Higgs production with forward protons : ATLAS Physics potential?

Hera-LHC start-up, Mar.2004

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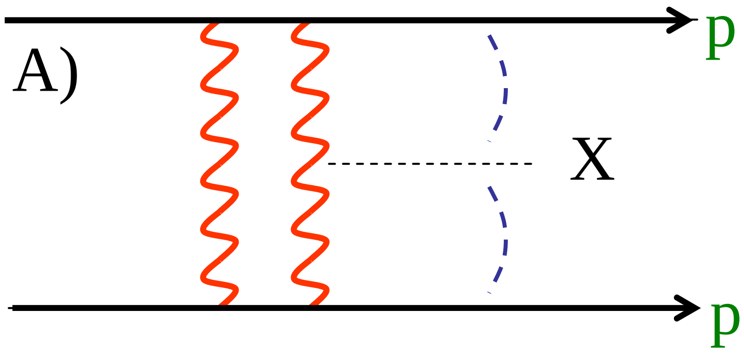
with R.Peschanski, C.Royon

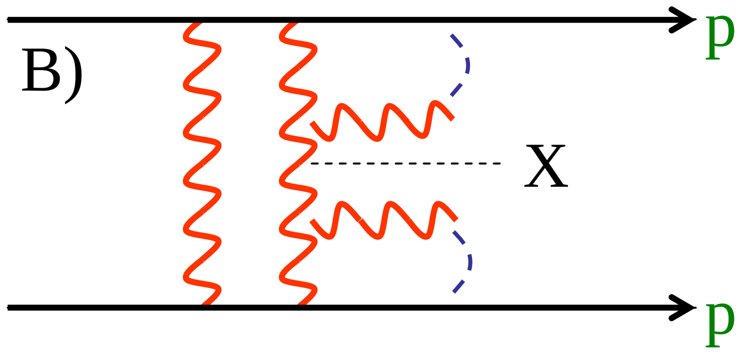
- Notation, conventions & other jargon
- Topologies and other rough properties
- Why this may be interesting (2 words)
- Towards a physics case?

Models

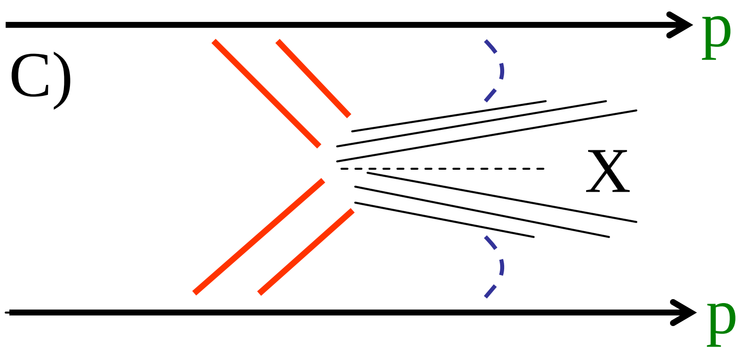
QCD, Exclusive



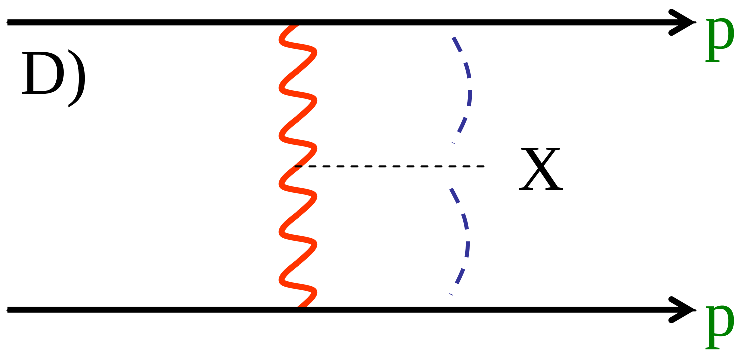
QCD, Inclusive, Non Factorized



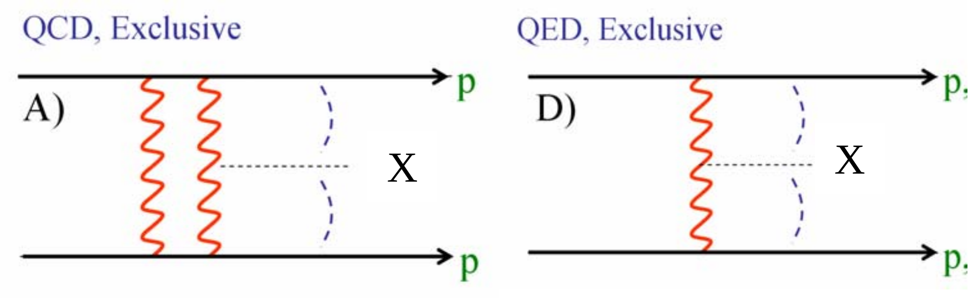
QCD, Inclusive, Factorized



QED, Exclusive



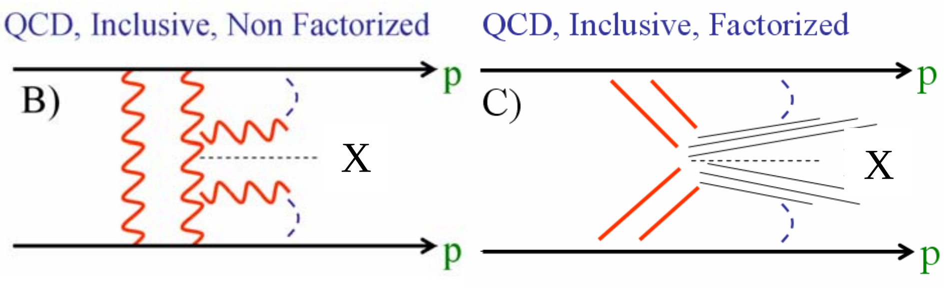
Models A&D



- Topology
  - 2 outgoing protons + hard central system ; large rapidity gaps ; QCD mediated

