The 2007 Physics Activities: Preparing for Early Physics in CMS

June 8, 2007

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Special thanks to P. Jenni, H. Frisch, Ian Low, P. de Jong, J. Alcaraz, P. Sphicas, C. Campagnari and others.
Early Discoveries

• Several categories come to mind
  – Self-Calibrating
    • mass peaks
  – Astounding
    • Event count $>>$ SM prediction or
    • distribution of some kinematical quantity that is overtly inconsistent with the SM or
    • an all new topology…

• In the absence of such things, the job is difficult and may be slow
### Hadron Colliders History: SpS

**SPS Collider operation, 1982–1985**

<table>
<thead>
<tr>
<th>Operational features</th>
<th>1982</th>
<th>1983</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam Energy (GeV)</td>
<td>273</td>
<td>273</td>
</tr>
<tr>
<td>$\beta_s^p$ (m)</td>
<td>1.5</td>
<td>1.3</td>
</tr>
<tr>
<td>$\beta_s^n$ (m)</td>
<td>0.75</td>
<td>0.65</td>
</tr>
<tr>
<td>Integrated luminosity (nb$^{-1}$)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>average per store</td>
<td>0.5</td>
<td>2.1</td>
</tr>
<tr>
<td>average per day</td>
<td>0.4</td>
<td>1.8</td>
</tr>
<tr>
<td>per year</td>
<td>28</td>
<td>153</td>
</tr>
<tr>
<td>Luminosity (10^{25} cm$^{-2}$s$^{-1}$)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>peak</td>
<td>0.5</td>
<td>1.7</td>
</tr>
<tr>
<td>average per store</td>
<td>0.1</td>
<td>0.5</td>
</tr>
<tr>
<td>Hours scheduled</td>
<td>1750</td>
<td>2064</td>
</tr>
<tr>
<td>Hours realised</td>
<td>746</td>
<td>689</td>
</tr>
<tr>
<td>Number of stores</td>
<td>56</td>
<td>72</td>
</tr>
<tr>
<td>Average store duration (h)</td>
<td>1.3</td>
<td>1.2</td>
</tr>
<tr>
<td>% stores terminated by faults</td>
<td>41</td>
<td>40</td>
</tr>
</tbody>
</table>

- **Engineering run 1981 ~1 nb$^{-1}$**
  - 1$^{st}$ dijets at a hadron collider!
  - Measurement of Production and Properties of Jets…

- **Physics run 1982 ~20 nb$^{-1}$**
  - The first few UA1/UA2 publications:
    - Co-discovery of the W
    - *Inclusive Charged Particle Production* ...

- **1983 ~ 130 nb$^{-1}$**
  - Co-discovery of the Z
6 events in UA1 and the $W$ was discovered!

First dijets at a hadron machine
Publication came out of the 1981 run!

UA2 saw 4 $W$ events: they obtained a central value of 80 GeV for $M_W$
Good stuff comes early...and late.

- **SPS**
  - 683 GeV com and ~100 GeV mean com partons

- **Tevatron I**
  - 1800 GeV com and ~270 GeV mean com partons

- **SPS & Tevatron Discoveries**
  - SPS turn-on led to quick major discoveries
  - Not true at the Tevatron

- **SPS had a lot of data**
  - Already probed quite a bit higher than the mean constituent com energy (~100 GeV)
  - Tevatron needed to ~match SPS integrated luminosity to in order to probe a “new” energy domain
    - And then discovered top!

- **Early discoveries have been followed by other important results at hadron colliders – but these have generally come late**
LHC will startup in new territory

- At 1 TeV constituent com energy
  - $gg$: 1 fb$^{-1}$ at Tevatron is like 1 nb$^{-1}$ at LHC
  - $qq$: 1 fb$^{-1}$ at Tevatron is like 1 pb$^{-1}$ at LHC
Early and Late

- **Parton Luminosity falls steeply**
  - In multi-TeV region, ~ by factor 10 every 600 GeV

- **New states produced near threshold**
  - Suppose you have a limit on some pair-produced object, $M > 1$ TeV. How does your sensitivity improve with more data?
    - By $\sim (600/2) = 300$ GeV = 30% for 10 times more integrated luminosity

Improving sensitivity is tough.... but you can turn evidence into an observation.
What we know we’ll see at 14 TeV

Mainly jets!
\[
\approx 10 \, \mu b/\text{GeV} @ 100 \, \text{GeV}
\]
\[
\approx 0.1 \, \text{pb/GeV} @ 1 \, \text{TeV}
\]

