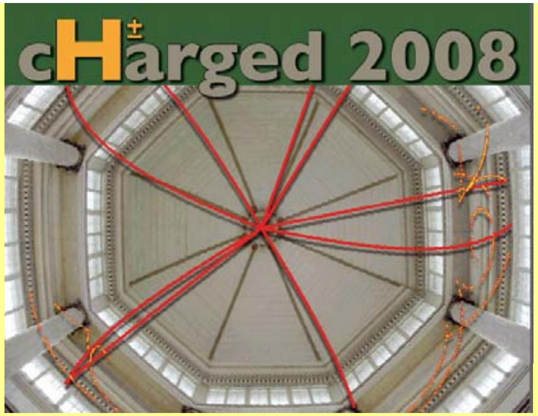


Luminosity measurement at LHC

Charged Higgs Workshop
Uppsala
16-19 September 2008
Per Grafstrom
CERN

Motivation-why we need to measure the luminosity

- Measure the cross sections for "Standard " processes
  - Top pair production ← Theoretically known to ~ 10 %
  - Jet production
  - ……

- New physics manifesting

  in deviation of σ x BR

  relative to the Standard Model predictions.

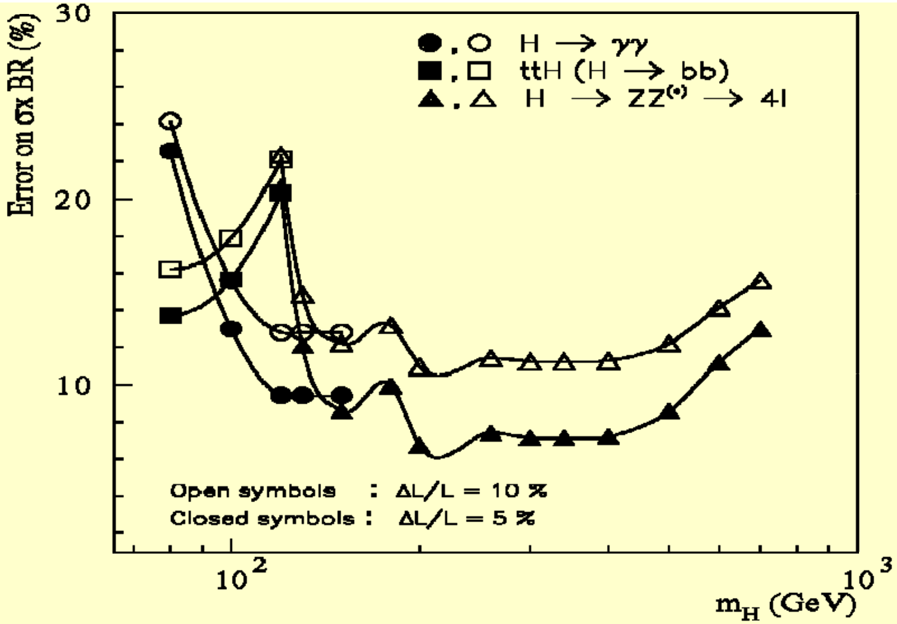
  Precision measurement becomes more

  important if new physics not directly seen.

  (characteristic scale too high!)

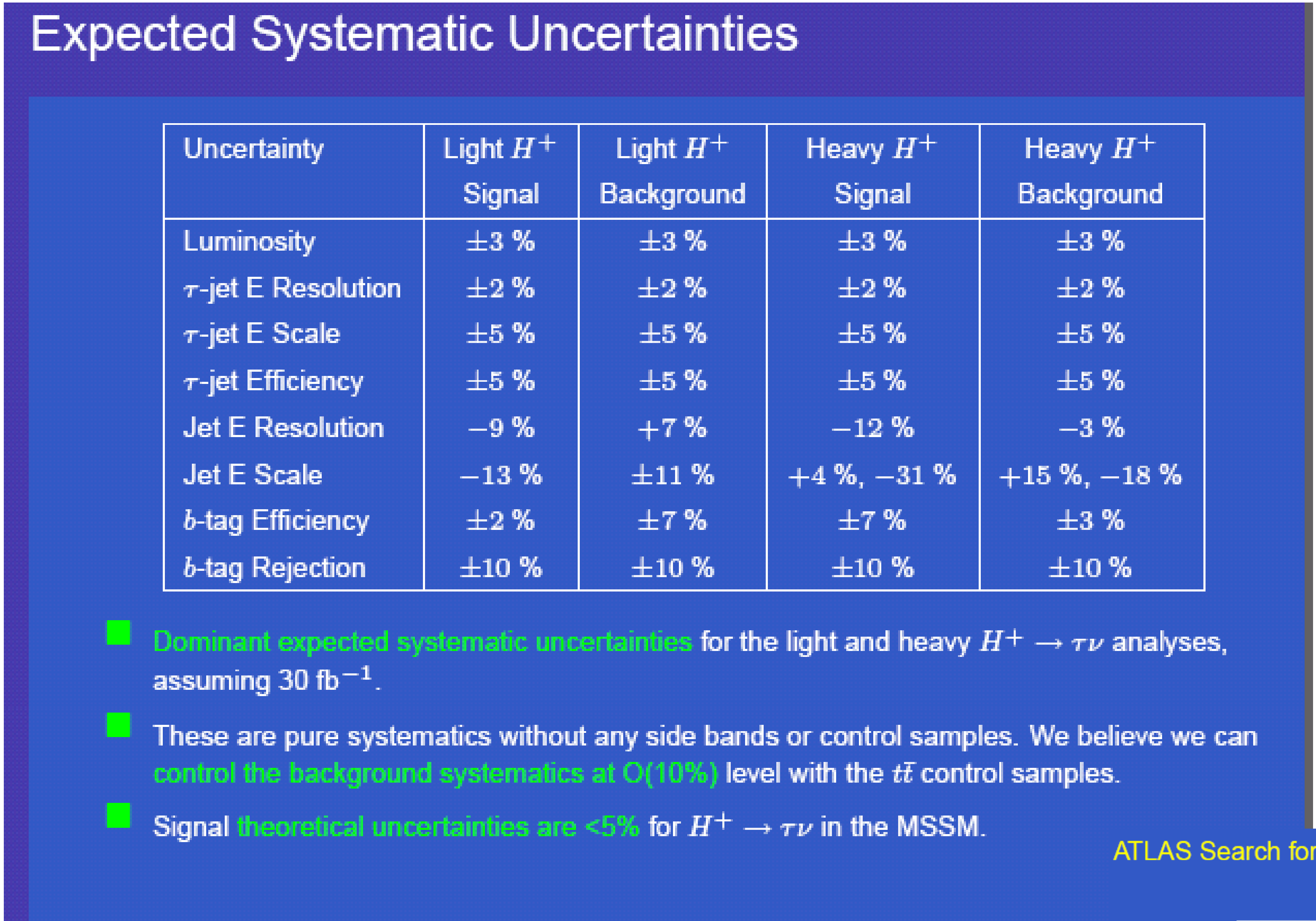
- Important precision measurements
  - Higgs production σ x BR
  - tanβ measurement for MSSM Higgs
  - …….