- A few hints on phenomenology
  - Process is a potential jackpot; wide range of predictions
  - Model A-1 : Bialas-Landshoff (Regge-inspired, non-perturbative) : **σ_H ~ 100 fb (disf.)**
  - Model A-2 : Khoze, Martin, Ryskin (Entirely perturbative) : **σ_H ~ 3 fb**
  - Model D : QED **σ_H ~ 0.1 fb**
- Experimental remarks (relevant for LHC)
  - H mass range bounded by $\xi_{min}\xi_{min}s$
  - Mass resolution down to 1% (→ Helsinki best case)
  - s/b : H → bb / bb continuum O(1), thanks to several suppression mechanisms (central system has Jz=0, is color singlet)

Models B&C



- Topology
  - 2 outgoing protons + hard central system + Pomeron remnants
  - Small, very forward (undetectable, if m_X large) rapidity gaps

- A few hints on phenomenology
  - Process exists (≡ DPE dijets are being measured) and is fairly large ; **σ_H ~ 100-300 fb**
  - Model B : Boonekamp-Peschanski-Royon, extension of the original (exclusive) Bialas-Landshoff model.
  - Model C : Cox-Forshaw; factorization assumes Hera fluxes (←Pomwig)

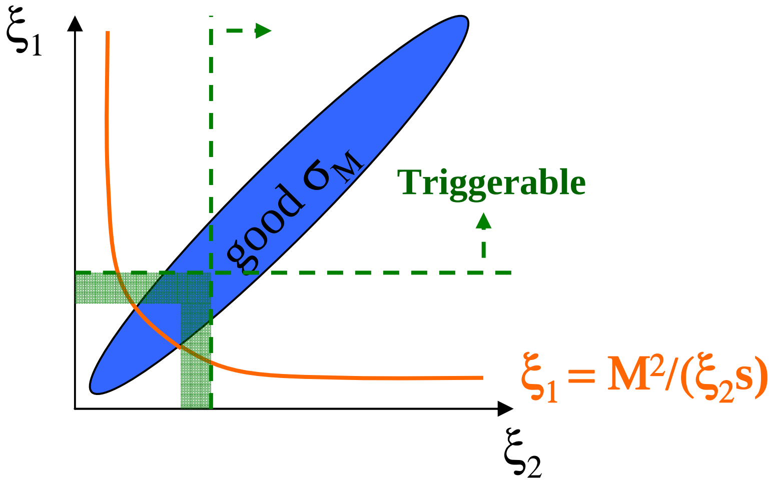
- Experimental remarks (relevant for LHC)
  - Background to the exclusive models
  - Any improved mass reconstruction relies on Pomeron remnants detection
  - s/b : H → bb / bb continuum O(10^{-3}-10^{-4})

Situation today

- Process studied since beginning of 90's : many groups, many models (some of them complementary, e.g. inc⊕exc), large variety of predictions

- Meanwhile : much experimental interest, since it was realized (Albrow, Rostovtsev) that Missing Mass measurements would provide extraordinary mass resolution at the Tevatron. LHC study performed since then (Finland group):

  Forward proton detector setup :
  complicated interplay →



- 3-4 more years before LHC start-up
  - Physics case still to be made
  - Is this a discovery channel, or a confirmation channel+bonus?

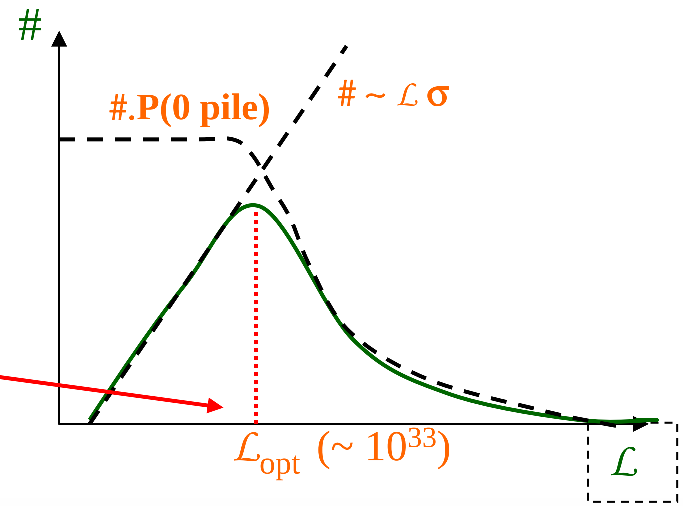
- Monte-Carlo programs : Pomwig (← Herwig), SCI (← Pythia)