But also: b\bar{b}, W, Z, t\bar{t}

- \( \sigma(\text{b}\bar{b}, \text{high } P_T) \sim 1 \, \mu b \)
- \( \sigma(W \rightarrow l\nu) \sim 60 \, \text{nb} \)
- \( \sigma(WW) \sim 200 \, \text{pb} \)
- \( \sigma(tt) \sim 1 \, \text{nb} \)
Overall (CMS) plan

• **Global priorities:**
  1. Detector completion and commissioning
  2. Detector Performance
  3. Physics Objects
  4. Physics Analysis

• **Physics-wise: focus on discovery**
  - The priority is the new physics for which the LHC was conceived

• **And, of course, we also need to:**
  - Complete and commission trigger
  - Complete software
  - Deploy computing model – and use it effectively
Critical Path

Schedule
- Services: Cooling, power, cabling…Power supplies
- Pixels: Goal = ready for installation in November
- Tracker installation: Goal=Late August

General readiness issues
- Commissioning ~7x10^7 channels!

Alignment and Calibration
- Calibration of the calorimeters + muons (t_o) etc.
- Alignment of the pixels + tracker + muons that will determine our real ability to do physics

A huge amount of work remains… but at the moment, there are no showstoppers
ECAL and Tracker

• Major progress in past 18 months
  – There were extremely serious concerns
  – Now it appears they will both be ready for first physics
End of May 07.
EB- installation complete
ECAL Calibration with Cosmics

Cosmics calibration: barrel $\pm 1.4\%$ uniformity
Tracker is complete
Tracker Construction Alignment

• Tracker
  – ~99.9% operational channels

• Cosmics in outer barrel:
  <200 μm “out of the box” with no alignment corrections

• We’ll take cosmics for several months
  – Reasonable alignment ~70 μm (rφ) of central tracker is possible before collisions

Courtesy of Jim Lamb
Laser Alignment System

Track-based alignment: 9 (20) μm inner (outer) barrel, 20 μm forward with 0.5 fb⁻¹
6.6. Alignment


Table 6.17: Expected RMS values for $\Delta x$, $\Delta y$, $\Delta z$ and $R_z$ for layers and disks (after laser alignment). These values are used for the “First Data Taking” scenario.

<table>
<thead>
<tr>
<th>Layer</th>
<th>$\Delta x$ (µm)</th>
<th>$\Delta y$ (µm)</th>
<th>$\Delta z$ (µm)</th>
<th>$R_z$ (µrad)</th>
<th>LAS available</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pixel Barrel</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>no</td>
</tr>
<tr>
<td>Pixel Endcap</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>no</td>
</tr>
<tr>
<td>Strip Inner Barrel</td>
<td>100</td>
<td>100</td>
<td>500</td>
<td>90</td>
<td>yes</td>
</tr>
<tr>
<td>Strip Outer Barrel</td>
<td>70</td>
<td>70</td>
<td>500</td>
<td>60</td>
<td>yes</td>
</tr>
<tr>
<td>Strip Inner Disk</td>
<td>400</td>
<td>400</td>
<td>400</td>
<td>100</td>
<td>no</td>
</tr>
<tr>
<td>Strip Endcap</td>
<td>60</td>
<td>60</td>
<td>500</td>
<td>45</td>
<td>yes</td>
</tr>
</tbody>
</table>

- Two alignment scenarios considered in PTDR studies
  - “First Data” (~0.1 fb$^{-1}$): no track-based alignment of strip tracker due to limited statistics for high momentum tracks.
  - “Long-term” (~1.0 fb$^{-1}$): Assumes full track-based alignment everywhere. Strips improve by order of magnitude

- Pixels aligned with tracks in both cases to ~ 10-20 µm
Promising areas for early searches and examples of important physics objects
Physics Technical Design Report Vol. II

  - General Focus: $2 \times 10^{33} \text{ cm}^{-2}\text{s}^{-1}$ operation and integrated luminosities up to 60 fb$^{-1}$
  - But, many studies also considered very early data
    - From a few pb$^{-1}$ to a few fb$^{-1}$

Will show a few examples:

- Cannot cover everything (it will just seem like I do)
- Not an expert on these analyses (except $t\bar{t}H, H \rightarrow b\bar{b}$ which we seem to have killed…)

Physics objects will be a parallel theme
SM Higgs
muons

Muon in Silicon Tracker

Hits and Track Segments

Global Muon Track

Standalone Muon Track
H \rightarrow WW(*)

- **H \rightarrow WW \rightarrow l\nu\ l\nu**
  
  gg\rightarrow H, q\bar{q} \rightarrow V\ V\ q'\bar{q}' \rightarrow Hq'\bar{q}'

- **counting experiment**
  
  - Must understand backgrounds by direct measurement of SM and fakes.

