - Simulations alone does not suffice

Lab-E
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Pointer 41°50'52.62" N 88°14'58.77" W elev 744 ft
Streaming ||||||||||| 100%
Eye alt 5488 ft