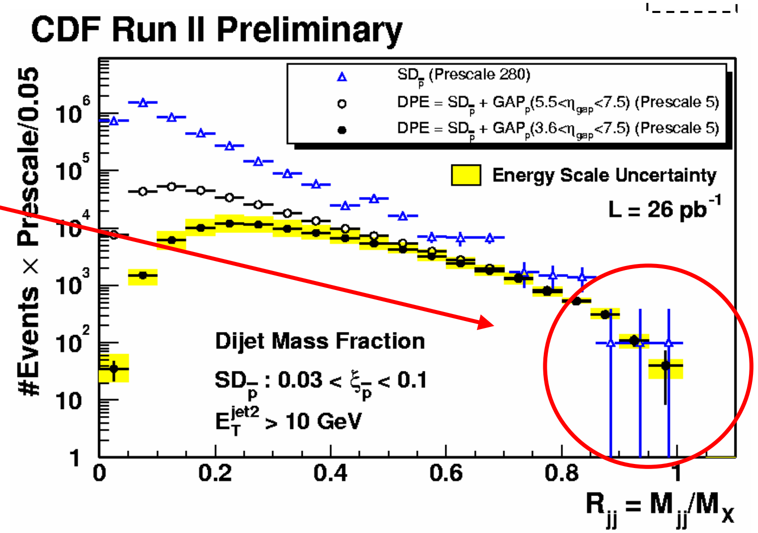
Studies to be performed (→ Physics case)

- Inclusive models : Determination of Regge parameters on forthcoming Run2 CDF and D0 data → Predictions at the LHC
- L1 trigger with FPD's
- L1 trigger with central detectors : large gaps may help us : find $\mathcal{L}_{opt}$, and request it
- Exclusive models : perform analysis at hadron/detector level

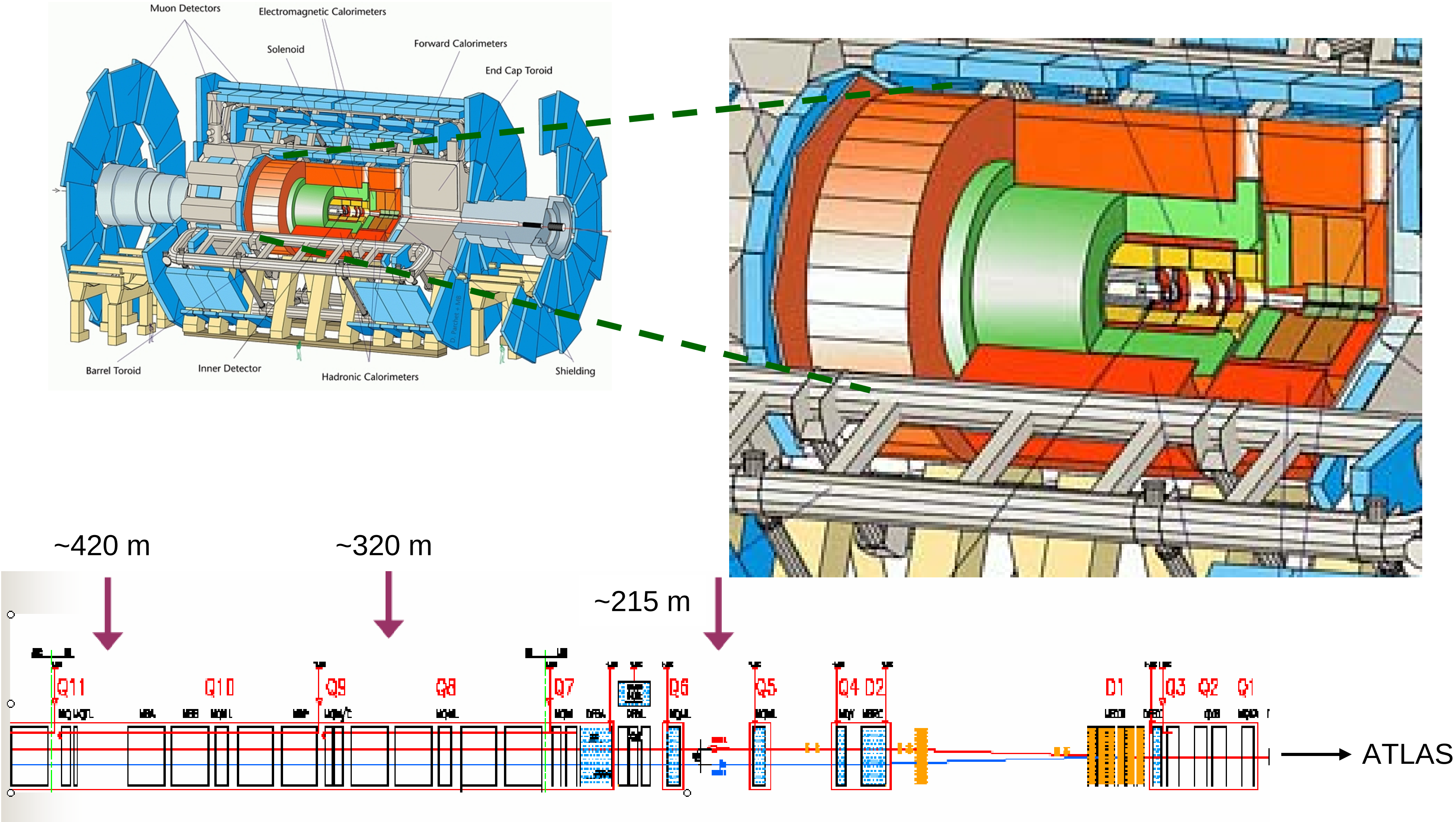
  Take background from Inclusive production as found above
- Worst case : exclusive given by γγ exchange

  → do we still see something? (surely no discovery, maybe spin/parity in the long term?)