- **Backgrounds:**
  
  qq\rightarrow WW, gg\rightarrow WW, tt\rightarrow WWbb,
  tWb\rightarrow WWb(b), ZW\rightarrow ll\nu, ZZ\rightarrow ll\nu\nu etc.
**Selection**

- **Trigger**
  - Single $\mu$ 97% eff.
- **Optimize separately**
  - Isolation variables
    - To kill $b\bar{b}$
  - Jet and MET thresholds
    - Central jet veto kills $t\bar{t}$
      - $E_T > 15$
    - MET Kills DY
      - Net efficiency a few per 10 million!

---

The best selection is obtained with:

\[
\Delta R_{\text{Tracker}} = 0.25 \quad P_T < 2.0 \text{ GeV/c} \quad \Delta R_{\text{calo}} = 0.3 \quad E_T < 4.7 \text{ GeV}
\]  

(3.9) corresponding to $x = 1.8$ for the energy deposition and $P_T$ cut. The isolation cuts used in the analysis were:

\[
\Delta R_{\text{Tracker}} = 0.25 \quad P_T < 2.0 \text{ GeV/c} \quad \Delta R_{\text{calo}} = 0.3 \quad E_T < 5.0 \text{ GeV}
\]  

(3.10)
Results

\[ H \rightarrow WW \rightarrow 2\mu 2\nu \]
Results for $H \rightarrow ZZ^*$

- $4\mu$ channel has some potential for 95% CL exclusion at a few fb$^{-1}$
- 10’s of fb$^{-1}$ for 5 $\sigma$ discovery
Mystery of dark matter in the universe solved: it’s in front of CMS/ATLAS ECAL...

Affects electrons and photons: energy loss, conversions

From P. De Jong - Moriond 2007
Electrons (below 50 GeV)

- substantial bremsstrahlung at low energies
  - Use an energy loss model in tracking to take Brem into account. Momentum at innermost layer $p_{\text{in}} > p_{\text{out}}$ at outermost layer and difference ($f_{\text{brem}}$) is correlated with Radiated energy
  - ECAL superclusters incorporate radiated energy
$f_{\text{brem}}$ used to estimate material budget
Classifying Low E Electrons

Four Classes
- Different corrections

- $E_{sc}/P_{in}>0.9$
  - Golden
    - $F_{brem}<0.2$
    - $\Delta \phi < 0.15$
  - Big Brem
    - $F_{brem}>0.5$
    - $\Delta \phi < 0.15$
  - Narrow
    - Complement of the other two

- All the rest
  - Showering

<table>
<thead>
<tr>
<th>Class</th>
<th>ECAL barrel fraction of electron (%)</th>
<th>Jets (%)</th>
<th>ECAL endcaps fraction of electron (%)</th>
<th>Jets (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Golden</td>
<td>24</td>
<td>4</td>
<td>17</td>
<td>2</td>
</tr>
<tr>
<td>Narrow</td>
<td>9</td>
<td>1</td>
<td>5</td>
<td>0.5</td>
</tr>
<tr>
<td>Big Brem</td>
<td>4</td>
<td>0.5</td>
<td>3</td>
<td>0.2</td>
</tr>
<tr>
<td>Showering</td>
<td>53</td>
<td>85</td>
<td>69</td>
<td>96</td>
</tr>
<tr>
<td>Boundary</td>
<td>10</td>
<td>9.5</td>
<td>6</td>
<td>1</td>
</tr>
</tbody>
</table>

Electrons
5-50 GeV
Jets
25-50 GeV
ECAL versus Tracker: Electron Resolution

\[ \sigma_{\text{eff}} / E \]

- ECAL
- Tracker
- Combined

\[ E^e (\text{GeV}) \]
Photons: $H \rightarrow \gamma\gamma$

**Generation:** PYTHIA + k-factors

**Full simulation**

**Resolution:** 0.3% (EB) to 1% (EE)

**Isolation**

Tracks: none with $p_T > 1.5$ in $\Delta R < 0.3$

Calo: Barrel (Endcap) < 6(3) GeV in $0.06 < \Delta R < 0.35$

- 1 fb$^{-1}$
  - Above: Signal x10 and backgrounds
  - Signal efficiency is of order 20-30%
- Need ~ 10 fb$^{-1}$
  - At right: 120 GeV Higgs in 7.7 fb$^{-1}$
Electrons: $H \rightarrow ZZ^{(*)} \rightarrow eeee$

