CMS: en route to data 1994-2009… (software, computing and physics)

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CERN & NKUA
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DESY, Mon Jun26, 2023

- **Introduction**
  - **Brief reminder of where we stood in 92 and 94…**
- **The formative years**
  - **CCS, PRS, HLT and first OO-based code**
- **The next iteration**
  - **CPT, Physics TDRs and the introduction of CMSSW.**
  - **Tests, Challenges…**
- **And the last stretch to the startup…**
- **Pseudosummary**

Back in the early 90s…

The top quark had not been discovered yet (but we had established the utility of low(er)-p_T jets and b-tagging)

The SSC was going to have its engineering run in 1997

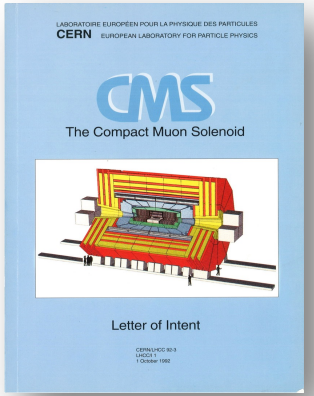
Tevatron Run II was going to start in ~97-98

The LHC was presented as a machine that would start "roughly at the same time as the SSC"; at 16 TeV…

1993: the year that changed the history of HEP

- **US congress decided to stop the SSC**
  - **An unprecedented event; a change of plan with colossal implications**
- **From one day to the next, "the plan" [physics at the Tevatron or LEP and then at the SSC] was no longer on the table**
- **And the LHC was left as the only viable option**
- **Meanwhile, in Europe, post-Aachen workshop…**
  - **Eagle-Ascot had given birth to ATLAS**
  - **CMS and L3P had given birth to… CMS**

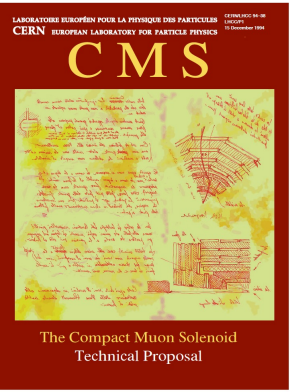
1992 LoIs: ATLAS, CMS & L3P

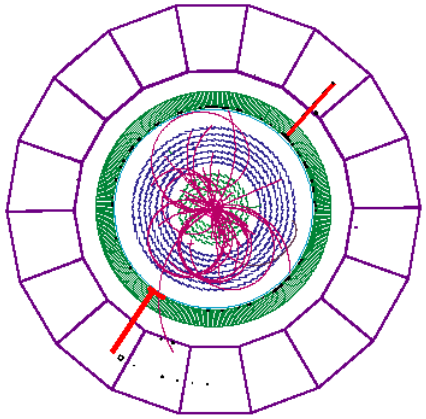


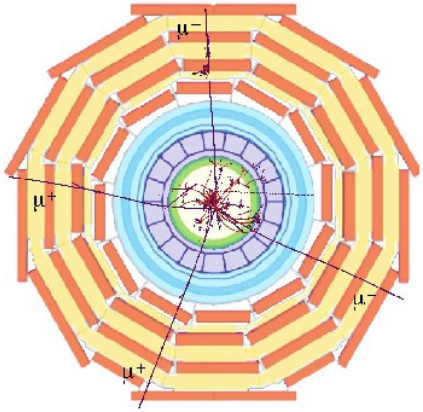
- **First major turning point: the Technical Proposal (1994)**

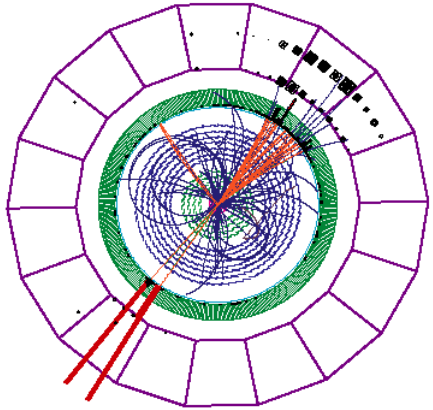
CMS TP Legacy example: Higgs in the detector

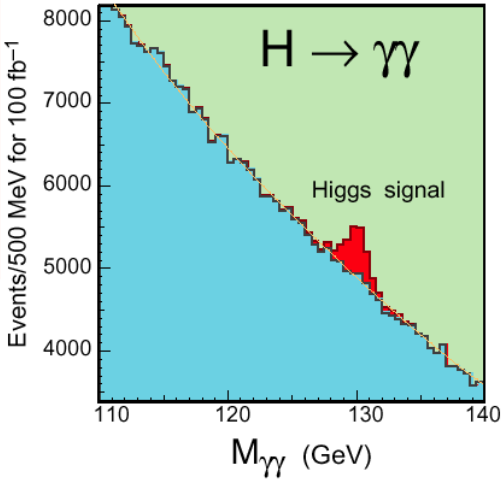
TP in 1994

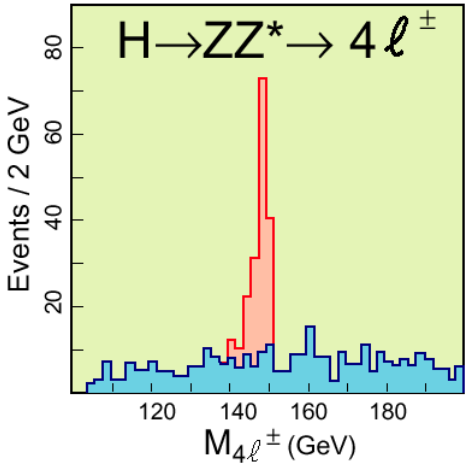


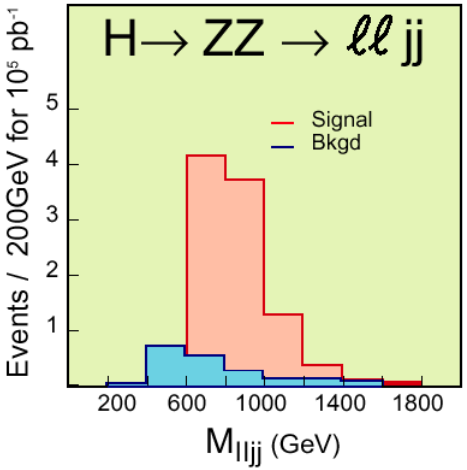












The big issues that had to be addressed in order to "do physics at the LHC"

What happens if the pileup blinds us

Viability of the CMS two-level trigger system

And once things are on "tape", then what? Computing/Software/Networking models of the 80s and 90s were deemed not viable for the LHC

Challenge 1: operating with 25 events pileup…

CMS-LOI/92-LF

ANSWERS TO PROFESSOR LORENZO FOA

QUESTION 0:
General question that concerns all experiments: What can your e.m. calorimeter do in a "stand alone" mode, I mean if you have to switch off your inner tracking because of excessive rate ?

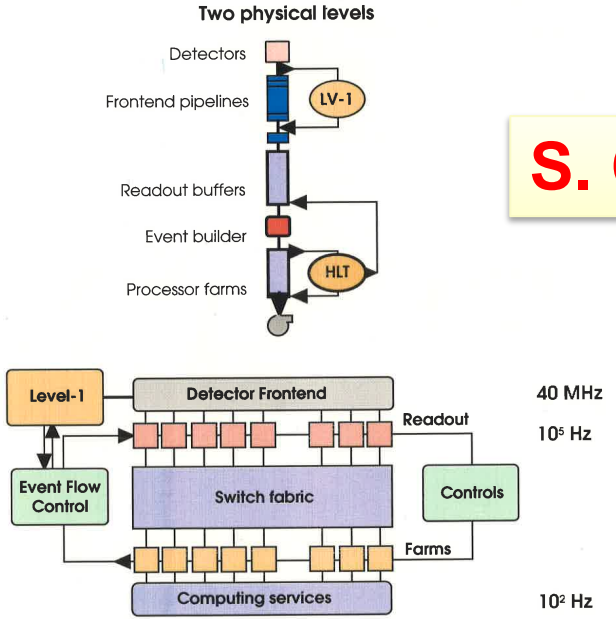
We would like to distinguish between two scenarios, namely:

i) all inner tracking fails. We consider this to be an unlikely scenario.

ii) tracking is still possible in the area close to the calorimeters i.e. the last four points are still measurable. We would like to stress that the 4 T field considerably reduces the density of charged tracks in the outer regions of the tracking cavity. Even if we have underestimated the minimum bias background by a factor of 10 the occupancies in this region will remain below a few percent. We do not believe that beam related backgrounds would drastically affect this region which is ≥ 1.2 m from the beam-line in the barrel.