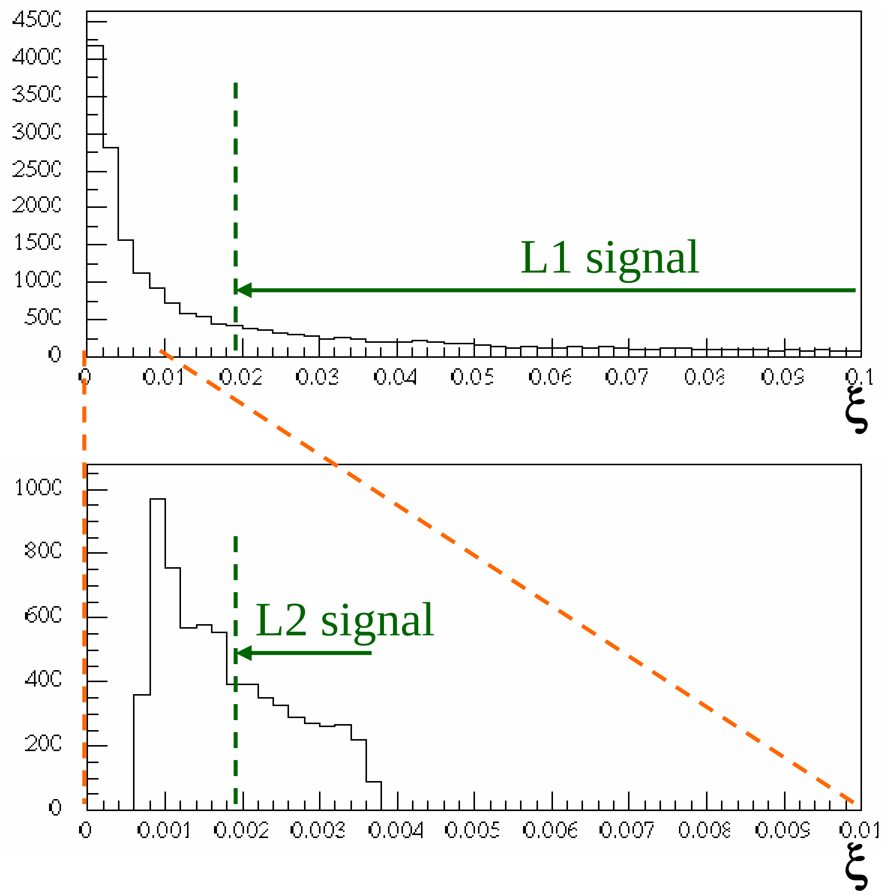


Considered experimental setup



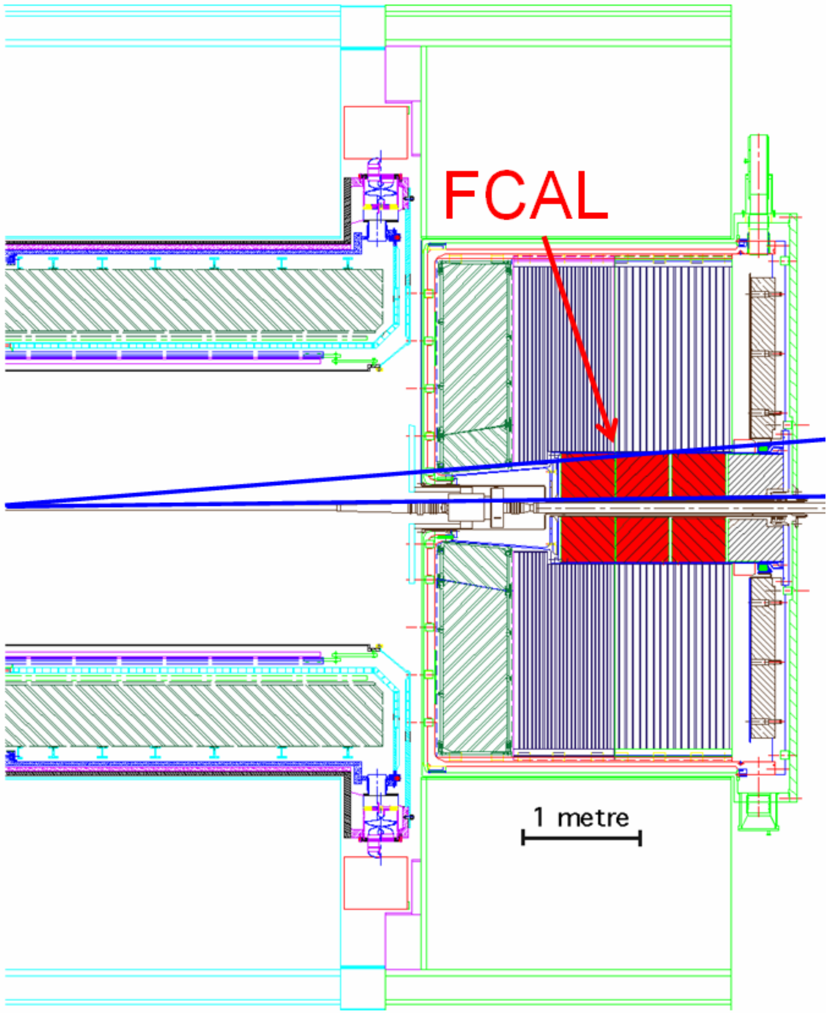
L1 trigger : forward protons

- Setup used :
  - **1** : 215 m : $0.02 < \xi < 0.2$, $|t|<2$ GeV^2 (warm section, ~L1 triggerable)
  - **2** : 320 m : $0.003 < \xi < 0.025$, $|t|<2$ GeV^2 (warm section)
  - **3** : 420 m : $0.002 < \xi < 0.016$, $|t|<2$ GeV^2 (cold section)
- Exclusive Higgs, m_H=120 GeV
  - 1 signal in **1** : 67%
  - Confirmed by 2 calo jets (pT>20 GeV) : 48% **ε(L1)**
  - opposite signal : 24% **ε(L2)**
- Missing mass resolution not optimal in this configuration. Other cuts needed to reduce the diffractive background