- 30 fb$^{-1}$ shown: 1 fb$^{-1}$ signal is too small
  - $\sigma \cdot B \sim 1 - 4$ fb (NLO)
- Backgrounds (Direct ZZ$^{(*)}$, Z$b\bar{b}$, $t\bar{t}$) $\sim 20, 120, 200$ fb
Higgs @ 1fb$^{-1}$

Luminosity for 5$\sigma$ discovery, fb$^{-1}$

$M_{H}, \text{GeV}/c^{2}$

- $H \rightarrow \gamma\gamma$ cuts
- $H \rightarrow \gamma\gamma$ opt
- $H \rightarrow ZZ \rightarrow 4l$
- $H \rightarrow WW \rightarrow 2l2\nu$
High mass dimuons:

Z’, graviton resonances, large extra dimensions…

Tracking: alignment and propagation muons ↔ tracker important

As noted yesterday: Mass resolution (and so discovery potential) not too strongly affected by tracker alignment scenario

Efficiencies from data
SUSY Benchmark Points from PTDR

- **Selection of 13 Points**
  - Low mass LM1 → LM9
  - High mass HM1 → HM4
- **Important**: different topologies/decay modes, i.e. on different signatures
  - LM1, 2, 6, 9 are also close to WMAP benchmarks
Signature based analyses

- A Variety of inclusive analyses @ a specific benchmark point then extended to the $m_{1/2}$-$m_0$ plane using FAMOS
  - MET + jets @ LM1: MET>200
  - Muons + MET + jets @ LM1: MET>130
  - Same sign di-muons @ LM1: MET>200
  - Opposite sign dileptons @ LM1: MET>200
  - Di-taus @ LM2: $\tilde{\chi}_2^0$ decays 95% to $\tau\tau$: MET>150
  - Inclusive analysis with Higgs @ LM5: MET>200
  - Inclusive $Z^0$ @ LM4: MET>230
  - Inclusive top @ LM1: Top plus leptons: MET>150
LM1: MET and $\geq 3$ jets

- MET in QCD (left)
  - QCD MET tends to be along leading or 2$^{nd}$ leading jet directions
  - SUSY populates a distinct region
- Hard to get real picture without data…
Veto Electrons (Indirectly)

- To eliminate $W$, $Z$+jets, $t\bar{t}$ etc.
  - Require the two leading jets to be non-EM
    - $EM/(Had+EM)<0.9$
Jets + Missing $E_T$

Low mass SUSY

Normalizing $Z \rightarrow \nu\nu$ $E_T^{\text{miss}}$ to $Z \rightarrow \mu\mu$ using data

CMS $E_T^{\text{miss}}$ + multijets, 1 fb$^{-1}$

$E_T^{\text{miss}}$ @ LM1
Inclusive SUSY searches

- Low-mass SUSY ($M_{sp} \sim 500\text{GeV}$) accessible with $\sim 0.1\text{ fb}^{-1}$. $\Delta t$ to discovery determined by:
  - Time to understand detector performance: $E_T^{\text{miss}}$ tails, jet performance and energy scale, lepton id
  - Time to collect control samples -- e.g. $W+$jets, $Z+$jets, WW, top..
Prior to data, backgrounds are an open issue....

- And are more of a relevant issue for High Mass (HM) points
SUSY signals (cascades)

\[ \tilde{\chi}_2^0 \rightarrow \ell \tilde{\chi}_1^0 \rightarrow E_T^{miss} \]

Can be discovery channel for the Higgs

\[ h^0 \]

CMS

1 fb\(^{-1}\)

Number of lepton pairs

M(\ell\ell) (GeV/c\(^2\))

Events

M_{inv} (GeV)
1 fb⁻¹ is well into new territory:
Jets up to ~3-3.5 TeV
Di-jet masses up to ~5-6 TeV

Challenges:
Jet energy scale,
Parton density functions (PDF),
underlying event, trigger, jet definition

CDF Run II Preliminary

Data corrected to the parton level
NLO pQCD EKS CTEQ 6.1M (μ = P_{T,jet}/2)
Midpoint (R_{core}=0.7, f_{merge}=0.75, R_{spt}=1.3)
0.1<|Y|<0.7 \int L=1.04 fb⁻¹

(CDF)

Deviation from SM

\begin{itemize}
\item \Lambda_{\text{alt}}=20000 \text{ GeV}
\item \Lambda_{\text{alt}}=30000 \text{ GeV}
\item \Lambda_{\text{alt}}=40000 \text{ GeV}
\end{itemize}
Maybe nature has some REAL SURPRISES in store…

Large extra dimensions, Planck scale ~ EW scale

Possible micro black hole production; decay via Hawking radiation into photons, leptons, jets…

CMS and ATLAS might see this with 1-100 pb⁻¹!