Challenge 2: get (the best…) events to storage

Two Physical Trigger Levels



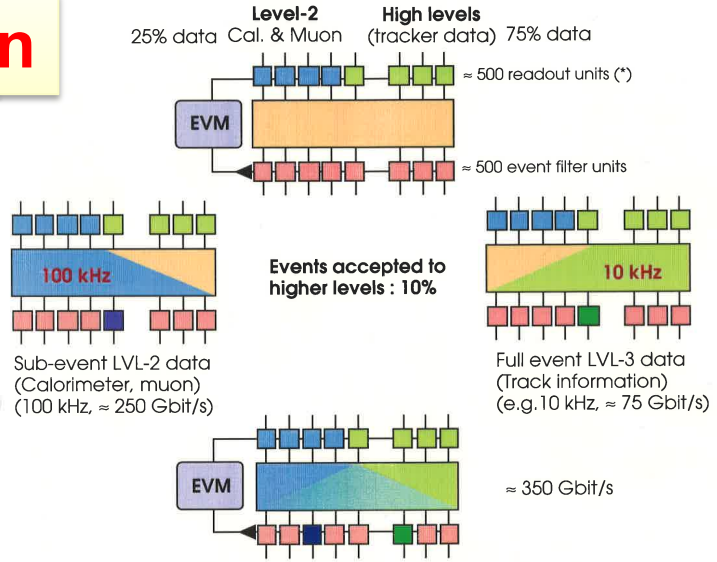
HLT: BOTH LEVEL-2 & LEVEL-3 TRIGGERS IN PROCESSOR FARM

P. Sphicas/MIT; US_CMS DOE Review, May 1997

S. Cittolin

DAQ: CMS High-Level Trigger(s)

EVENT BUILDING by STEPS allows the full exploitation of the switch bandwidth and the handling of up to LV1 100 kHz

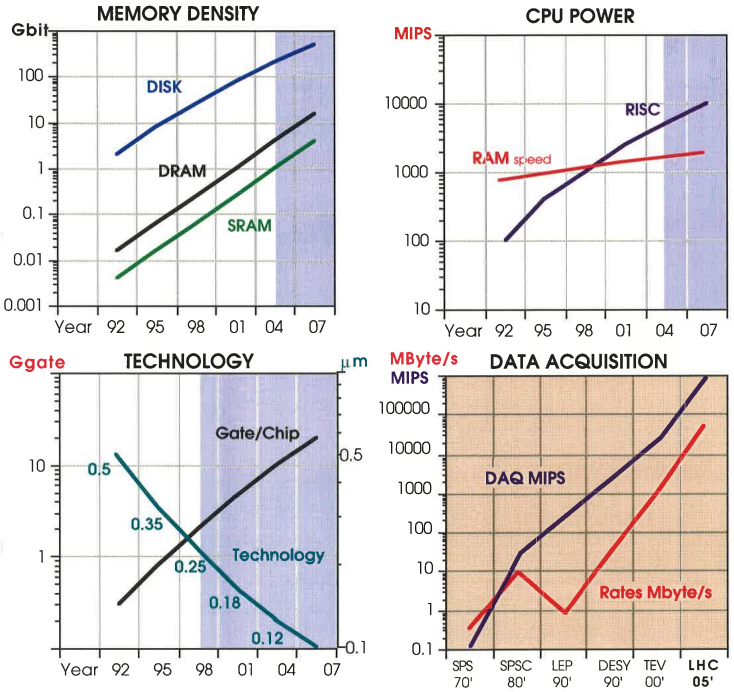


HLT: BOTH LEVEL-2 & LEVEL-3 TRIGGERS IN PROCESSOR FARM

P. Sphicas/MIT; US_CMS DOE Review, May 1997

Challenge 2.5: predicting the future (or not)

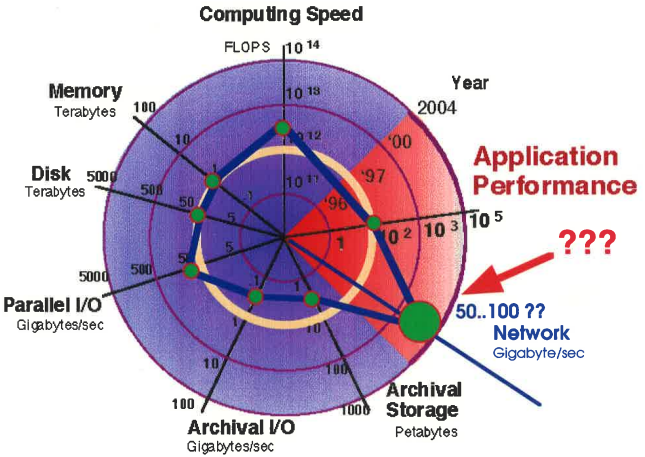
Technology & DAQ trends



P. Sphicas/MIT; US_CMS DOE Review, May 1997

Trends(*) CMS/SuperC

(*) Accelerated Strategic Computing Initiative. ASCI 97



The computing power, the data storage and the channel bandwidth needed for the CMS DAQ are already available today (1997) in advanced supercomputer structures.

We expect these performances will be available by commodities in the years 2000. Switching network bandwidth (not MPP systems) trends are less clean.

S. Cittolin

P. Sphicas/MIT; US_CMS DOE Review, May 1997

Challenge 3: Computing/Software/Networking

- Planning for an experiment that would commence in 2005 (…):
- The world of HEP spoke FORTRAN and PAW; the rest of the world had gone Object-Oriented with UML and C++
- Mainframes on their way out; clusters were in; but with what/which data access model?
  - Billions of events…. PB of data…. The CMS HLT farm was estimated at 50000 CPUs (1990s units)
  - Aggregate computing capacity at CERN was no-where near what was needed for reconstruction of data, simulations and analysis
  - The “Grid” was being “invented”

Challenge 3.5: external pressure and reality

- **And of course, during changeover, several requirements in conflict:**
  - **Review committees wanted full simulations, "real" reconstruction code; BUT constant pressure to produce "physics reach/benchmarks" with very significant extrapolations for "the physics at 300 fb^{-1}; and in some cases 30 fb^{-1}"**
  - **Needed to demonstrate viability of detector and trigger; BUT the software was not ready.**
  - **We needed many people; we had only a few (yes…) – and even fewer ones that were proficient in OO.**

What transpired

On the way to 2007/8/9 (I)

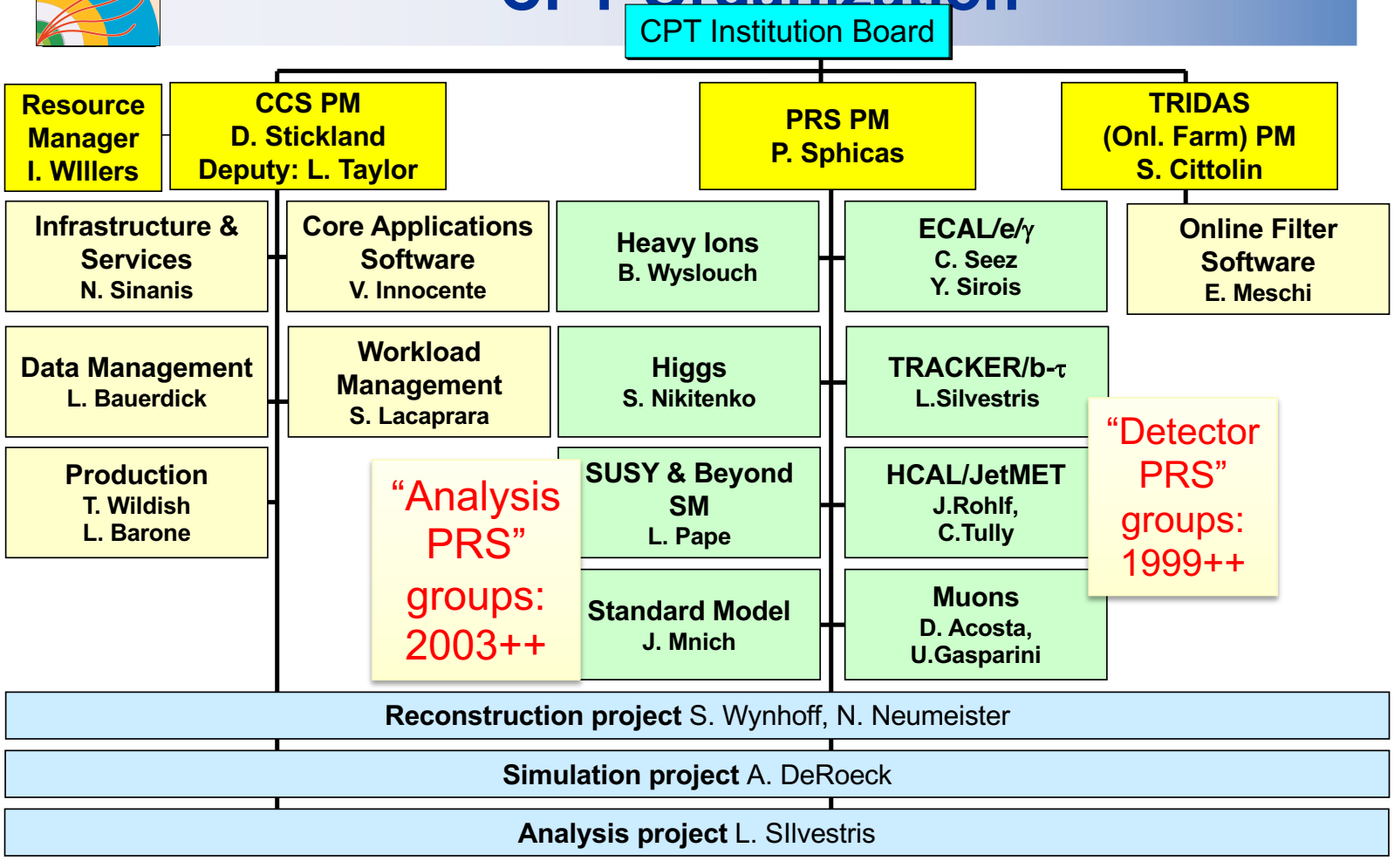
- **LHC experiments turned to C++**
  - Huge challenges; GEANT3 was in FORTRAN; CMSIM was in FORTRAN; HEP brains thought in FORTRAN
- **Storage and analysis systems**
  - CMS had adopted the ODBMS paradigm, and was using "Objectivity"
  - First used by Babar @ SLAC
- **"Real" simulation and "real" reconstruction code; most urgently, proof of the single-farm paradigm for the HLT**
- **There was ORCA, OSCAR, FAMOS… And they helped us write the DAQ/HLT and the Computing TDRs – and were used to showcase to the LHCC our first "C++ physics code"**
- **Organization:**
  - Computing & Core Software (CCS); Physics Reconstruction and Selection (PRS); High Level Trigger (HLT)

On the way to 2007/8/9 (II)

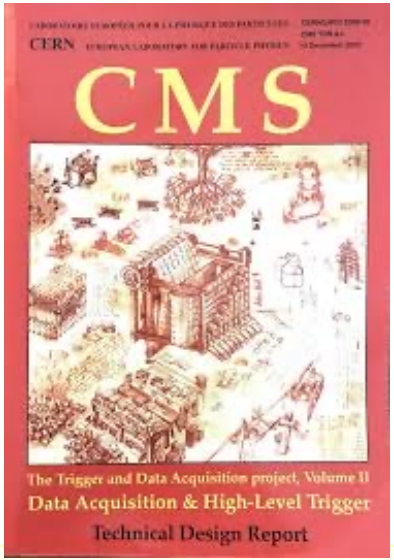
- ATLAS had proceeded to write a “Physics TDR” (two volumes) early on
  - This created pressure on CMS to produce results that would compare to them.