L1 trigger : calorimeter gaps

- Trigger on dijets (E_T>20-30 GeV)
- ATLAS cannot do jet topology at L1
  - Only counting
- Forward E_T!
- FCAL : forward calorimeter;
  $3.2 < |\eta| < 4.9$

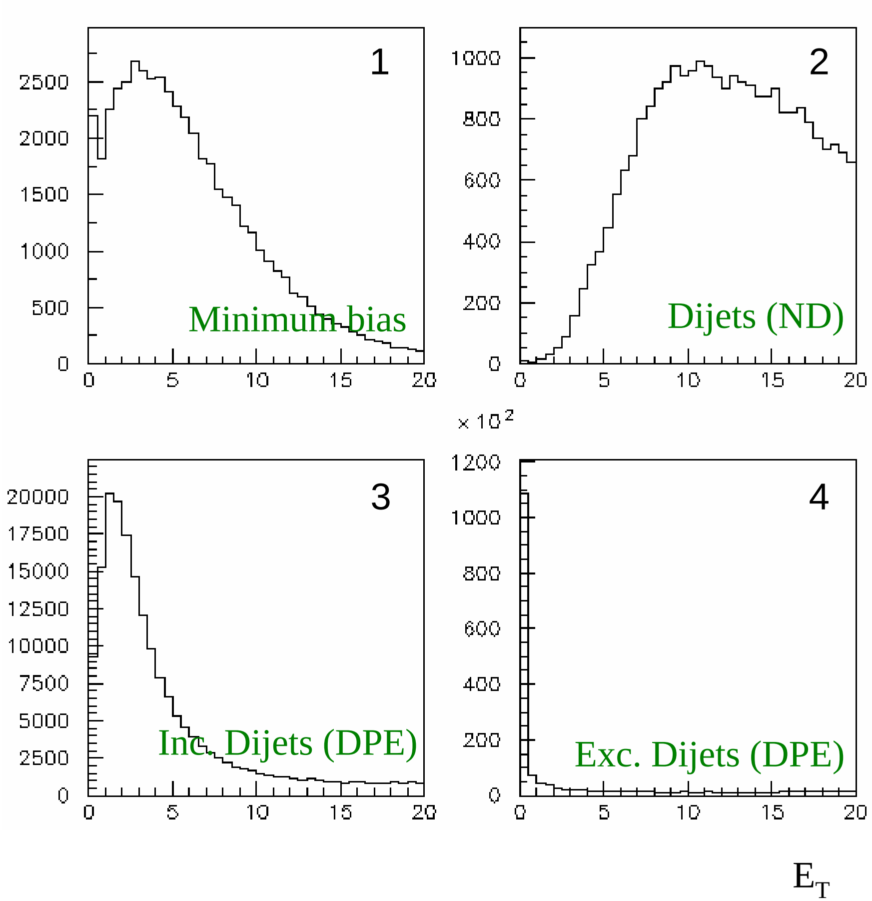


L1 trigger : calorimeter gaps

- First attempt: veto on total forward E_T
- I do not even consider calorimeter noise…

- Very low lumi : 4 vs 2
  → OK!

- Add 1 minimum bias event : (4+1) vs 2
  There is already ~no discrimination anymore…