Higgs coupling



Relative precision on the measurement of σ_H×BR for various channels, as function of m_H, at $\int Ldt$ = 300 fb^{-1}. The dominant uncertainty is from Luminosity: 10% (open symbols), 5% (solid symbols).

(ATLAS Physics TDR , May 1999)



Expected Systematic Uncertainties

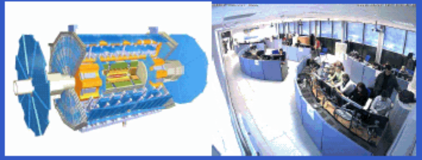
Uncertainty	Light H^+ Signal	Light H^+ Background	Heavy H^+ Signal	Heavy H^+ Background
Luminosity	±3 %	±3 %	±3 %	±3 %
τ-jet E Resolution	±2 %	±2 %	±2 %	±2 %
τ-jet E Scale	±5 %	±5 %	±5 %	±5 %
τ-jet Efficiency	±5 %	±5 %	±5 %	±5 %
Jet E Resolution	−9 %	+7 %	−12 %	−3 %
Jet E Scale	−13 %	±11 %	+4 %, −31 %	+15 %, −18 %
b-tag Efficiency	±2 %	±7 %	±7 %	±3 %
b-tag Rejection	±10 %	±10 %	±10 %	±10 %

- Dominant expected systematic uncertainties for the light and heavy $H^+ \to \tau\nu$ analyses, assuming 30 fb^{-1}.
- These are pure systematics without any side bands or control samples. We believe we can control the background systematics at O(10%) level with the $t\bar{t}$ control samples.
- Signal theoretical uncertainties are <5% for $H^+ \to \tau\nu$ in the MSSM.

SUSY08, Ju

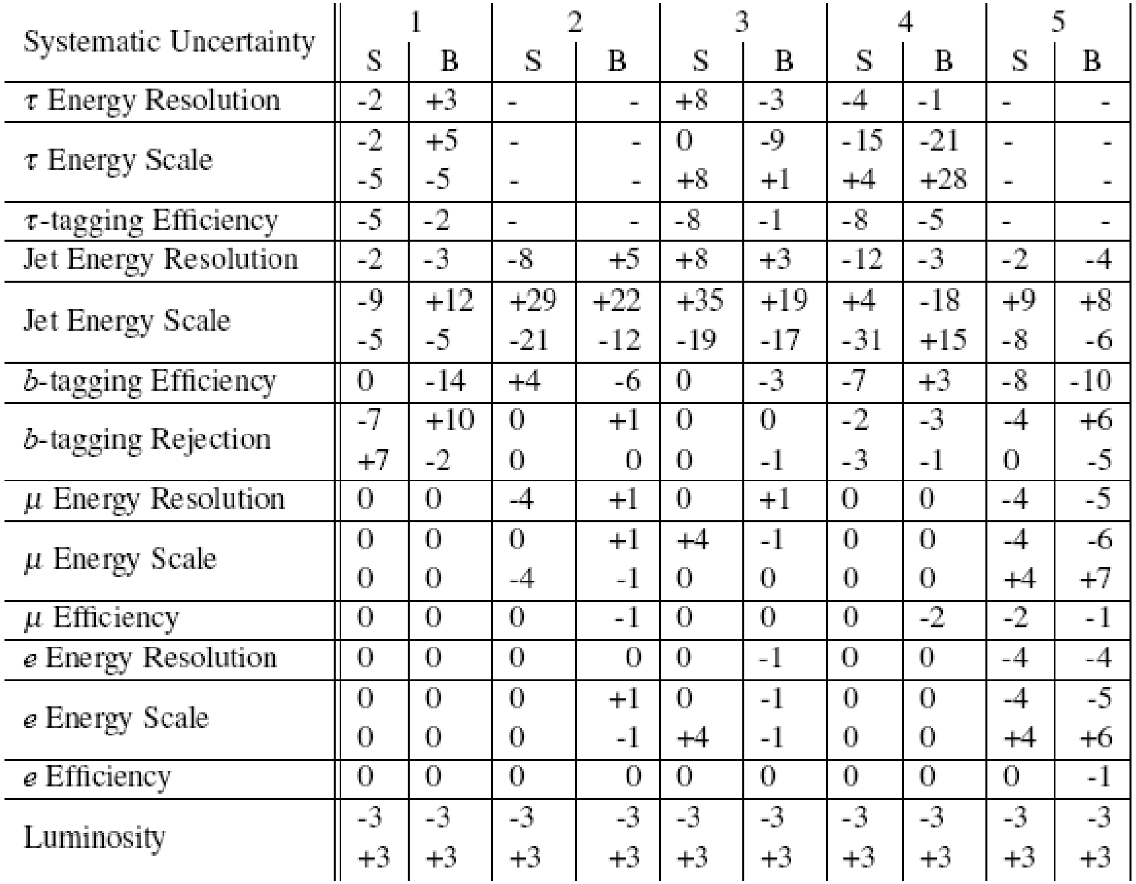
3 % will take some time !!!