From P. DeJong
Moriond 2007
The New CMS Organization

• **Design Specifications**
  
  – Focus on what’s important
    
    • Detector completion and commissioning
      1. Detector Performance
      2. Physics Objects
      3. Physics
    
    – Focus on communication
      
      • All of the above should be linked
    
    – Focus on discovery
      
      • Streamlined SM studies
      • Maximum visibility of all results
CMS Working Groups and Interfaces

- Detector PM + Commissioning
- Physics Coordination
- Detector Performance
- Physics Objects
- Physics Analysis (pp)
- Physics Analysis (Heavy Ions) (Super LHC)
- MC Generators
- Online Selection
CMS Physics Organization

Physics Coordinator
P. Sphicas
Deputy: J. Incandela

US CMS

Higgs
A. Nikitenko
Y. Sirois

SUSY-BSM
S. Eno
M. Spiropulu

MC generators
P. Bartalini
F. Moortgat

ECAL DPG
P. Meridiani
C. Seez

HCAL DPG
C. Tully
M. Velasco

MUON DPG
U. Gasparini
M. Maggi
M. Schmitt

TRACKER
F. Palla
D. Contardo

e/γ
D. Futyan
P. Vanlaer

Jets/MissET
G. Dissertori
N. Varelas

Muons
N. Amapane
N. Neumeister

b-tagging
T. Speer
I. Tomalín

ParticleFlow/τ
R. Cavanaugh
P. Janot

Diffraction
M. Groethe

Heavy Ions
D. D'Enterria
B. Wyslouch

Super LHC
D. Denegri

Onl Selection
S. Dasu
C. Leonidopoulos

QCD
K. Rabbertz

EWK
R. Tenchini

Top
J. D'Hondt
J. Mnich

B physics
U. Langenegger

ALL
Analysis Groups

We are geared towards discovery physics

- Which goes through the Standard Model
- The high-pt Standard Model groups (QCD, EWK, Top) are an integral part of the “new physics program”

So, EWK group is not really there to prepare for measuring M(W) to a 15 MeV precision

- Instead, it is there to measure the Standard Model – to establish that we have something new (when there is something new)

- Diffraction and B-physics have dedicated measurements – and they also have “new physics” elements in them

Focus in 2007 will be the 1fb⁻¹ limit.

- Simple guideline: work on a subject IFF it yields a result with 1fb⁻¹. Definition of result: discovery or limit.
  - All other work should be treated as “R&D” – and set to <10% of the total group effort.
CMS Discovery Group

- Physics Coordinator
- + Deputy

- e/γ
- Jets/MissET
- ParticleFlow w/τ

- Muons
- b-tagging
- Onl Selection

- Diffraction
- Heavy Ions
- Super LHC

- QCD
- EWK
- Top

- Higgs
- SUSY-BSM
- MC generators

- B physics
In Practice

- **Physics plenary meetings held monthly**
  - Goal: A global view that is meant to be widely accessible
  - Afternoon sessions reserved for key overviews to allow greatest accessibility for US and other collaborators unable to attend in person

- **Trigger/Physics weeks: Twice per year**

- **Working groups**
  - Schedule meetings quasi independently with an eye toward minimizing conflicts and maximizing accessibility
    - System is over-constrained
## General physics meetings

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feb 6-8</td>
<td>Physics Days (this week…)</td>
</tr>
<tr>
<td>Feb 26-Mar 1</td>
<td>CMS week</td>
</tr>
<tr>
<td>Mar 27-29</td>
<td>Physics Days</td>
</tr>
<tr>
<td>Apr 23-27</td>
<td>Physics/Trigger week</td>
</tr>
<tr>
<td>May 22-24</td>
<td>Physics Days</td>
</tr>
<tr>
<td>Jun 12-14</td>
<td>Physics Days* (skip if Jun CMS wk ok)</td>
</tr>
<tr>
<td>Jun 18-22</td>
<td>CMS week</td>
</tr>
<tr>
<td>Jul 17-19</td>
<td>Physics Days</td>
</tr>
<tr>
<td>Aug 28-30</td>
<td>Physics Days</td>
</tr>
<tr>
<td>Sep 17-21</td>
<td>CMS week</td>
</tr>
<tr>
<td>Oct 22-26</td>
<td>Physics/Trigger week</td>
</tr>
<tr>
<td>Dec 10-14</td>
<td>CMS week</td>
</tr>
</tbody>
</table>

ALL MEETINGS (INCLUDING PHYS/TRIG WEEKS) @CERN

May add/change meetings in between Oct Phys/Trig week and Dec CMS week. Wait until Fall schedule is known.
2007 Analyses: Basic program of work

• All physics groups now concentrating on what we can do with up to 1 fb\(^{-1}\).
  – Mainly to chart out the “how” we will do things: to prepare methods, tools and people.