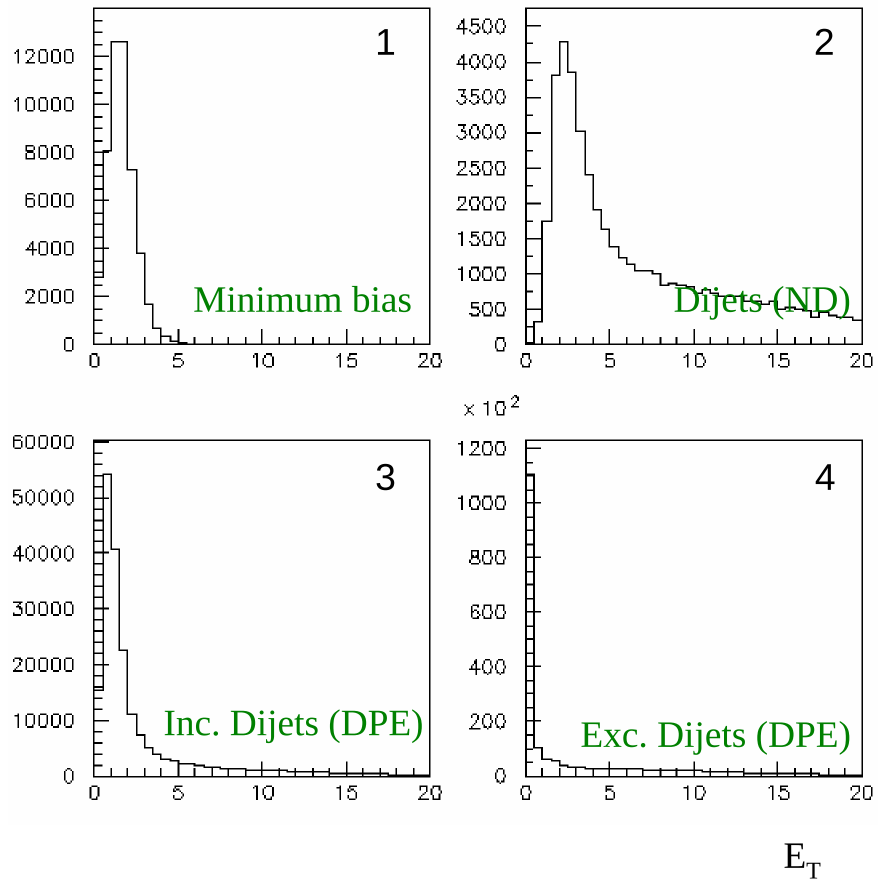


L1 trigger : calorimeter gaps

- Second attempt: veto on local E_T maximum (FCAL phi-wedge)
- Still no calorimeter noise…

- Very low lumi : 4 vs 2
  → OK!

- Add 1 minimum bias event : (4+1) vs 2
  Clear difference in the tail (resp. absence and presence of hard forwardradiation)
  But the discrimination is insufficient!



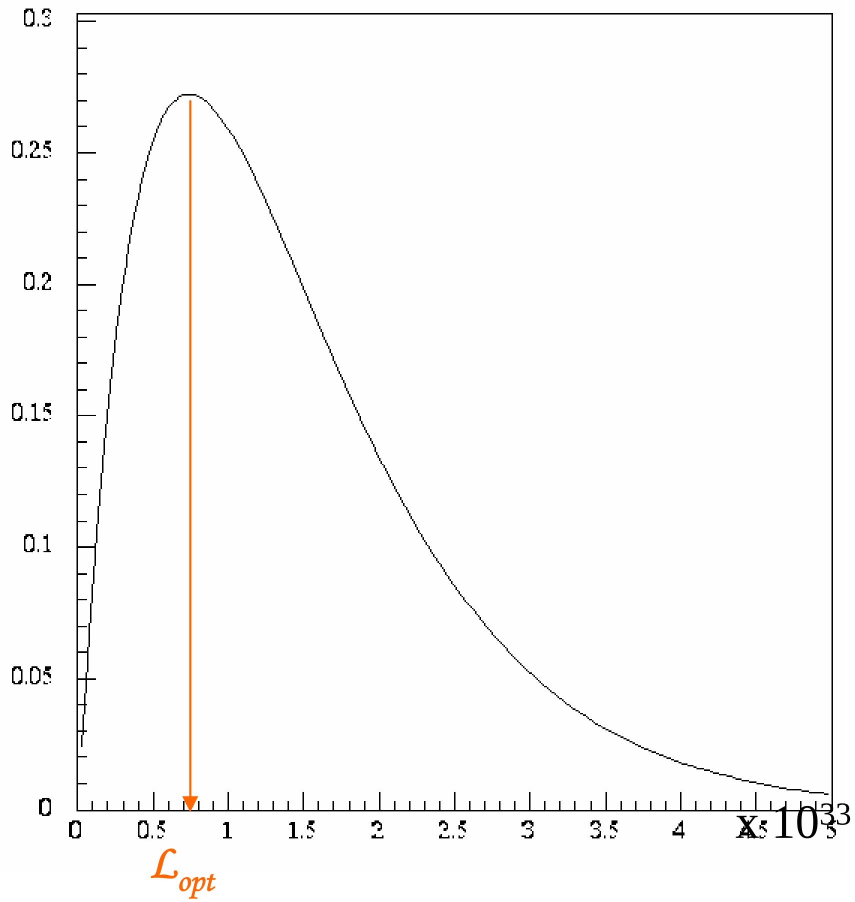
"Optimal luminosity"

- Maximize the probability to have:
  - 1 hard, interesting process per bunch-crossing (small cross-section)
  - 0 overlapping minimum bias events
  - → **$P \propto \mathcal{L}.\exp(-\sigma_{mb}\mathcal{L}/f)$**
- σ_{mb} = 55 mb (inelastic)

  f = 40 10^6 Hz (25 ns between b.c)
  - → $\mathcal{L}_{opt}$ = 7.3 10^{32} /cm^2/s
- Nota bene :

  $\langle N_{mb}\rangle = \sigma_{mb}\mathcal{L}_{opt}/f$ = **1**

  and $P(0|1) = e^{-1}$ = **0.37**
- **So : if you need gaps, you lose a lot of time, and 2/3 of the signal**