ATLAS Search for the Charged MSSM Higgs Boson



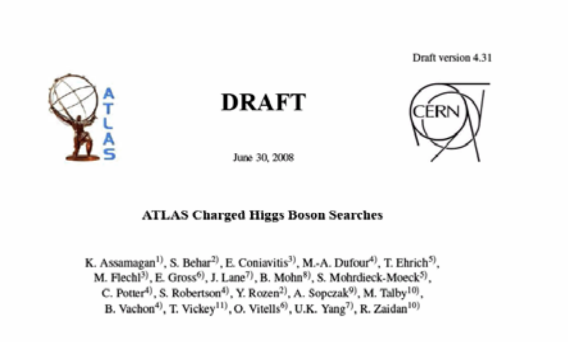
Chris Potter (for the ATLAS Collaboration)

McGill University, Montreal, Canada



Systematic Uncertainty	1		2		3		4		5	
	S	B	S	B	S	B	S	B	S	B
τ Energy Resolution	-2	+3	-	-	+8	-3	-4	-1	-	-
τ Energy Scale	-2 -5	+5 -5	- -	- -	0 +8	-9 +1	-15 +4	-21 +28	- -	- -
τ-tagging Efficiency	-5	-2	-	-	-8	-1	-8	-5	-	-
Jet Energy Resolution	-2	-3	-8	+5	+8	+3	-12	-3	-2	-4
Jet Energy Scale	-9 -5	+12 -5	+29 -21	+22 -12	+35 -19	+19 -17	+4 -31	-18 +15	+9 -8	+8 -6
b-tagging Efficiency	0	-14	+4	-6	0	-3	-7	+3	-8	-10
b-tagging Rejection	-7 +7	+10 -2	0 0	+1 0	0 0	0 -1	-2 -3	-3 -1	-4 0	+6 -5
μ Energy Resolution	0	0	-4	+1	0	+1	0	0	-4	-5
μ Energy Scale	0 0	0 0	0 -4	+1 -1	+4 0	-1 0	0 0	0 0	-4 +4	-6 +7
μ Efficiency	0	0	0	-1	0	0	0	-2	-2	-1
e Energy Resolution	0	0	0	0	0	-1	0	0	-4	-4
e Energy Scale	0 0	0 0	0 0	+1 -1	0 +4	-1 -1	0 0	0 0	-4 +4	-5 +6
e Efficiency	0	0	0	0	0	0	0	0	0	-1
Luminosity	-3 +3	-3 +3	-3 +3	-3 +3	-3 +3	-3 +3	-3 +3	-3 +3	-3 +3	-3 +3

Table 23: Effects of systematic uncertainties for all channels under investigation. The numbers are given in terms of percentage changes in cross section. The channels are: 1: $t\bar{t} \rightarrow bH^{+}bW \rightarrow b\tau(had)\nu bqq$ (see Section 4.1), 2: $t\bar{t} \rightarrow bH^{+}bW \rightarrow b\tau(lep)\nu bqq$ (see Section 4.2), 3: $t\bar{t} \rightarrow bH^{+}bW \rightarrow b\tau(had)\nu b\ell\nu$, (see Section 4.3) 4: $gg/gb \rightarrow t[b]H^{+} \rightarrow bqq[b]\tau(had)\nu$ (see Section 4.4) and 5: $gg/gb \rightarrow t[b]H^{+} \rightarrow t[b]tb \rightarrow bW[b]bWb \rightarrow b\ell\nu[b]bqqb$ (see Section 4.5).



Draft version 4.31

DRAFT

June 30, 2008

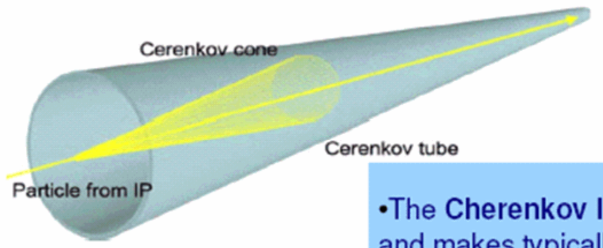
ATLAS Charged Higgs Boson Searches

K. Assamagan1), S. Behar2), E. Coniavitis3), M.-A. Dufour4), T. Ehrich5), M. Flechl3), E. Gross6), J. Lane7), B. Mohn8), S. Mohrdieck-Moeck5), C. Potter4), S. Robertson4), Y. Rozen2), A. Sopczak9), M. Talby10), B. Vachon4), T. Vickey11), O. Vitells6), U.K. Yang7), R. Zaidan10)

Relative versus absolute luminosity

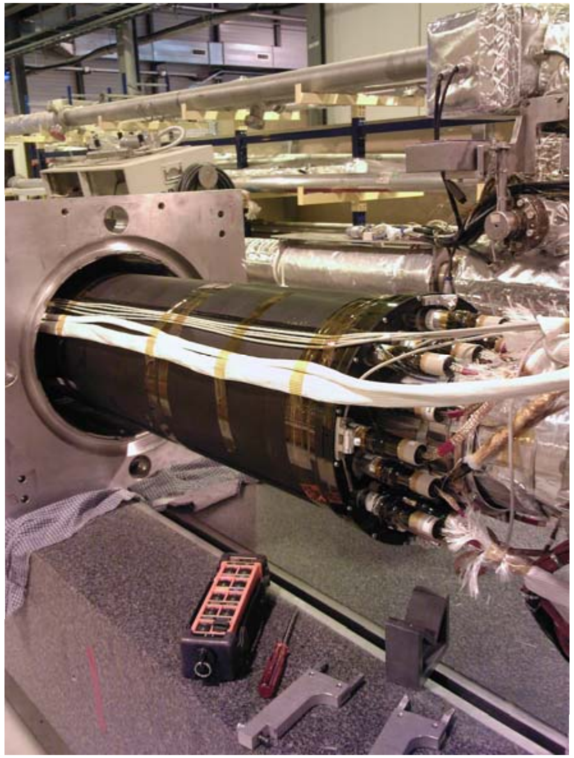
With *relative luminosity* we mean a measurement of L which is proportional to the actual luminosity in a constant but unknown way.

LUCID dedicated
relative monitor



**LUminosity measurement
with a Cherenkov
Integrating Detector**

- The **Cherenkov light** is produced at a 3° angle and makes typically 3 reflections while passing down the tube.
- The **Cherenkov light** is read out by Photo Multipliers (PMT) at the end of the tubes



Other possible
relative monitors

- Min. Bias Scint
- LAr/Tile current
- Beam Cond. Monitor.
- Zero Degree Cal.