- Nevertheless, CMS decided to hold off and write the P-TDR using the “real” software (simulation, reconstruction and selection)
- Also planned for
  - Deployment in Testbeam;
  - Computing/Software/Analysis (CSA) challenges;
  - Along the road came the MTCC; CRAFT….

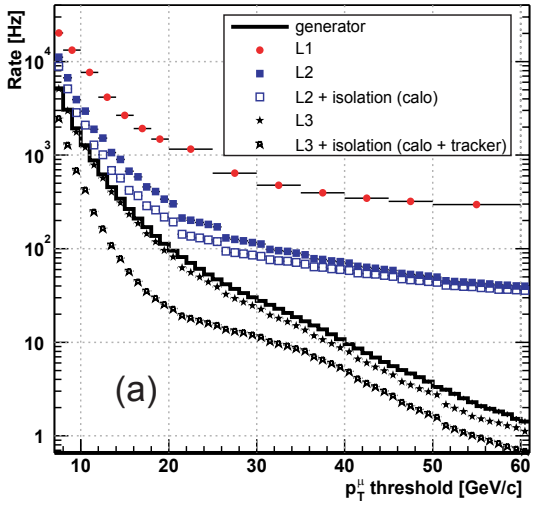
CPT Organization

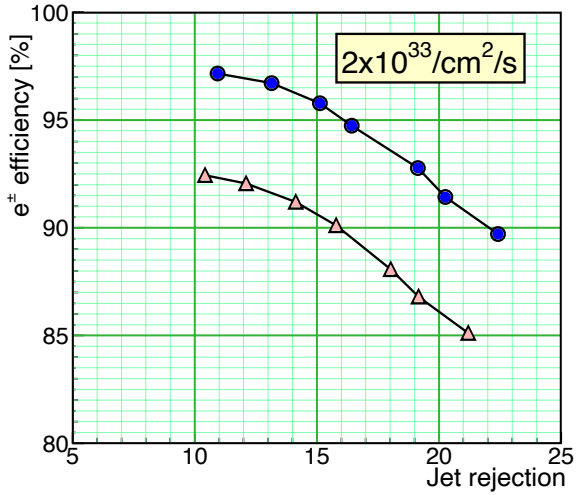


The DAQ/HLT milestone

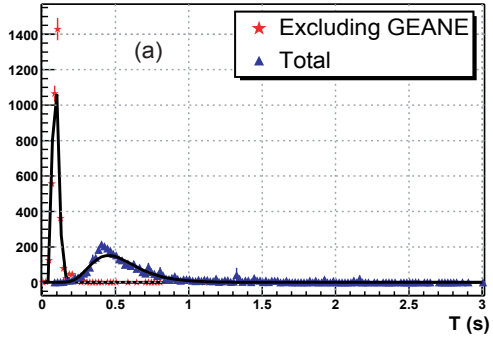


HLT Algorithm	Mean CPU Time (ms/event) L=2×10³³cm⁻²s⁻¹, P_T>10 GeV/c	
	Total	Excluding GEANE
Level-2	640	100
Calorimeter isolation	100	25
Level-3	420	200
Pixel isolation	65	65
Tracker isolation	190	190
Total/L1 event	710	125

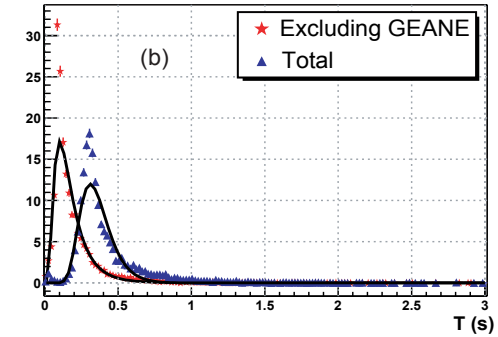




Total L2 time



Total L3 time



From CR2003: Summary

- **Detector PRS groups continuing work on simulation**
  - reconstruction, calibration, data-handling & physics objects at much lower pace; test-beams better off
  - support from CCS has been, still is, and will be, essential
- **Analysis-PRS groups (four) established in 2003**
  - To cover the "what physics" question in the Physics TDR
- **Physics TDR effort is launched**
  - Three-year project, to end in 2005 (startup-1.5)
  - To document what physics we will do and how we will do it
  - It will be used to prepare the people and the computers alike
- **Online Farm: much progress this year**
  - But need people to maintain momentum
- **Shortage of people**
  - Working on it within CMS; creating list of jobs to be done
  - Schedule is tight

LHCC Sep 2004

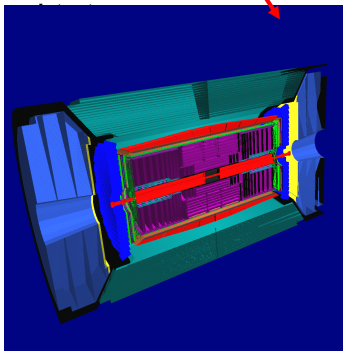
2003-2005

- **The three-year period 2003-2005 was very intense on two fronts:**
  - **Progress on "Core Software", including fully-OO almost physics-ready versions of simulation, reconstruction and selection**
  - **Prototypes of "Tier-X centers"…**
  - **The work towards the Physics TDR**
    - **Recall: delayed to be done with the "real" software.**
  - **We also had the MTCC, for which we wanted to use the OO software**

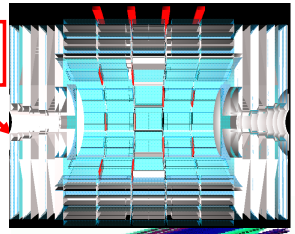
- **The major thrust of this program was to prepare for the real thing (LHC beams) and put the physics extrapolation(s) on lower priority.**

OSCAR: Geometry

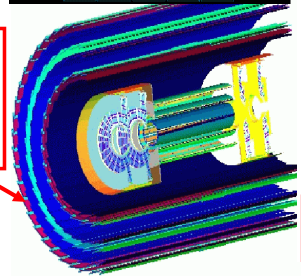
View of full CMS



muon detectors



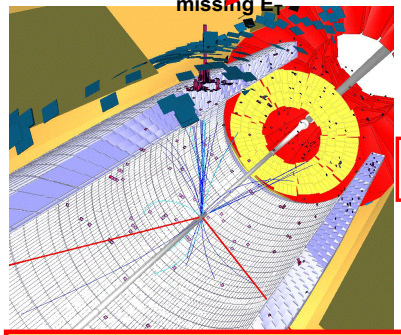
Sliced view of CMS barrel detectors



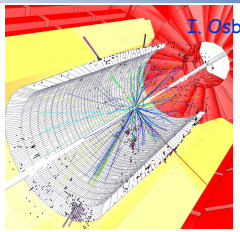
Complete CMS detector geometry included

Physics Events with OSCAR

SUSY events (LM4 point: leptons, missing E_T)

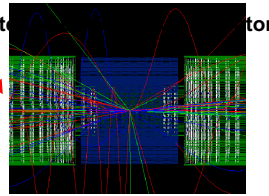


I. Osborne



View of 180 GeV Higgs event

simulator



Samples of "standard sets" of events now Automatically produced for each new release

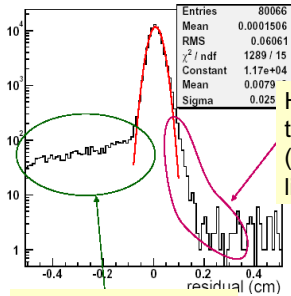
OSCAR: program performance

- **CPU time of 2.4.5 is 2xGEANT3 time.** M. Stavrianakou et al
  - Improvements implemented by G4 team, and by CMS through more optimized access to/use of the (new) magnetic field.
  - We have now a 20-30% better performance of OSCAR compared to the version 2.4.5 (so we are at 1.5 x GEANT3; effort is continuing)
- **Memory usage in 2.4.5: 220 MB OSCAR vs 100 MB GEANT3 simulation. But:**
  - much more sophisticated cut/region scheme
  - more conservative cuts than for CMSIM
  - more detailed physics in G4
  - Further optimization led to ~110 Mb/event for pp (>500 Mb/event for HI)
- **Crashes occurred with 2.4.5: about 1/10000 for pp events. Mostly hadronic physics (baryon decays, γ-nuclear int.)**
  - Latest stress test (800K single particles, 300K full QCD events) showed. No single crash.

Many thanks to G4 for help!