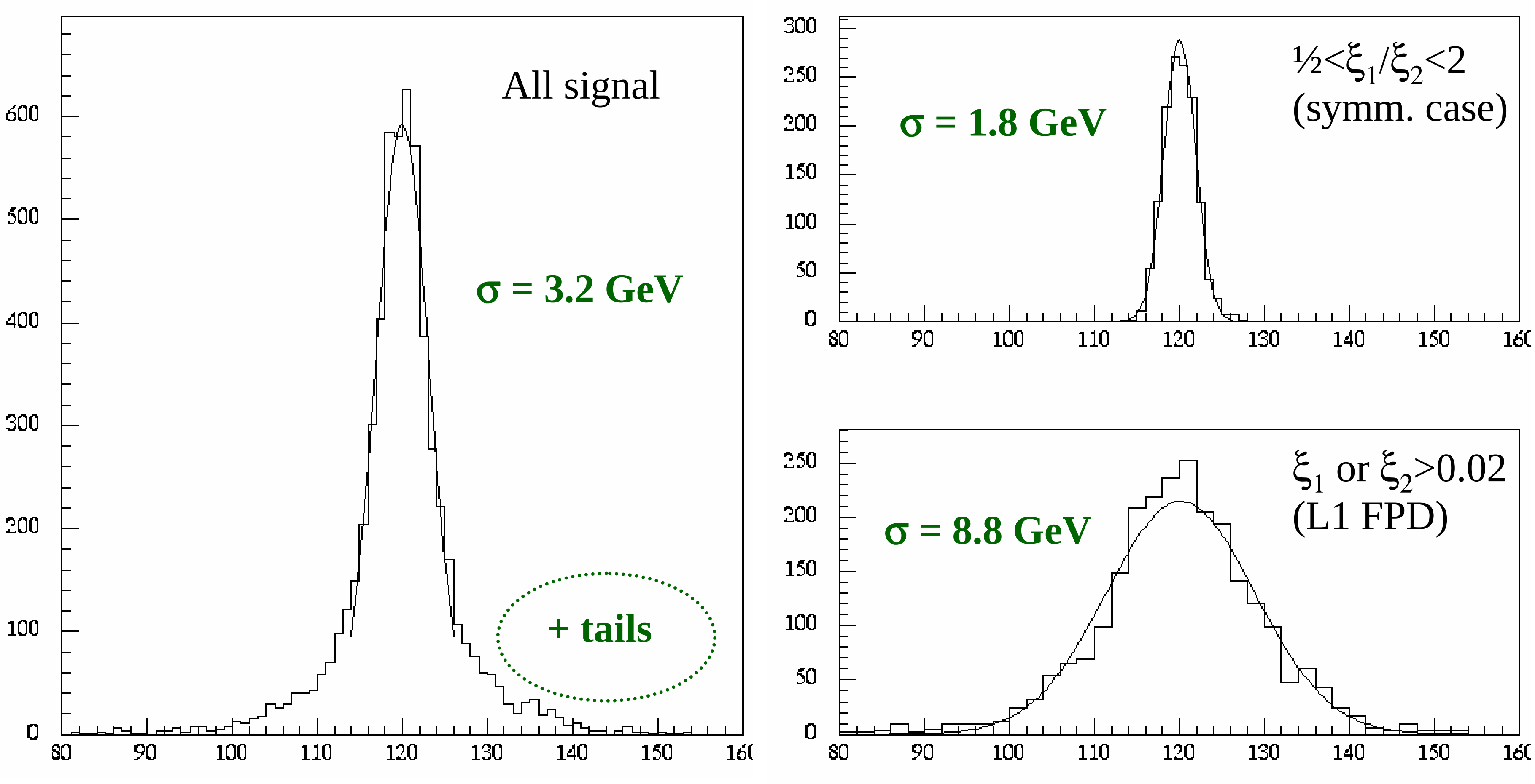
Signals and backgrounds

- Processes & cross-sections : obtained with Pomwig v2

Process	Raw cross section	Normalisation
pp → pp + JJ/bb/cc + X	1.9 10^5 / 0.9 10^3 / 0.9 10^3 pb	×3.8 (CDF Data)
pp → pp + H + X	43.5 fb	×3.8 (CDF Data)
pp → pp + JJ/bb/cc, B-L	4.2 10^5 / 55 / 6 pb	× 0.03 (KMR surv.)
pp → pp + H, B-L	131 fb	× 0.03 (KMR surv.)
pp → pp + bb/cc, QED	0.66 / 1.15 fb	× 0.85 (KMR surv.)
pp → pp + H, QED	0.1 fb	× 0.85 (KMR surv.)

- Ingredients for simulation
  - Atlfast : fast detector response (ATLAS calorimeters)
  - Heslsinki FPD acceptances and resolutions