Absolute Luminosity measurement implies to determine the calibration constants for any of those monitors.

Absolute Luminosity Measurements

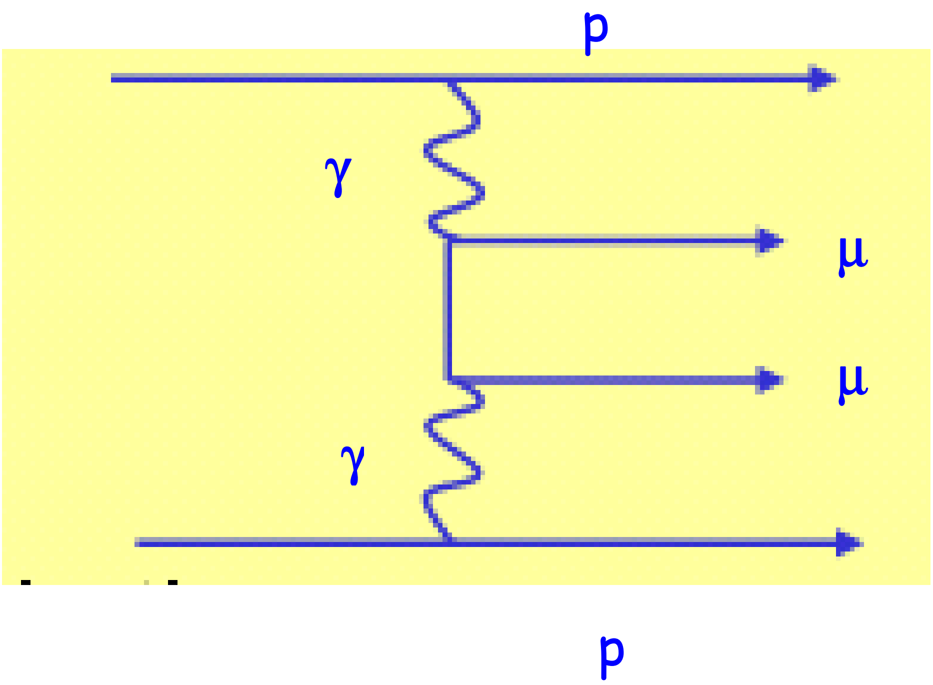
Goal: Measure L with $\lesssim 3\%$ accuracy (long term goal)

How? Three major approaches

- LHC Machine parameters - ATLAS/CMS
- Rates of well-calculable processes: e.g. QED (like LEP), EW and QCD - ATLAS/CMS
- Elastic scattering
  - Optical theorem: forward elastic rate + total inelastic rate. **CMS- mainly**
  - Luminosity from Coulomb Scattering –**ATLAS mainly**
  - Hybrids
    - → Use σ_{tot} measured by others
    - → Combine machine luminosity with optical theorem

We better pursue all options

Two photon production of muon pairs-QED



- Pure QED
- Theoretically well understood
- No strong interaction involving the muons
- Proton-proton re-scattering can be controlled
- Cross section known to better than 1 %