• There are two major milestones
  – HLT milestone (mid-June)
  – Completion of 1 fb\(^{-1}\) exercise (mid-Oct)

• We have been struggling with
  – lack of “data” samples
  – multiple and overlapping code releases

• Samples are imminent or already available!
2007 Analyses: first of two iterations

- Identified physics we’ll do in 2008 with $\leq 1\text{fb}^{-1}$.
  - The lists are long: See Twiki pages

- We split the time remaining before LHC startup into two equal-time periods
  - So, taking $t_o \sim$ Feb 07, mid-point is $\sim$Oct 07

- First period: items likely to need iteration.
  - This is the reason why the analyses we have (the 2007 analyses) are relatively few
Up to October

- Approach “1 fb⁻¹” by successive approximations.
  - 10 pb⁻¹ and 100 pb⁻¹ stages also highlighted.
  - What can we achieve at each stage?
- June CMS week: a preliminary look at the 100 pb⁻¹ studies.
- October: Results for 10, 100 pb⁻¹ and 1 fb⁻¹
  - Brief note (30 pages) on the “CMS plan for X pb⁻¹” summarizing each of these stages (10, 100, 1000 pb⁻¹) across all groups

Detector Groups to provide new guidance on performance for these startup datasets
And the following six months

- **Dec 07 to May 08: Final preparations for actual data.**
- **Goals:**
  - All HLT code in place
  - Full trigger monitoring system (code + people) in place
  - All Monte Carlo events in place
  - The full data-analysis org. (code + people) in place
  - Analyses geared for 10 pb\(^{-1}\) and 100 pb\(^{-1}\) warmed up and ready to absorb the data (i.e. ALL actions are pre-planned)

- **6 months leading up to May 2008, we must complete**
  - The 2007 analyses, injecting even more realism (noise, dead channels, really bad mis-reconstruction)
  - The Monte Carlo samples for the startup
  - The Trigger studies
How to get involved

• If you’re not, but want to be …you can
  – Contact the DP, PO, PA groups.
    – Look over the quite detailed plans of work, other
      information (see links on the slide at end of this talk)
    – Come to physics days at CERN
  – You can also contact the LPC coordinators
    and WG conveners.
  • LPC unrivaled outside CERN
    – Knowledgeable experts – many of the US people having
      a strong influence on CMS Detector and Physics groups
      are at the LPC
    – Hadron collider experience
    – Tutorials, training, general support etc…
  – Attend the LPC Physics workshop in June
Top Quark: organisation aspects

- Early observation of top quark events [People involved]
  - Observation of di-leptonic top quark pairs (muons and electrons): [More information]
  - Observation of semi-leptonic top quark pairs (muons and electrons): [More information]
  - Observation of the top quark mass peak from semi-leptonic top quark pairs (electrons and muons): [More information]

- Measurement of cross sections [People involved]
  - Measurement of the cross section of di-leptonic top quark pairs (muons, electrons, taus): [More information]
  - Measurement of the cross section of semi-leptonic top quark pairs (muons, electrons, taus): [More information]
  - Estimation of the background rate for di-leptonic top quark physics via control samples: [More information]
  - Estimation of the background rate for semi-leptonic top quark physics via control samples: [More information]
  - Measurement of exclusive t\bar{t}+Njets cross sections (di-lepton): [More information]
  - Measurement of exclusive t\bar{t}+Njets cross sections (semi-lepton): [More information]

- Measurement of the top quark mass [People involved]
  - Measurement of the top quark mass from semi-leptonic top quark pairs (muons, electrons, taus): [More information]
  - Measurement of the top quark mass from di-leptonic top quark pairs (muons, electrons, taus): [More information]

- Measurement of important differential distributions sensitive to new physics [People involved]
  - First differential distribution HT (semi-leptonic): [More information]
  - First differential distribution mt\bar{t}t (semi-leptonic): [More information]
  - First differential distribution pT top quark (semi-leptonic): [More information]

- Using top quark events to estimate the jet energy scale [People involved]
  - Measurement of the jet energy scale corrections using mass constraints in top quark events: [More information]

- Using top quark events to estimate the b-tag performance [People involved]
  - Measurement of the b-tag performance using di-leptonic and semi-leptonic top quark pairs: [More information]