Missing mass resolution : m_H=120 GeV



Analysis cuts

- I just enumerate…

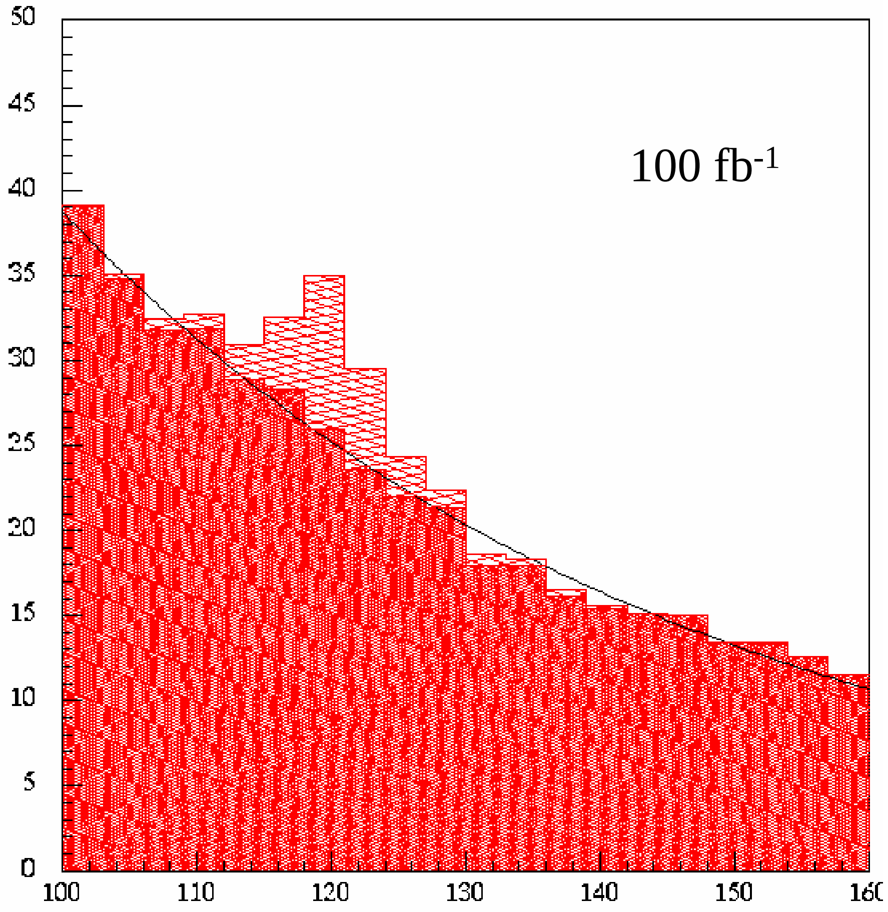
- 2 protons tags
- No Forward E_T (<1 GeV)
- 2 central jets : p_{T1}>45 GeV, p_{T2}>30 GeV, back-to back in ϕ
- B-tagging ($\varepsilon_b \sim 60\%$, $\varepsilon_g \sim 1\%$)
- Central mass fraction : $M_{JJ}/M_{Tot} > 0.75$
- Central to missing mass : $M_{JJ}/(\xi_1\xi_2 s)^{1/2} > 0.8$

Results

- Normalization reminder:
  - σ_{bb} = 55 pb, σ_H = 131 fb, from Bialas-Landshoff
  - From KMR we take a survival probability of 3%
  - ~6% signal efficiency
  - So in total ~23 events of signal for 100 fb^{-1}, *forgetting about pile-up*

- Remind : we asked for gaps, so 100 fb^{-1} means, actually, ~300 fb^{-1} to account for the requirement of having no overlapping event.

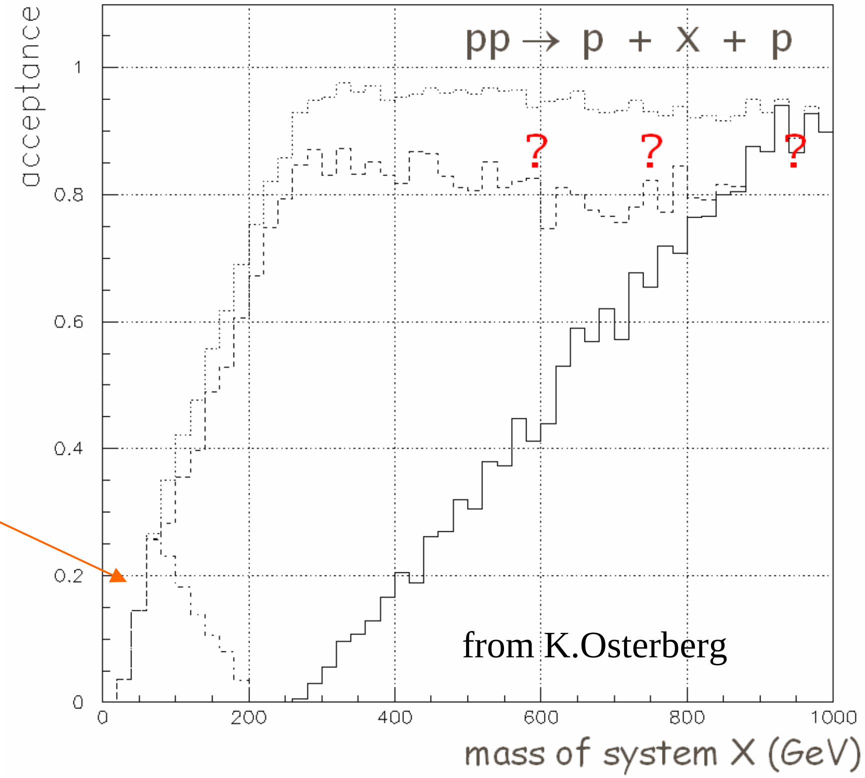
- At a speed of 7.3 10^{32}.



m_H (GeV)

Comparison with KMR estimates, and other caveats

- In summary, KMR estimates s/b ~3, and a realistic simulation finds ~1/3
- Reasons, to my understanding :
  - σ_{KMR} = 1 GeV ; $\sigma_{realistic}$ ~3 GeV
  - Integrate over ±2σ to get 95% of signal



Other caveat :

- Low mass Susy Higgs bosons :

  There is no acceptance!

  Recent papers on low-mass

  CP violating Higgs bosons

  seem to neglect this ?!

Conclusions, to my sadness

- It is hard to believe in :
  - A standard model Higgs boson visilibity in DPE, unless a factor 10 is gained in Missing mass resolution
  - Low-mass Susy Higgs bosons : the acceptance is too small

- Rapidity gaps can reduce backgrounds, and help to trigger:
  - → $\mathcal{L}_{opt}$: slow…
  - Don't forget to add another factor 1/3 to the signal normalization (or a factor 3 to the require luminosity).

- All this starts to be a lot of difficulties.