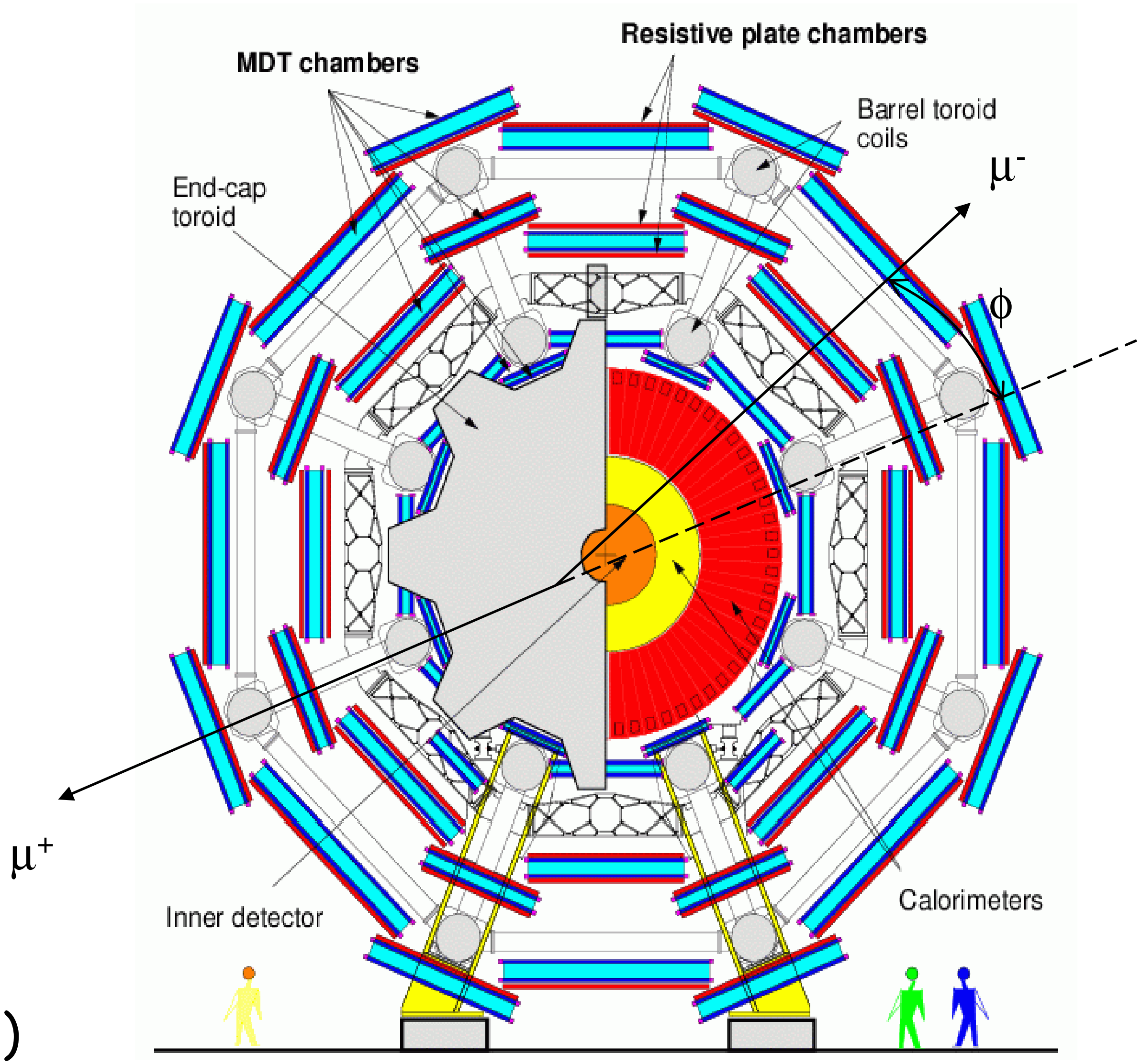
Two photon production of muon pairs

$P_t > 3$ GeV to reach the muon chambers

$P_t > 6$ GeV to maintain trigger efficiency and reasonable rates

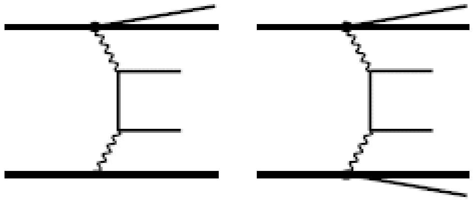
Centrally produced
$\eta < 2.5$

$P_t(\mu\mu) \sim 10\text{-}50$ MeV
Close to back to back in φ (background suppression)

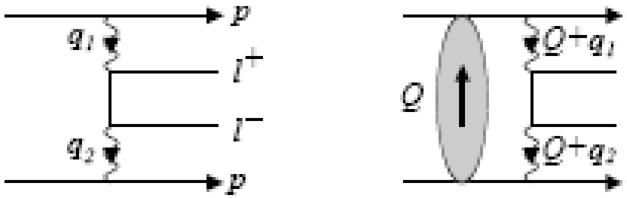


Backgrounds

- Strong interaction of a single proton



- Strong interaction between colliding proton



- Di-muons from Drell-Yan production

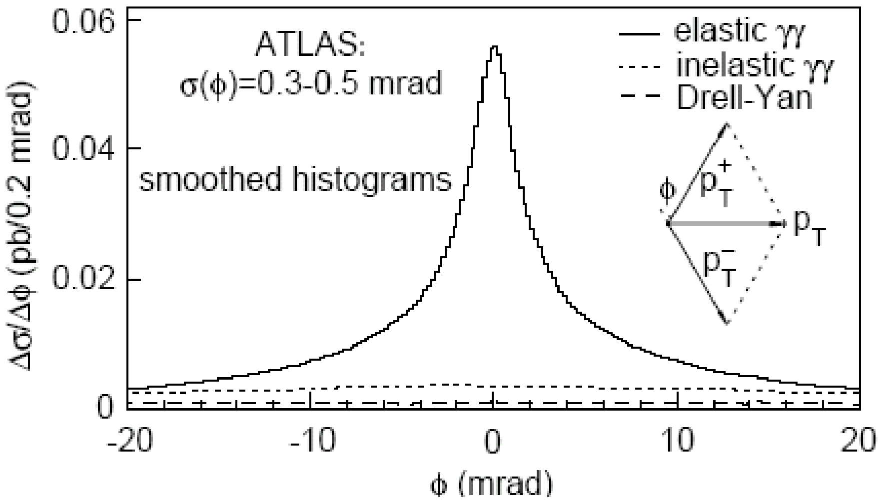
- Muons from hadron decay

Muon pairs

Event selection-two kind of cuts

- Kinematic cuts

  P_t of muons are equal within 2.5 σ of the measurement uncertainty



Suppresses efficiently proton excitations and proton-proton re-scattering

- Good Vertex fit and no other charged track

  Suppress Drell-Yan background and hadron decays

What are the difficulties ?

- The resolution

  The p_t resolution has to be very good in order to use the $P_t(\mu\mu) \sim$ 10-50 MeV cut.

- The rate

  The kinematical constraints ⇨ $\sigma \sim 1$ pb
  A typical 10^{33}/cm^2/sec year ~ 6 fb $^{-1}$ and $\sim$ 150 fills
  ⇨ 40 events fill ⇨ Luminosity MONITORING excluded
  What about LUMINOSITY calibration?
  1 % statistical error ⇨ more than a year of running

- Efficiencies

  Both trigger efficiency and detector efficiency must be known very precisely. Non trivial.

- Pile-up

  Running at 10^{34}/cm^2/sec ⇨ "vertex cut" and "no other charged track cut" will eliminate many good events