Muon simulation; progress

- **Detector Geometry: final description in DD database**
- **Digitization:**
  - out-of-time pileup hits included in DT
  - better d-ray treatment in DT cell, multihits included
- **Improved DT segment reconstruction (wire signal propagation)**



Hits very near to wires (cell non-linearities)

Hits from δ-rays (were partially masked in previous code)

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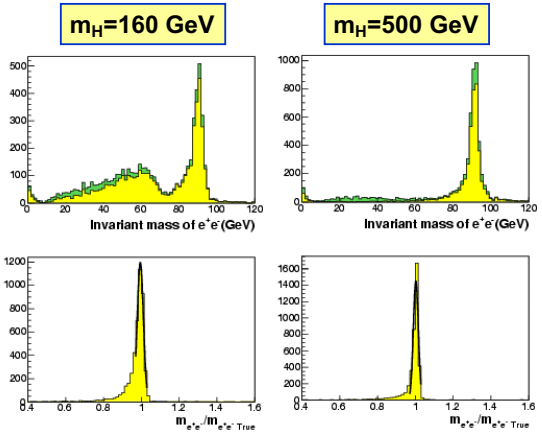
e/γ: Result with prototype DST

- $H \rightarrow ZZ^{(*)} \rightarrow 4e$



All electrons

electrons direct from Z

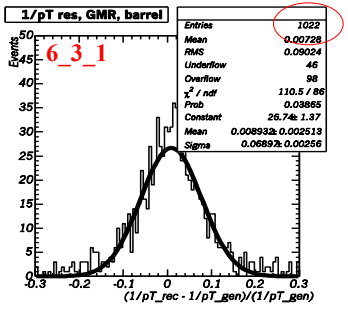
electrons from Z via τ

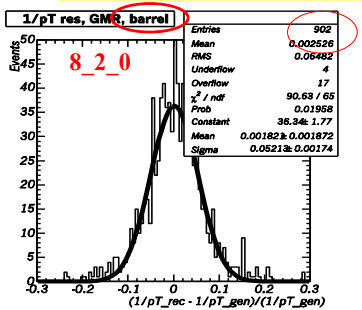
D. Futyan

Muon reconstruction: TeV muons

- **Data Sample: Z' (3 TeV) →μμ**
  - **Significant improvement in resolution w.r.t. DAQ TDR code (ORCA 6_3);**
  - **However, efficiency drop (10%) in barrel and overlap regions. In progress…**

(Mumford, Valuev, Belotelov)





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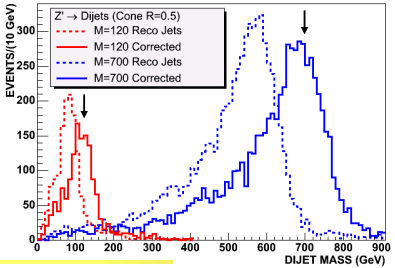
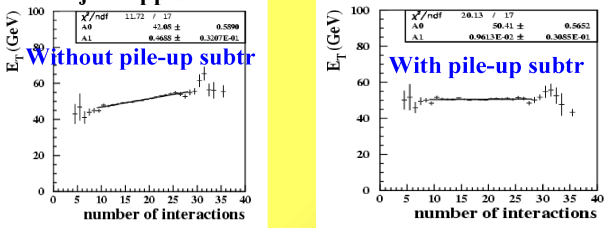
Jet response and corrections

- **Step 1: jet corrections**
- **Step 2: pileup subtraction**

R. Harris



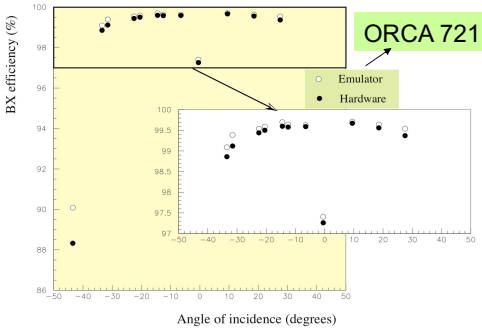
50 GeV jet in pp at Lumi=10^{34}



2003 DT testbeam

- **Test /validation DT L1 trigger (BTI,TRACO,TSS)**
- **Test syncronization procedure with bunched beam**
- **Detailed comparison between real and emulator data (all implemented in ORCA)**

Correct bunch-crossing efficiency



Vanini, Zotto, Lippi

Physics TDR

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- **Outline**
  - Volume I: one person to provide overall coherence, etc. Parts split to the detector PRS group responsibles.
  - Volume II, part 1: given all that is presented in Volume I, a detailed expose of early procedures and physics. "First-run" plans, explanation of deployment of various tools, turning CMS from a 12,500-ton object to a detector – and last the 1fb-1 physics reach.
  - Volume II, part 2: full analyses, given Vol I and all that will have been achieved in Vol II part I.
  - Volume II, part 3: the physics of 10 and 30 fb^{-1}. Include a chapter on asymptotic (300 fb-1) reach.
  - Volume II, part 4: Heavy Ion Physics; also in Vol I where needed.
- **"Special" chapters go to corresponding piece**
  - Diffractive Physics – the CMS-TOTEM combination – goes to Vol I (detectors), Vol II.1, II.2, II.3
  - Luminosity (measurement and monitor): in Vol I. Also in Vol II.1

The change of our core software and organization

- In parallel to the Physics-TDR, there was a desire to simplify things
  - The experience with objectivity from the Babar startup was a sobering one
  - OSCAR-ORCA combination: very good and useful, but was not easy to use.
    - Most importantly: the analysis part required both a big learning curve and not-so-easy to use interactive tools
  - The idea came to move away from Objectivity, towards a ROOT-based system
    - Other experiments, with ALICE at the forefront, were "there" already
  - There were many, many discussions about this at the time… Some were very intense.
- Above all, there was huge pressure on all fronts to

  (a) validate completely the HLT scheme

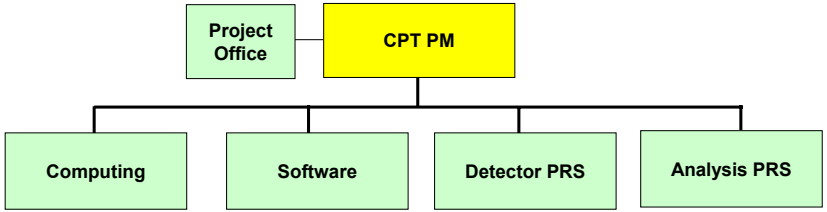
  (b) to get a P-TDR into the hands of the LHCC

  (c) to be ready for the startup in 2007 (!!!) [Thankfully, this was moved to 2008]

- By 2005, we were ready for some major changes…

CPT Organization: major elements (I)

- **First element: merging of CCS and PRS.**
  - Four major areas in CPT

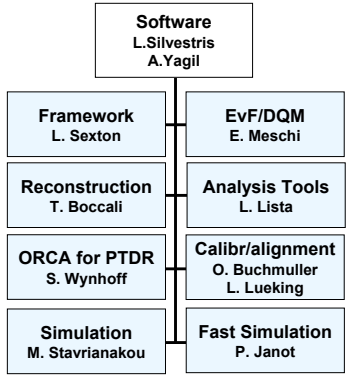


  - Two co-coordinators per area
  - Project office: system architecture, technical guidance, resource management, project tracking, code reviews, etc

From CMS-CR 2005

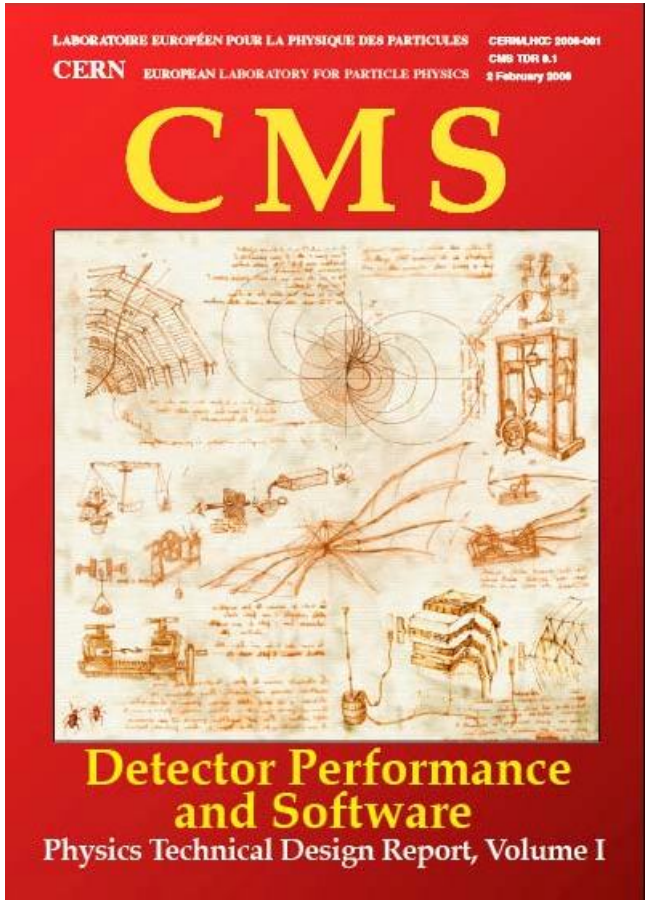
CPT organization: major elements (II)

- **2nd element: software project**
  - Coherence between "core software" and "physics software" (by definition)
  - All the PROMs (R, S, A) disappear – they become Lvl-2 tasks in Software
  - Coverage of unfilled/late projects
    - Calibration code/databases – really late at this point
    - Analysis Tools
    - Data-Quality monitor (add to EvF)
  - Two reconstruction tasks: to cover both the current (and up to P-TDR) and new (P-TDR and beyond)



From CMS-CR 2005

Physics TDR Volume 1



- **Physics TDR Volume 1 is out!**
- **Browseable PDF version and picture gallery:**
  - **http://cmsdoc.cern.ch/cms/cpt/tdr/**
- **A massive undertaking**
  - **548 pages, 553 figures**
  - **>40 CMS Notes approved in January and February**
- **Congratulations/thanks to authors and Darin Acosta**
- **Special thanks to reviewers**

From Mar06 LHCC

CSA06: What is it?

- **Computing, Software, & Analysis Challenge 2006**
- **Definition:**
  - A 50 million event exercise to test the workflow and dataflow associated with the data handling model of CMS
  - Receive previously simulated (some HLT-tagged) events
  - Perform prompt reconstruction at Tier-0, including determination and application of calibration constants
  - Stream into physics datasets (5-10)
  - Local creation of AOD
  - Distribution of AOD to all participating Tier-1s
  - Distribution of some FEVT to participating Tier-1s
  - Calibration jobs on FEVT at some Tier-1s and proto-CAF
  - Physics jobs on AOD at some Tier-1s
  - Skim jobs at some Tier-1s with data propagated to Tier-2s
  - Physics jobs on skimmed data at some Tier-2s

After the Physics TDR (Volume II)

LHCC June 2006

CSA06: What is it?

- Computing, Software, & Analysis Challenge 2006
- Definition:
  - A 50 million event exercise to test the work… …w associated with the data handling m…
  - Receive previously simulated …
  - Perform prompt recon… determination an… …nstants
  - Stream int…
  - Lo…
  - …participating Tier-1s
  - …e FEVT to participating Tier-1s
  - …obs on FEVT at some Tier-1s and proto-CAF
  - …cs jobs on AOD at some Tier-1s
  - Skim jobs at some Tier-1s with data propagated to Tier-2s
  - Physics jobs on skimmed data at some Tier-2s

After the Physics TDR (Volume II)

CSA ran from Sep to Nov 2006
It was successful, in that we learnt a lot about what worked; and a lot more about what did not.