Names are being added on the TWiki page
Useful Links

• Physics Page on iCMS:

• Hypernews:
  – Global Physics Announcements
    – hn-cms-physics-announcements

• Offline:
  – Release Schedule
    • https://twiki.cern.ch/twiki/bin/view/CMS/ReleaseSchedule
Summary

• Many studies documented in PTDR
• Much achieved, but much more to learn
  – Focus on the first data (0.01 to 1.0 fb\(^{-1}\)) from now until first collisions
  – Many improvements in tools and our understanding of our capabilities are expected
• Initial detector performance and speed of optimization will be crucial
Additional Information
But we will probably see something that is not so easy to interpret
The Importance of Being (Ready) Early

The ISR missed the $J/\psi$ and later missed the $\Upsilon$ “*”

“...it took a long time to overcome two major difficulties of collider physics. The first... the relatively low luminosity... The second...the very wide angle spread over which particularly interesting events, such as lepton pair events, may occur...

The answer is, of course, sophisticated detectors covering at least the whole central region ($45^\circ < \theta < 135^\circ$) and full azimuth.”

“...they stumbled on an unexpectedly strong hadron yield; large-$p_T$ production had been discovered, a witness, as we now know, to the pointlike structure within hadrons.

- Early ISR experiments were not prepared for the $J/\psi$ and later ones were too late for the $\Upsilon$. They nevertheless learned a lot and paved the way for UA1 and UA2 which were well-prepared and on-time.

$l \equiv e \ or \ \mu$

Events per experiment*

*selection efficiencies assumed:
$W \rightarrow l\nu, Z \rightarrow ll : 20\%$
$tt \rightarrow l\nu X : 1.5\%$ (no b-tag)

similar statistics to CDF, D0 today

days at $10^{32}$

months at $10^{32}$
Cross sections: $H \rightarrow WW(*)$

- **All processes LO**
  - Signal and $W$-pair background phase-space dependent NLO k-factor reweightings

- Match PYTHIA $p_t$ distributions of the $H$ and $WW$ systems respectively to those predicted by MC@NLO

### Table 3.1. The cross section at the next-to-leading order for Higgs production through gluon fusion and vector boson fusion (VBF) processes and the number of generated events are reported.

<table>
<thead>
<tr>
<th>Higgs mass (GeV/c^2)</th>
<th>$\sigma^{NLO} \times BR(2l)$ (Gluon Fusion pb)</th>
<th>$\sigma^{NLO} \times BR(2l)$ (VBF pb)</th>
<th>$\sigma^{NLO} \times BR(2l)$</th>
<th>num. of events</th>
</tr>
</thead>
<tbody>
<tr>
<td>130</td>
<td>0.94</td>
<td>0.12</td>
<td></td>
<td>20000</td>
</tr>
<tr>
<td>140</td>
<td>1.39</td>
<td>0.19</td>
<td></td>
<td>20000</td>
</tr>
<tr>
<td>150</td>
<td>1.73</td>
<td>0.25</td>
<td></td>
<td>17000</td>
</tr>
<tr>
<td>160</td>
<td>2.03</td>
<td>0.31</td>
<td></td>
<td>44000</td>
</tr>
<tr>
<td>165</td>
<td>2.04</td>
<td>0.32</td>
<td></td>
<td>49000</td>
</tr>
<tr>
<td>170</td>
<td>1.95</td>
<td>0.31</td>
<td></td>
<td>40000</td>
</tr>
<tr>
<td>180</td>
<td>1.71</td>
<td>0.28</td>
<td></td>
<td>20000</td>
</tr>
</tbody>
</table>

### Table 3.2. The cross section at the next-to-leading order for the background processes. The $gg \rightarrow WW$ process is generated using a matrix element program linked to PYTHIA for the showering [70]. This process is only known at LO. (*) For $b\bar{b} \rightarrow 2\mu$ the pre-selection $p_T > 20, 10$ GeV/c was applied.