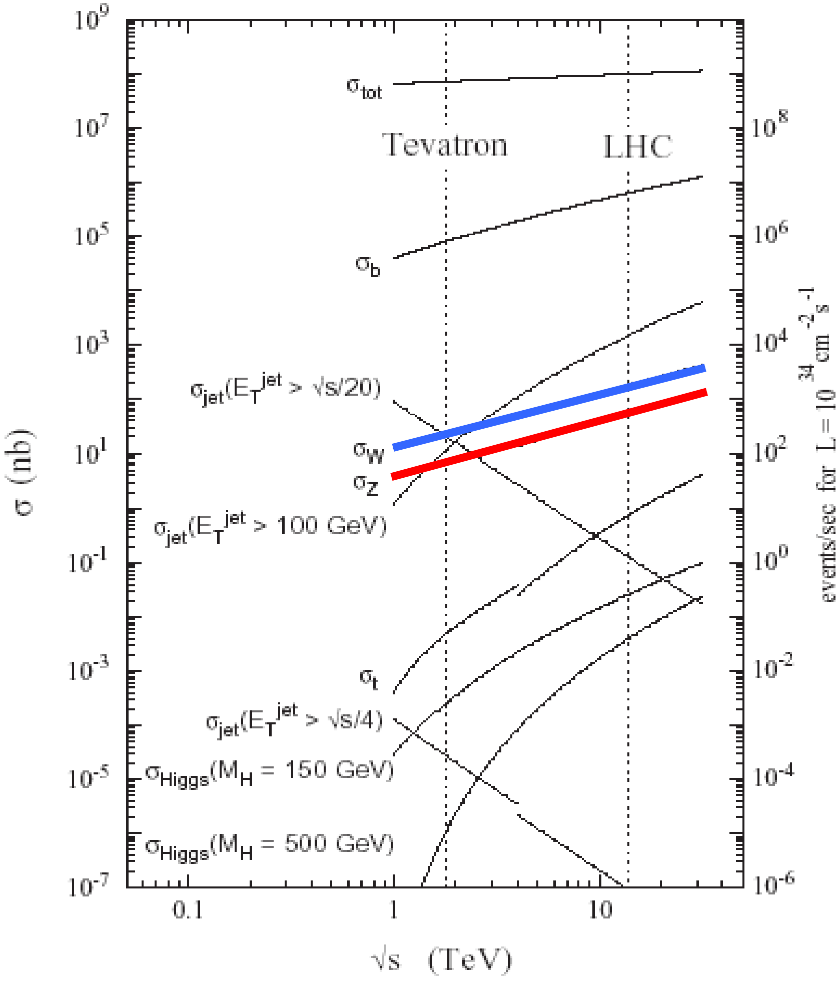
- CDF result

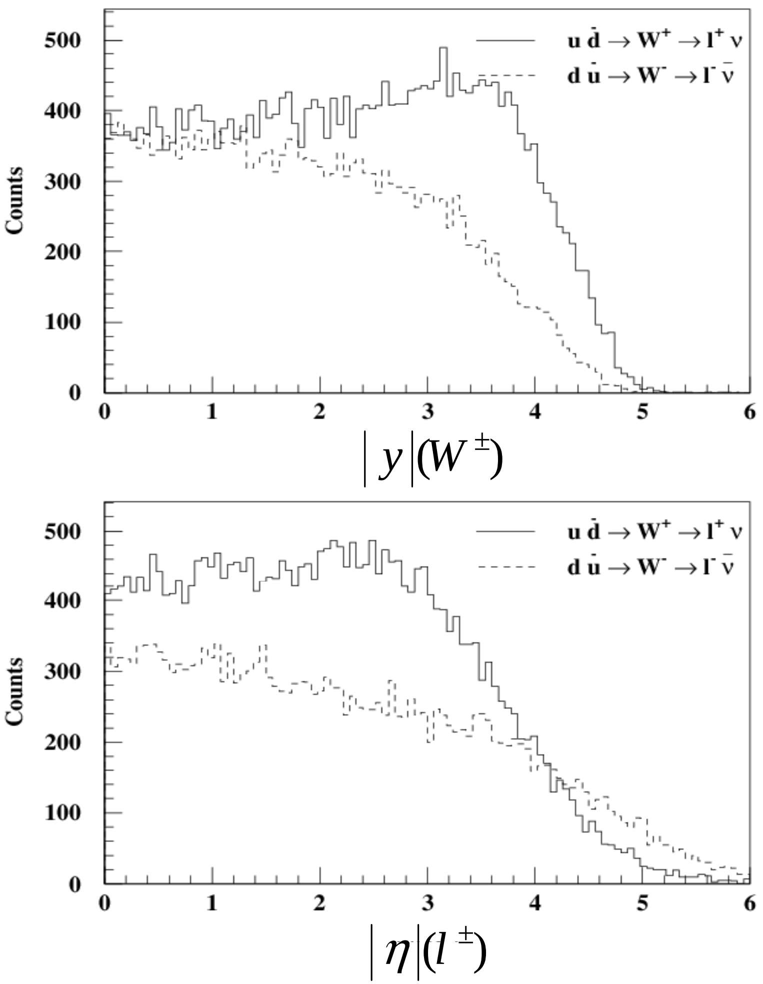
  First exclusive two-photon observed in e^+e^-. …. but….
  16 events for 530 pb^{-1} for a σ of 1.7 pb ⇨ overall efficiency 1.6 %

Summary – Muon Pairs

Cross sections well known and thus a potentially precise method.
However it seems that statistics will always be a problem.

W and Z counting





W and Z counting

- Constantly increasing precision of QCD calculations makes counting of leptonic decays of W and Z bosons a possible way of measuring luminosity. In addition there is a very clean experimental signature through the leptonic decay channel.

The Basic formula

$$L = (N - BG)/ (\varepsilon \times A_W \times \sigma_{th})$$

L is the integrated luminosity

N is the number of W candidates

BG is the number of back ground events

ε is the efficiency for detecting W decay products

A_W is the acceptance

σ_{th} is the theoretical inclusive cross section

Uncertainties on σ_{th}

- σ_{th} is the convolution of the Parton Distribution Functions (PDF) and of the partonic cross section

$$N_{pp\rightarrow W\pm} = L \text{ x } PDF(x_1, x_2, Q^2) \text{ x } \sigma_{q\bar{q}\rightarrow W^{\pm}}$$
$$N_{pp\rightarrow Z^0} = L \text{ x } PDF(x_1, x_2, Q^2) \text{ x } \sigma_{q\bar{q}\rightarrow Z^0}$$

- The uncertainty of the partonic cross section is available to NNLO in differential form with estimated scale uncertainty below 1 % (Anastasiou et al PRD 69, 94008.)

- PDF's more controversial and complex

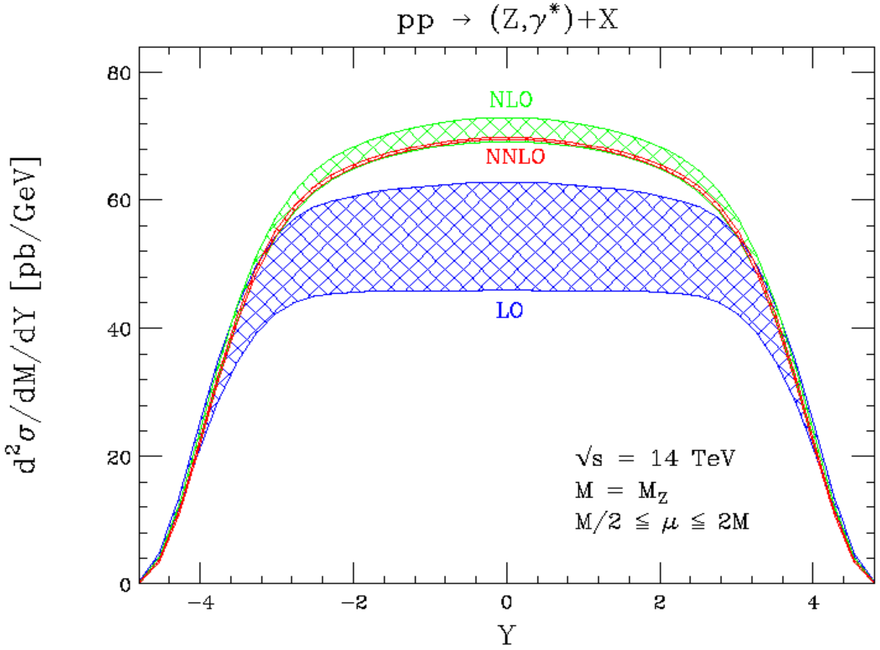
NNLO Calculations

Bands indicate the uncertainty from varying the renormalization (μ_R) and factorization (μ_F) scales in the range:

$M_Z/2 < (\mu_R = \mu_F) < 2M_Z$

- At LO: ~ 25 - 30 % x-s error
- At NLO: ~ 6 % x-s error
- At NNLO: < 1 % x-s error

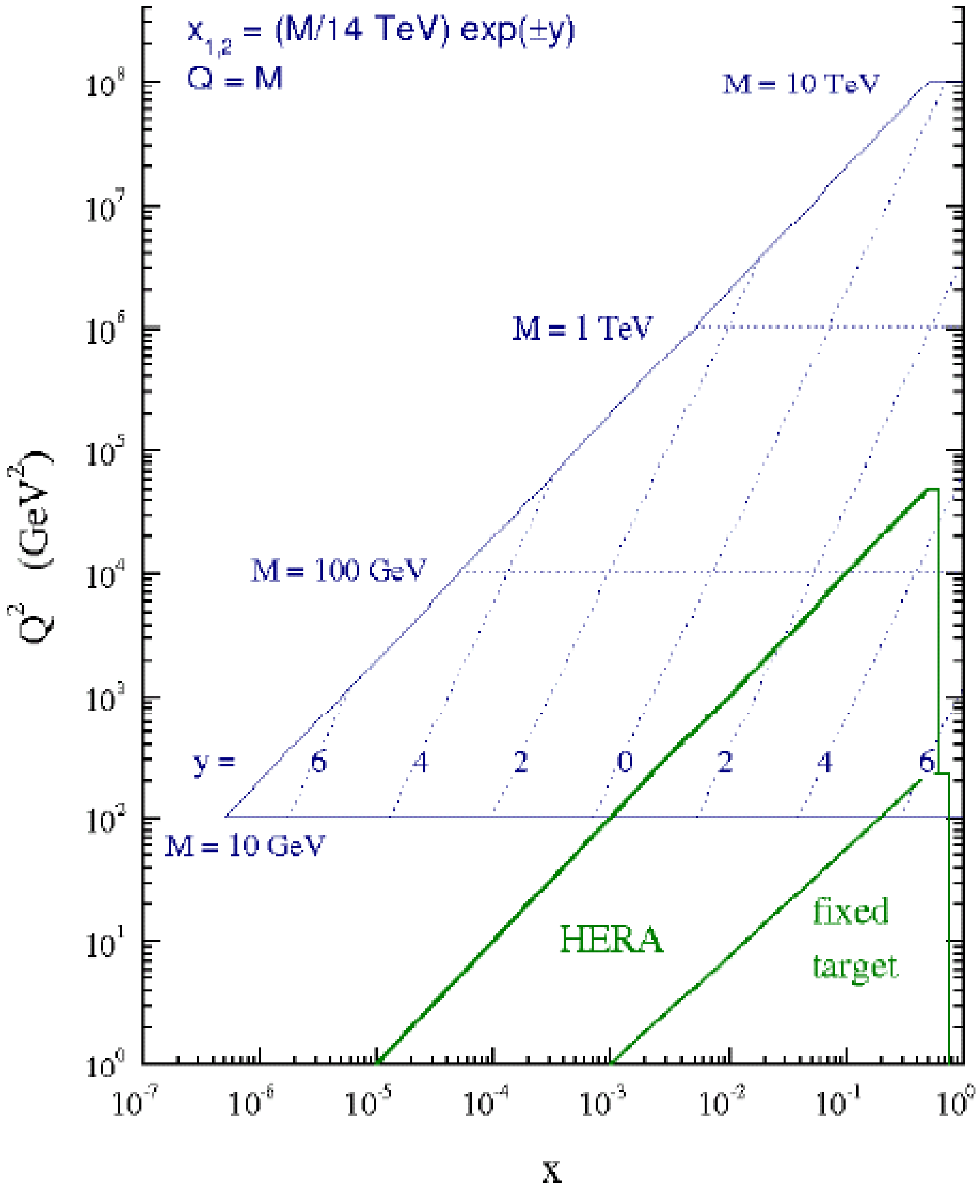
Anastasiou et al., Phys.Rev. D69:094008, 2004



Perturbative expansion is stabilizing and renormalization and factorization scales reduces to level of 1 %