LHCC June 2006

The changeover to today's organization

2007-2008 (then 2009 also):

The final years towards first LHC beams

This is when today's Computing, Software and Physics organization was put in place.

Along with the tools:

Full emphasis on data-driven

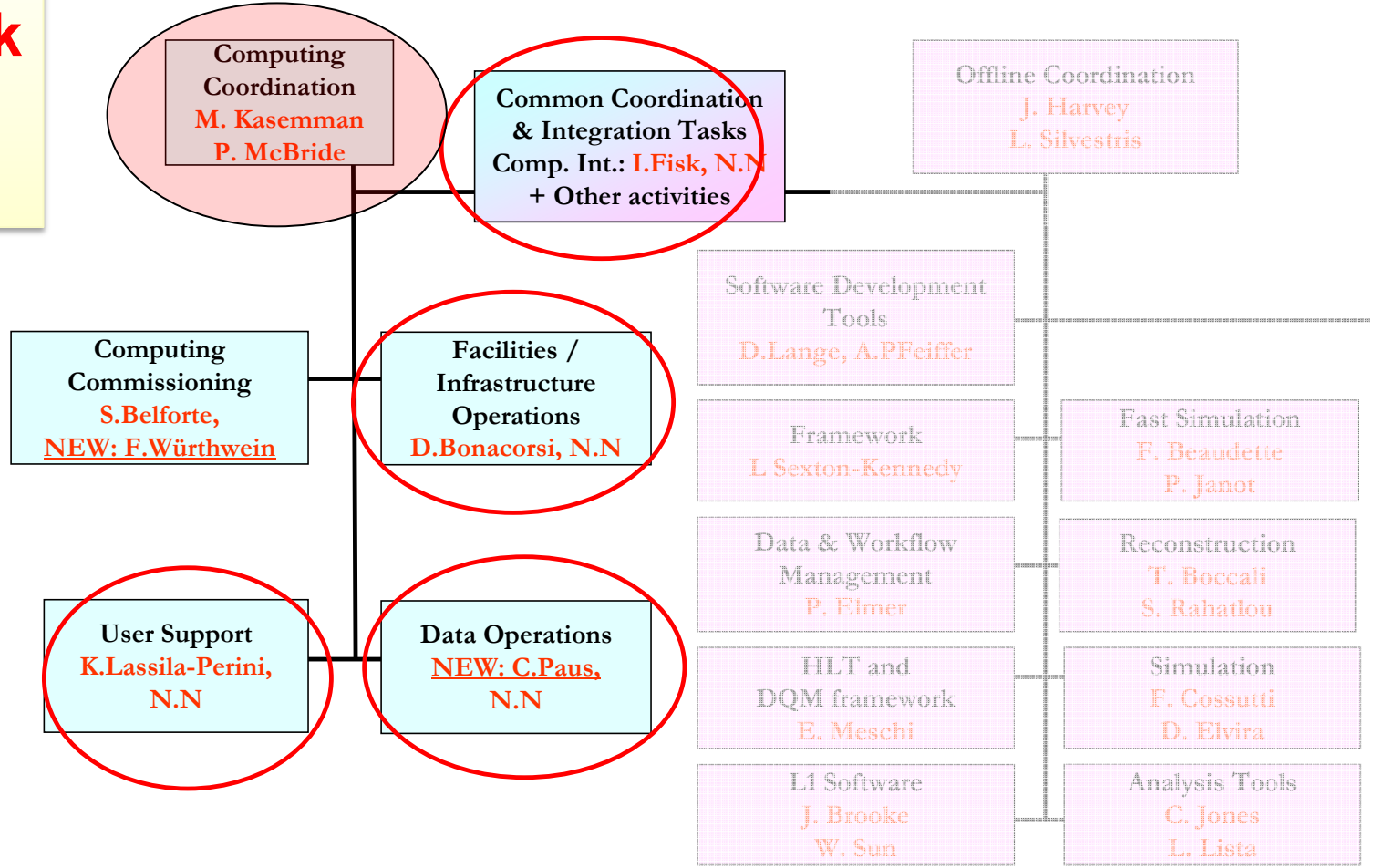
And the procedures/processes:

Approval system, ARCs, CADI, et al

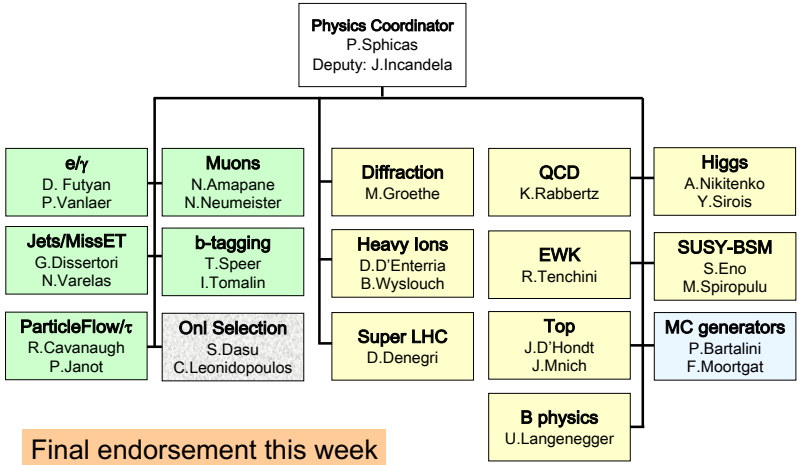
Computing Project: en route to data

CMS Organisation Chart: Computing, Offline

CMS Week Plenary Feb 2007



CMS physics organization



Final endorsement this week

CMS Week Plenary Feb 2007

Milestones

- **CMSSW validation complete**
  - **Physics-TDR Volume I recovered: Mar 1 2007**
  - **A joint Software-PRS task since Fall 2006. Lots of work, has provided a lot of valuable input into code development**
  - **Ends this week. Many thanks to Daniel Elvira & Patrick Janot**
    - **Meeting on Tue morning, grand summary on Friday morning (physics plenary)**
- **HLT exercise complete**
  - **Full trigger table, algorithms, CPU: Jun 15 2007**
  - **Plenty of progress. CPU measurements beginning to appear. Tuning of performance. Production samples appearing.**
- **First physics papers prepared**
  - **Full analysis breakdown; details of how and what for each physics analysis; LHCC write-up: Oct 15 2007**
    - **Date is tight, however, we want to avoid have two major milestones (detector and physics) fall on Nov 15…**

CSA07 and physics

from Sep CMS week

- **Main Tier-0 output: ~150 Mevt**
  - 100pb^{-1} of data (not quite, e.g. not enough QCD jets)
  - Reconstruct with calibration/alignment constants corresponding to "detector knowledge with 10pb^{-1} of data"
- **Tier-0 production ~200Mevt, have another 50Mevt to use**
  - Add "10pb^{-1} of data"; reconstruct with startup calib/align precision
- **AOD crated and distributed to (all/multiple) Tier-1s**
  - Run skim jobs on AOD at Tier-1's

CSA07 report on Thu (Joe D)

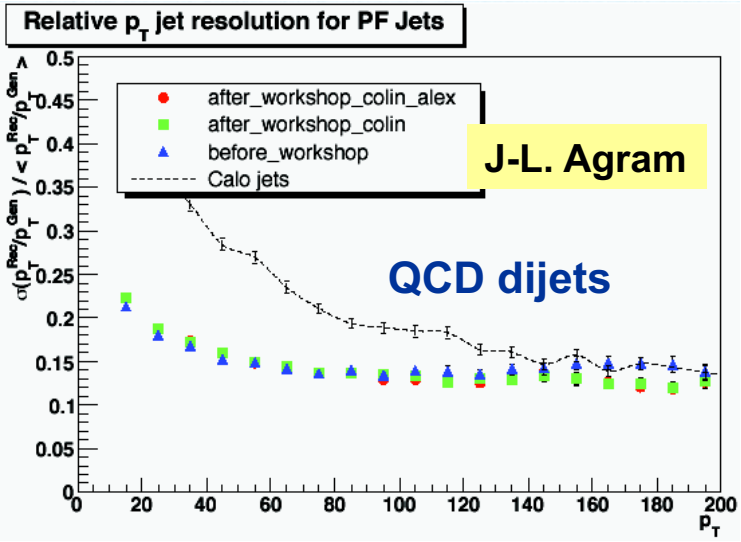
- **Test re-reconstruction at Tier-1**
  - Same data, so this time run with 100pb^{-1} constants
- **At Tier-2's: monitor incoming skim data; check/validate**
  - In parallel: run on older samples (for 2007 analyses).
    - All analyses must migrate to Tier-2s. Note this is mimicking life (typically full analysis runs on data "version-1".
  - Generate 50 Mevt Monte Carlo events
- **CAF: first tests (data, code, organization) of "Express Line"**
  - Three analyses: W/Z, Higgs and Z′. Would be nice to also inject signals (that go to the primary datasets at the Tier-2s as well). Currently in planning phase…

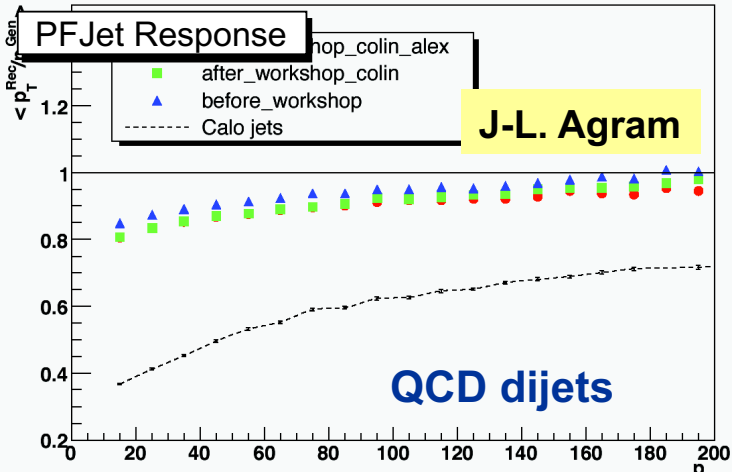
CAF report on Thu (Oliver B)