<table>
<thead>
<tr>
<th>Channel</th>
<th>$\sigma^{NLO} \times BR(2l)$ (pb)</th>
<th>num. of ev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$qq \rightarrow WW \rightarrow 2l$</td>
<td>11.7</td>
<td>164000</td>
</tr>
<tr>
<td>$\bar{t}t$</td>
<td>840</td>
<td>548000</td>
</tr>
<tr>
<td>$gg \rightarrow WW \rightarrow 2l$</td>
<td>0.54 (LO)</td>
<td>50000</td>
</tr>
<tr>
<td>$\gamma^*, Z$</td>
<td>145000</td>
<td>2700000</td>
</tr>
<tr>
<td>$b\bar{b} \rightarrow 2\mu$ (TevRA)</td>
<td>710 (LO)(*)</td>
<td>640000</td>
</tr>
<tr>
<td>$ZW \rightarrow 3l$</td>
<td>1.63</td>
<td>72000</td>
</tr>
<tr>
<td>$t\bar{t}Wb \rightarrow 2l$ (TorREX)</td>
<td>3.4</td>
<td>191000</td>
</tr>
<tr>
<td>$ZZ \rightarrow 2l$ (TorREX)</td>
<td>1.52</td>
<td>99000</td>
</tr>
</tbody>
</table>
H → WW(*) and bkd after selections

**Table 3.3.** The list of cuts applied to the signal and background samples.

<table>
<thead>
<tr>
<th>Cut</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1+HLT dimuon</td>
<td>MET &gt; 50 GeV</td>
</tr>
<tr>
<td>2 μ opposite charge</td>
<td>35 GeV/c &lt; $P_T(\mu_{max}) &lt; 55$ GeV/c</td>
</tr>
<tr>
<td>Isolation</td>
<td>25 GeV/c &lt; $P_T(\mu_{min})$</td>
</tr>
<tr>
<td>$\eta &lt; 2.0,</td>
<td>IP &lt; 3\sigma$</td>
</tr>
<tr>
<td>Jet Veto</td>
<td>$m_{\mu_1\mu_2} &lt; 50$ GeV/c²</td>
</tr>
<tr>
<td></td>
<td>$\Delta \phi_{\mu_1\mu_2} &lt; 0.8$</td>
</tr>
</tbody>
</table>

**Table 3.4.** The expected number of events for a luminosity of 1fb⁻¹ for the signal with Higgs masses between 130 and 180 GeV/c² and for the backgrounds.

<table>
<thead>
<tr>
<th>Mass (GeV/c²)</th>
<th>L1+HLT dimuon</th>
<th>All cuts</th>
<th>$\epsilon_{tot}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>130</td>
<td>112</td>
<td>0.68 ± 0.19</td>
<td>(0.07 ± 0.02)%</td>
</tr>
<tr>
<td>140</td>
<td>162</td>
<td>1.7 ± 0.4</td>
<td>(0.12 ± 0.03)%</td>
</tr>
<tr>
<td>150</td>
<td>228</td>
<td>5.3 ± 0.8</td>
<td>(0.26 ± 0.04)%</td>
</tr>
<tr>
<td>160</td>
<td>256</td>
<td>12.6 ± 0.7</td>
<td>(0.58 ± 0.04)%</td>
</tr>
<tr>
<td>165</td>
<td>264</td>
<td>14.3 ± 0.8</td>
<td>(0.64 ± 0.04)%</td>
</tr>
<tr>
<td>170</td>
<td>259</td>
<td>11.0 ± 0.7</td>
<td>(0.53 ± 0.03)%</td>
</tr>
<tr>
<td>180</td>
<td>233</td>
<td>5.9 ± 0.8</td>
<td>(0.30 ± 0.04)%</td>
</tr>
<tr>
<td>$qq \rightarrow WW$</td>
<td>1040</td>
<td>4.1 ± 0.5</td>
<td>(0.036 ± 0.005)%</td>
</tr>
<tr>
<td>$t\bar{t} \rightarrow 2\mu2\nu$</td>
<td>17007</td>
<td>2.6 ± 0.3</td>
<td>(0.012 ± 0.001)%</td>
</tr>
<tr>
<td>$gg \rightarrow WW$</td>
<td>58</td>
<td>1.0 ± 0.1</td>
<td>(0.18 ± 0.02)%</td>
</tr>
<tr>
<td>$\gamma*, Z \rightarrow 2\mu$</td>
<td>720653</td>
<td>0.3 ± 0.3</td>
<td>$(4 \pm 4)10^{-5}$%</td>
</tr>
<tr>
<td>$t\bar{t} \rightarrow 2\mu2\nu$</td>
<td>69374</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>$Wt$</td>
<td>615</td>
<td>0.57 ± 0.10</td>
<td>(0.017 ± 0.003)%</td>
</tr>
<tr>
<td>$ZZ$</td>
<td>218</td>
<td>0.18 ± 0.05</td>
<td>(0.012 ± 0.003)%</td>
</tr>
<tr>
<td>$ZW$</td>
<td>384</td>
<td>0.13 ± 0.05</td>
<td>(0.008 ± 0.003)%</td>
</tr>
</tbody>
</table>