P-flow: Jet Performance Studies

P. Janot

- **PF Jet Resolution**
  - Significantly better than "raw" CaloJets for $p_T < 120$ GeV
  - Improvements for high p_T Jets
    - See next page!
- **PF Jet Response**
  - Significantly better response than "raw" CaloJets
  - Approaches 1.0 for $p_T > 100$ GeV
    - Improvements still possible for low p_T Jets
- **Focus work to improve high p_T Jet Resolution**
  - high density
  - high multiplicity





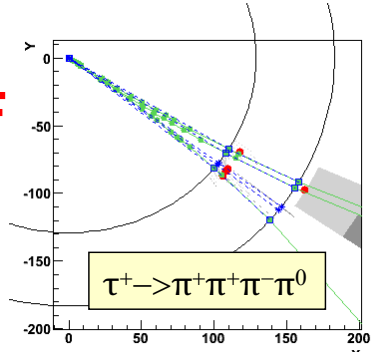
P-flow: Jet Performance Studies

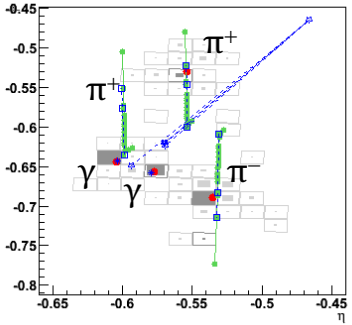
P. Janot

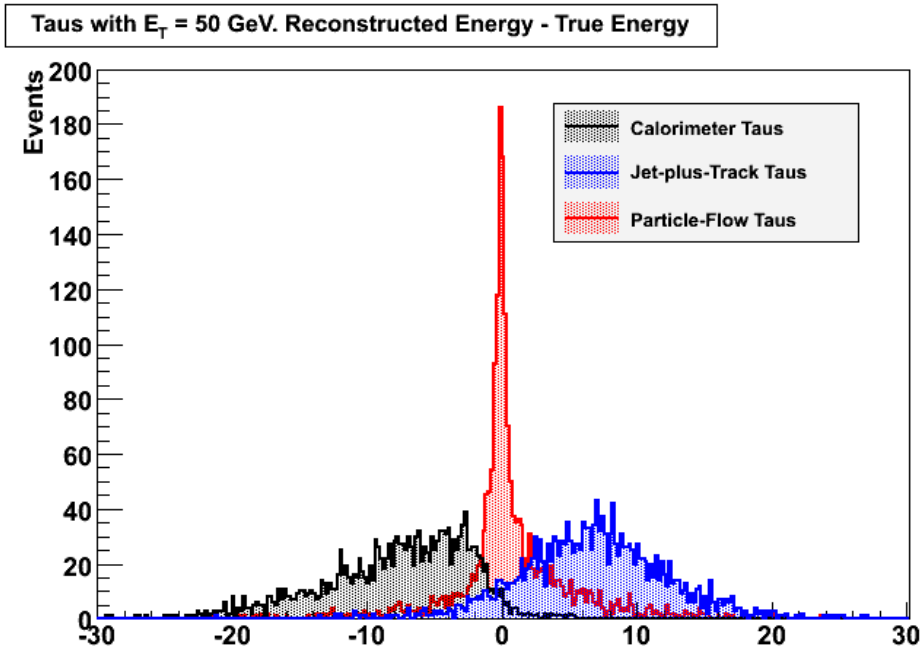
Reconstructing Taus With Particle Flow

- Optimal use of the granularity of the ECAL in Particle Flow Reco
  - Reconstruct all charged hadrons and photons from π^0's

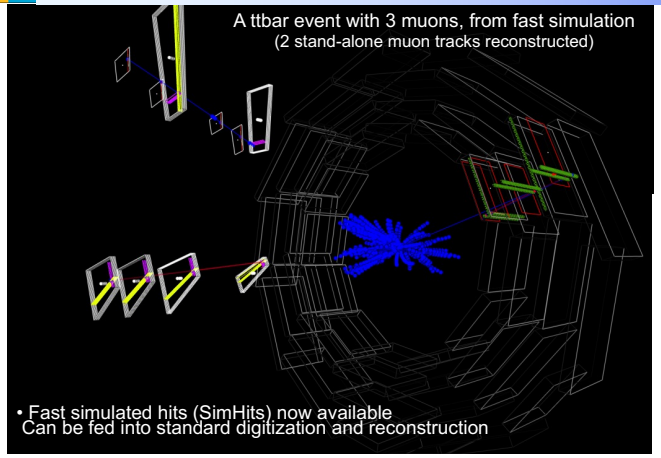
- PF
  -
  -
- PF
  -
  -
- Fo
  - p_T
  -
  - high multiplicity







Fast Simulation of Muon Hits



"Physics for the masses"
Advent of FastSim: beginning of a new era in CMS data/physics analysis preparations…

As we were entering the final stretch towards beams, the number of people turning to analysis preparations increased significantly…

Organization/human aspects

- **Super-obvious statement of the day: we have to put in place a system in which we work together effectively**
- **Primary tool: the promise that the "final-plot maker" will not walk away with all the credit.**
  - **Unless (s)he also does all the work leading up to the final plot**
    - **There do exist some very special individuals and we should acknowledge this. But the huge majority work in groups, utilize numerous ideas and contribute a fraction <1 of the total work on a single analysis.**
  - **One of the goals of the current exercise: split analyses into pieces that are worked on in a cross-institutional manner.**
    - **We have to learn how to do this while we have no pressure and we also have a chance to change everything (c culture!)**

+Analysis approval system…

Trigger Reviews

- Starting point: CSA08 HLT Menu had over 160 paths
  - Proof of principle that we can run with this many triggers
- Established a set of core triggers & thresholds at 8E29,1E31:
  - 8E29: collision menu for Day 1; 1E31: aimed for longer-term MC studies
- Collaborative work between Physics & Trigger: reviewed justification of all other triggers wrt. this core set triggers
  - Dec 11–Feb 4: reviews of JetMET, μ's, eγ, cross-triggers, b-tag/tau/p-flow, AlCa-MinBias-Commissioning triggers
- Exercise has been very useful. Leaner table in the works:
  - HLT: 60 triggers for 8E29, 80 triggers for 1E31
    - Plus 10 HLT bits for express stream for both 8E29, 1E31
  - Also for Lvl-1eliminate Lvl-1 triggers not needed as seeds for HLT
    - Old L1 menu: 110 algos, 303 Glob. Trig. conditions (firmware)
    - New L1 Menu: 64 algos, 132 Glob. Trig. conditions (firmware)
      - ➔ Review not finished, we expect additional changes.
- Much more in Trigger Coordination report

CMS Week Mar 2009
Plenary
(Physics report)

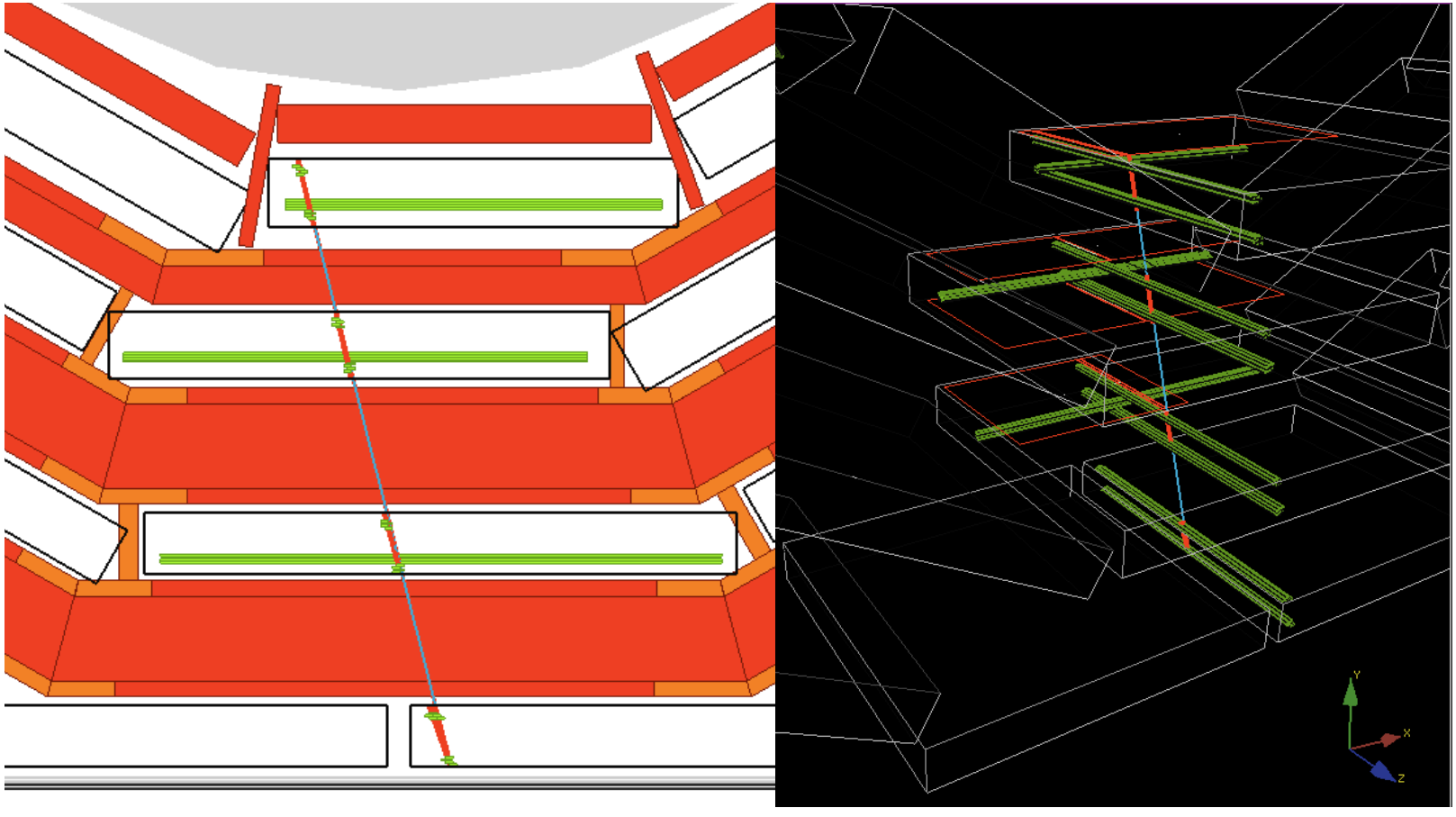
Skims: improved scheme considered

- Primary Datasets (PDs): based on trigger info. Then:
- Central skims:
  - Centrally produced; run on a PD, output 1-2 per PD, size 10% of PD
    - Could also have a "10% of everything" skim
  - Remake automatically at each re-reco production
  - Distribute to some Tier-2s (central storage). Also subscribed to if desired
- Group Skims
  - Designed by PH groups, run on Tier-2s
  - Input: Central Skims (preferred) or PDs
  - Output: in group and user space
  - Design size: ~10% of a central skim or ~1% of original full PD
- User Skims:
  - Anything beyond this. Understood to run at Tier-2 (or 3…)
- Much more on this week in Thursday plenary by Joe Inc (plus presentations to offline/computing earlier in the week)

CMS Week Mar 2009 Plenary (Physics report)

1) Maintenance & Operation		2) Software, Computing & Physics Analysis
	Jan	
	Feb	**Release CMSSW3_0** (limited validation, step towards 3_1)
Install ES1 **Install ES2**	Mar	
	Apr	**Deadline for Input for 3_1** CRAFT, Trigger Review (menu), Phys etc.
Tracker Cooling Plant Revised	May	**Release CMSSW3_1 (LHC Startup)** Full validation of 3_1 (incl. production and physics)
Close CMS Magnet Tests	Jun	**Start Fullsim production 3_1**
CRAFT	Jul	Use 3_1 widely CMS gets familiar with 3_1
	Aug	
CRAFT Contingency & pre-beam maintenance	Sep	**Start Fastsim production 3_1**
CMS READY for Beam	Oct	**CMS READY for Beam**

First real HLT muons!



- CosmicMuonReconstructor now producing the first real “Lvl-2” muons, on-line, in the filter farm

T1 and T2 Site Readiness

CMS Week Dec 2009 Computing Summary (Matthias Kasemann)

Site Readiness monitoring going to be updated to include Data Transfer Qualities

- averaged LoadTest transfers (Debug) and Production transfers (Prod) for all DDT-commissioned links.
  - A link is considered good if the transfer quality (in Prod+Debug) is better than 50%,
  - "good" if at least 50% of links are good, all kind of links-group, considered separately.

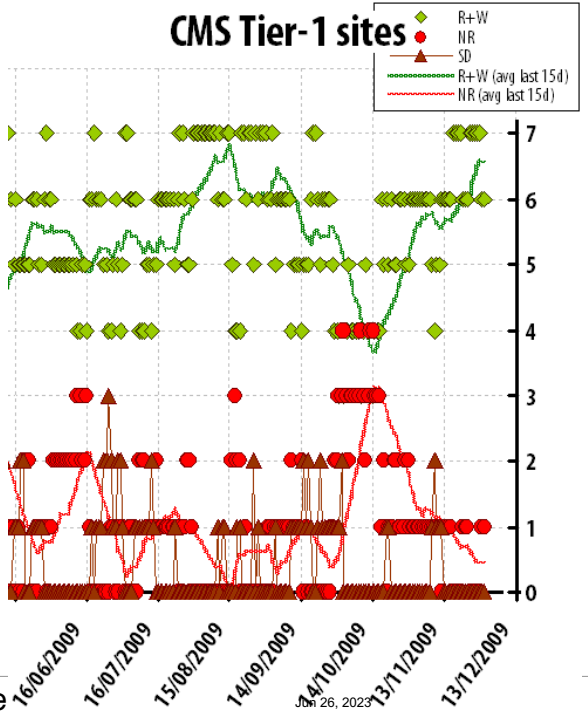
Development since Summer '09:

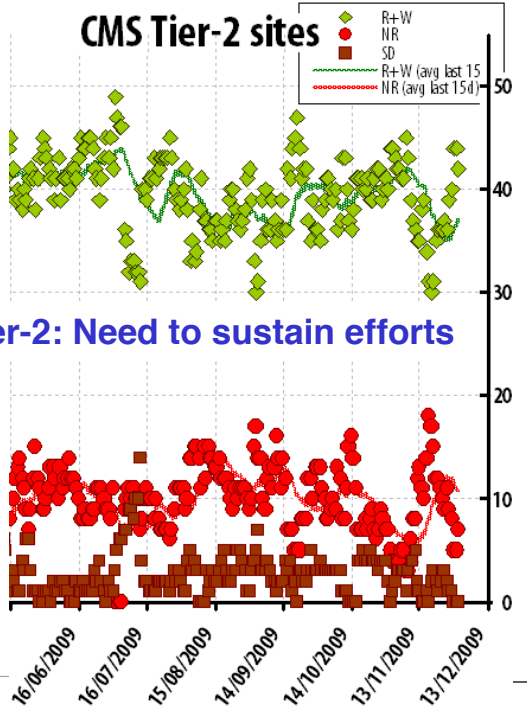
Tier-1: on good slope, still many issues

- Fall site visits were productive,
- action items followed

During First Running:

non-custodial data copies will ensure availability





Tier-2: Need to sustain efforts

T0 reconstruction performance

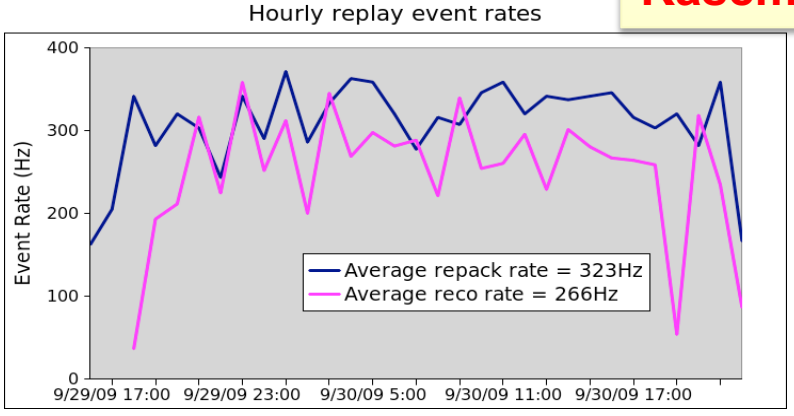
CMS Week Dec 2009 Computing Summary (Matthias Kasemann)

MC scale tests of T0 system in September/October

- **Produced special MC samples for 8E29 collisions**
  - worth several days of data taking at 300Hz

Results:

- **Capacity for 240Hz sustained @ 40% PD overlap**
  - Tested: 250Hz with 13% overlap on 1900 slots (of 2300 total)



- **Results for express processing:**
  - 25Hz express stream processing needs ~ 120 slots

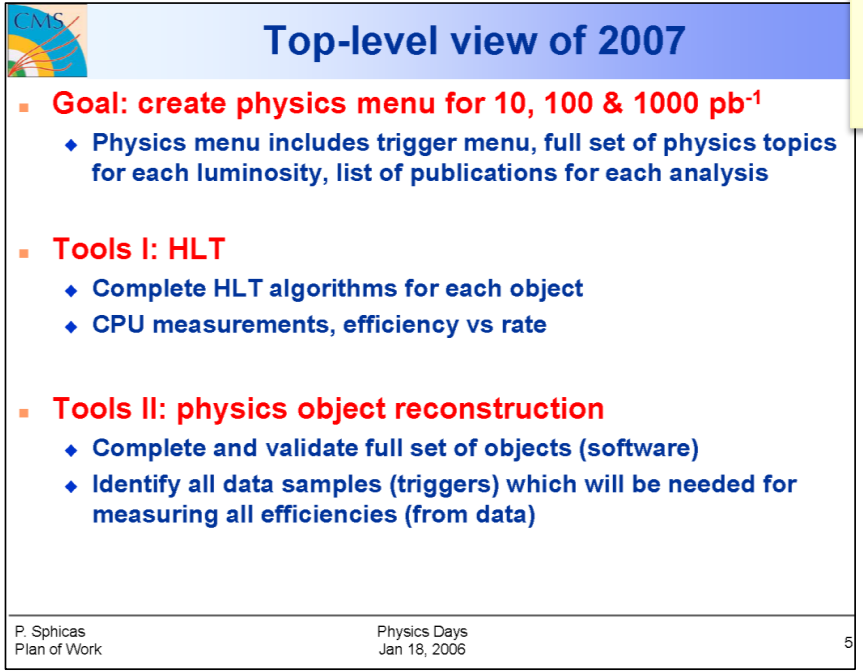
In November T0 CPU resources were increased by 20% to 100% of 2009-CMS request. Next increase is scheduled for June 2010.

T0 CPU resources are sufficient for the data taking expected.

Prologue

CMS Week Dec 2009 Physics Summary (Joe Incandela)

- Paris said it many times…
  - "We will prepare in a series of successive approximations…"
- And so we did…
- Past 3 years…
  - Transition from studies for 10's or 100's fb^{-1} to…
    - Physics accessible with < 1 fb^{-1}
      - Data-driven methods
      - Improved Object ID
    - Tracking down to ~100 MeV
    - Tracking jets (JPT), tcMET, Particle flow
    - Lean trigger table, primary and secondary datasets defined
    - October Exercise, Physics accessible with < 1 pb-1
    - 900 GeV 1st paper(s)
  - …Physics accessible with <1 nb^{-1}



Top-level view of 2007

- **Goal: create physics menu for 10, 100 & 1000 pb^{-1}**
  - Physics menu includes trigger menu, full set of physics topics for each luminosity, list of publications for each analysis
- **Tools I: HLT**
  - Complete HLT algorithms for each object
  - CPU measurements, efficiency vs rate
- **Tools II: physics object reconstruction**
  - Complete and validate full set of objects (software)
  - Identify all data samples (triggers) which will be needed for measuring all efficiencies (from data)

P. Sphicas
Plan of Work

Physics Days
Jan 18, 2006

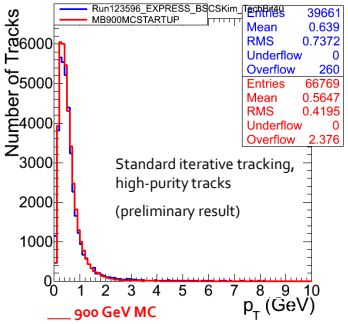
5

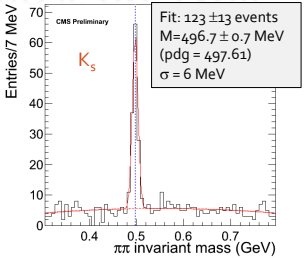
This talk mainly covers the last stretch

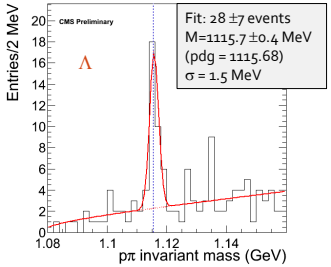
CRAFT09, Oct X and 900/2360 GeV

Physics and prep. for 2010 (7 TeV?)

Tracking is on a roll

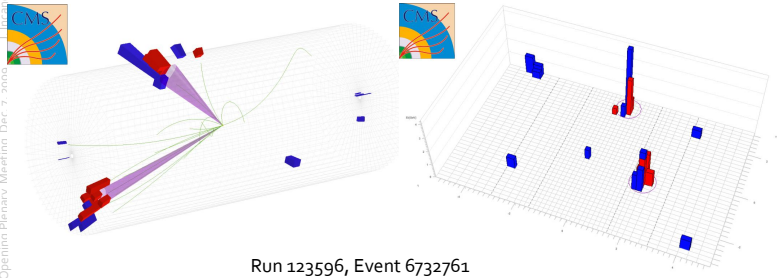






High P_T Dijet Event from Express Stream

Jet1: Raw pT = 13 GeV, Corr pT = 24 GeV, PF pT = 16 GeV, phi = -0.69, eta = 1.96, EMF = 0.66
PF constituents: Jet 2: 6 charged hadrons, 6 photons, 1 neutral hadron
Jet2: Raw pT = 12 GeV, Corr pT = 23 GeV, PF pT = 19 GeV, phi = 2.48, eta = 0.27, EMF = 0.50
PF constituents: : 6 charged hadrons, 7 photons, 0 neutral hadron

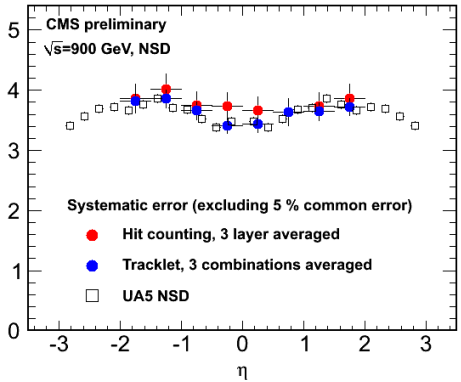


Run 123596, Event 6732761

CMS Week Dec 2009

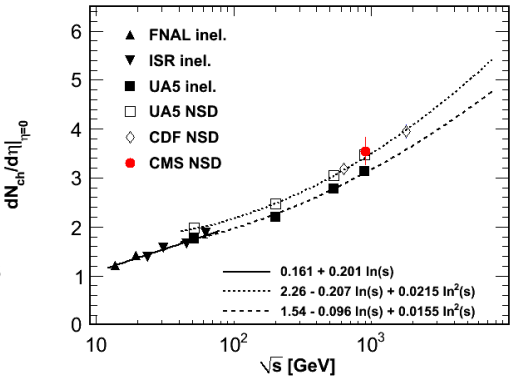
Comparison of the two methods

- Good agreement between methods
- Good agreement with UA5 (p+pbar at 900 GeV
- Significantly higher than PYTHIA D6T (~3)

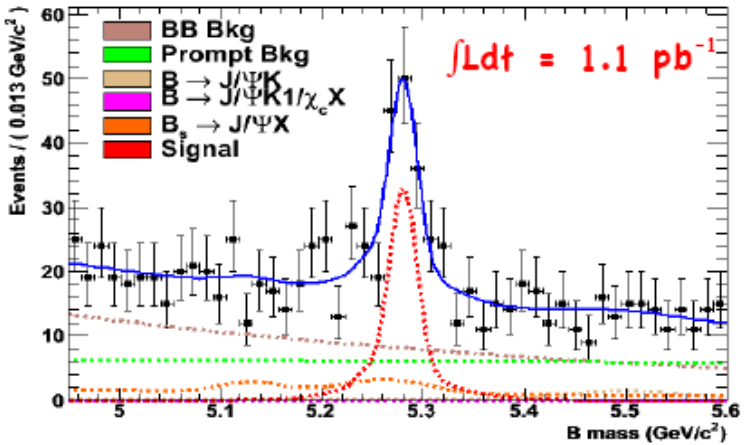


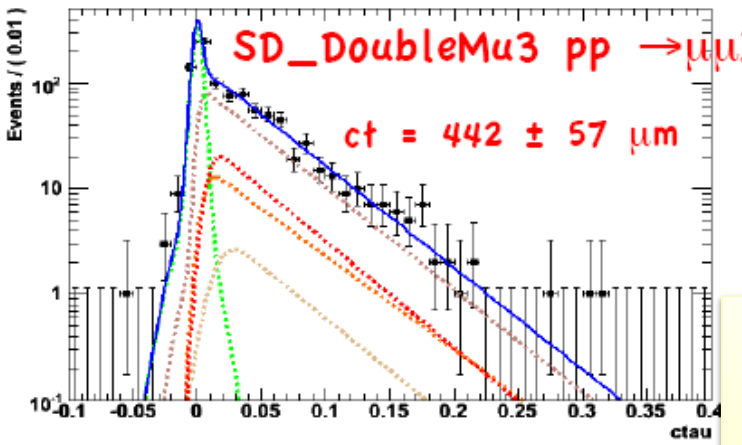
Collision energy dependence

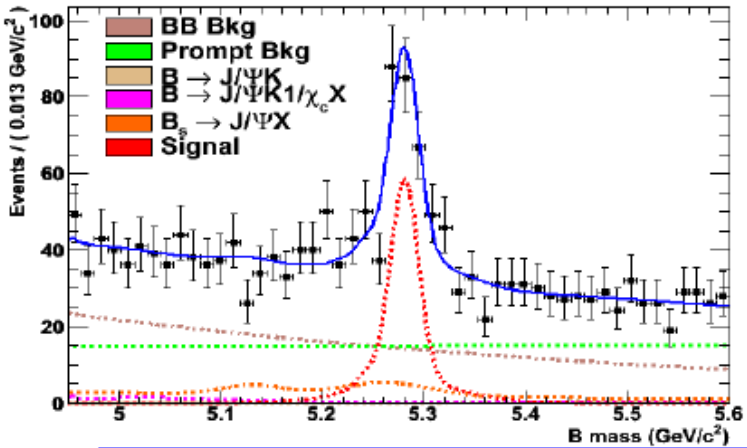
- The highest energy data point in p+p collisions
- Follows the trend measured in p+pbar collisions
- The first preliminary physics result from CMS on p+p collisions

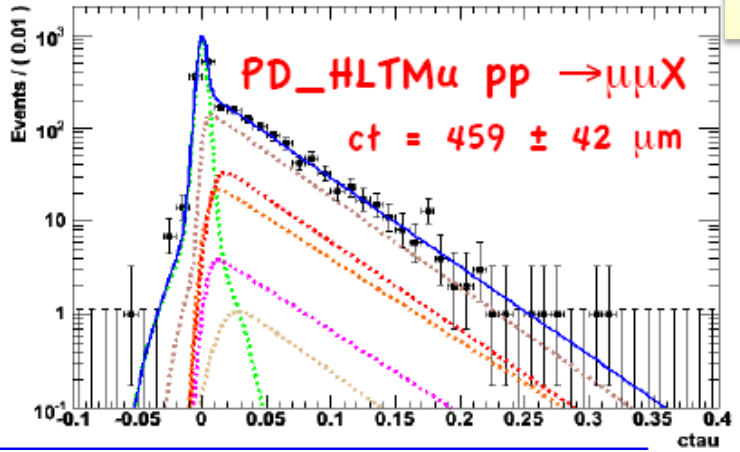


First 7 TeV studies: $B^0 \rightarrow J/\psi K^{*0}$









CMS Week Dec 2009 Physics Summary

And thus came the end of the “preparations”

The best was yet to come

Pseudosummary (I)

- **It was a very long road; to which this talk did not do justice**
  - **FORTRAN → C++/OO**
  - **Perennial lack of people; always short of software experts; and physicists willing to dig in for a significant amount of time**
  - **Continuous pressure from the outside to "demonstrate we can do it"**
  - **Continuous pressure from the outside to "document our physics capability/reach"**
  - **Continuous pressure from the inside to ensure widest possible participation…**
  - **The (natural?) inertia of any system and people to changes…**
  - **Major CMS-wide tests: MTCC, CSA06, CSA07, CSA08, CRAFT**
  - **Huge schedule pressure: we went from 2005, to 2007, to 2008, to 2009. For a long time, we were always "two" (or one) year away from startup**

Pseudosummary (II)

- **But… it worked; thanks to the huge effort, to which this single short (…) talk did not do justice**
  - **A special thanks is reserved for some key people whose tireless efforts made both a (big) difference and a gargantuan task possible**

  - **And of course, a huge thanks to the hundreds of colleagues and friends who invested themselves in this tremendous effort; and turned the detector into a science-producing engine. Their names would fill many pages, while the actual thanks owed to them would easily fill a book.**

- **We were ready on day 1. And a year later… and the year after... In brief: we made it!**

And even better:
this was just the beginning…

The best was yet to come…