W and Z

x and Q^2 range of PDF's at LHC



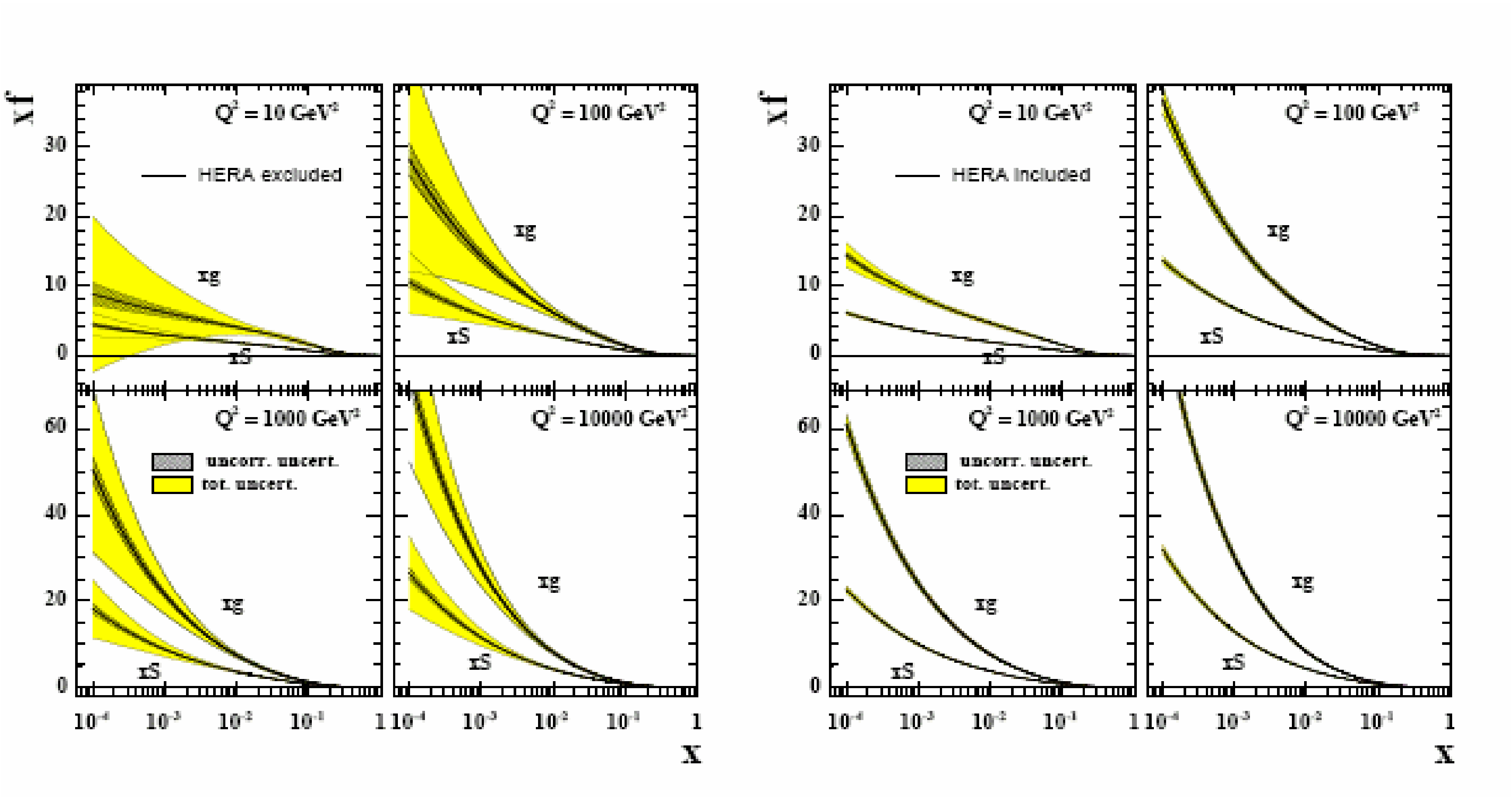
Sensitive to x values
$10^{-1} > x > x10^{-4}$

Sea quarks and antiquark dominates
g→qqbar

Gluon distribution at low x

HERA result important

Sea(xS) and gluon (xg) PDF's



PDF uncertainties reduced enormously with HERA.

Most PDF sets quote uncertainties implying error in the W/Z cross section < 5 %

However central values for different sets differs sometimes more !

Uncertainties in the acceptance A_W

The acceptance uncertainty depends on QCD theoretical error.

Generator needed to study the acceptance

The acceptance uncertainty depends on PDF,s , Initial State Radiation, intrinsic k_t.....

Uncertainty estimated to about 2 -3 %

Uncertainties on ε

Uncertainty on trigger efficiency for isolated leptons

Uncertainty on lepton identification cuts

Uncertainty also estimated to about 2-3 %
(for 50 pb^{-1} of data but …→ 0.5 % for 1 fb^{-1})

Summary – W and Z

W and Z production has a high cross section and clean experimental signature making it a good candidate for luminosity measurements.

The biggest uncertainties in the W/Z cross section comes from the PDF’s. This contribution is sometimes quoted as big as 8 % taking into account different PDF’s sets .
Adding the experimental uncertainties we end up in the 10 % range.

The precision might improve considerable if the LHC data themselves can help the understanding of the differences between different parameterizations ….. (A_W might be powerful in this context!)

The PDF’s will hopefully get more constrained from early LHC data .

Aiming at 3-5 % error in the error on the Luminosity from W/Z cross section after some time after the LHC start up

Luminosity from Machine parameters

- Luminosity depends exclusively on beam parameters:

$$\mathcal{L} = \frac{N^2 f_{\text{rev}} n_b}{4\pi\sigma^{*2}}$$

Depends on f_{rev} revolution frequency
n_b number of bunches
N number of particles/bunch
σ^* beam size or rather overlap integral at IP

$$\sqrt{1 + \left(\frac{\theta_c \sigma_z}{2\sigma^*}\right)^2}$$

The luminosity is reduced if there is a crossing angle (300 μrad)
1 % for β^* = 11 m and 20% for β^* = 0.5 m

- Luminosity accuracy limited by
  - extrapolation of σ_x, σ_y (or ε, β_x^*, β_y^*) from measurements of beam profiles elsewhere to IP; knowledge of optics, …
  - Precision in the measurement of the the bunch current
  - beam-beam effects at IP, effect of crossing angle at IP, …

> “ **We expect to be able to predict absolute luminosities for head-on collisions based on beam intensities and dimensions, to maybe 20-30 % and potentially much better if a special effort is made.** “
>
> **(Helmut Burkhardt)**

What means special effort?

Calibration runs

i.e calibrate the relative beam monitors of the experiments during dedicated calibration runs.

- Calibration runs with simplified LHC conditions
  - Reduced intensity
  - Fewer bunches
  - No crossing angle
  - Larger beam size
  - ….
- Simplified conditions that will optimize the condition for an accurate determination of both the beam sizes (overlap integral) and the bunch current.

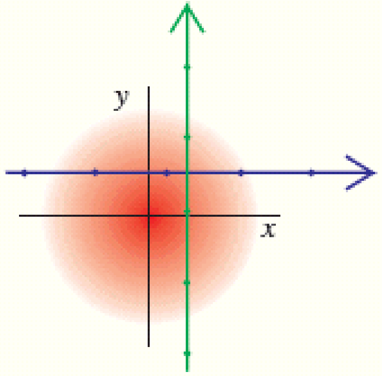
Determination of the overlap integral (pioneered by Van der Meer @ISR)

Luminosity with separation

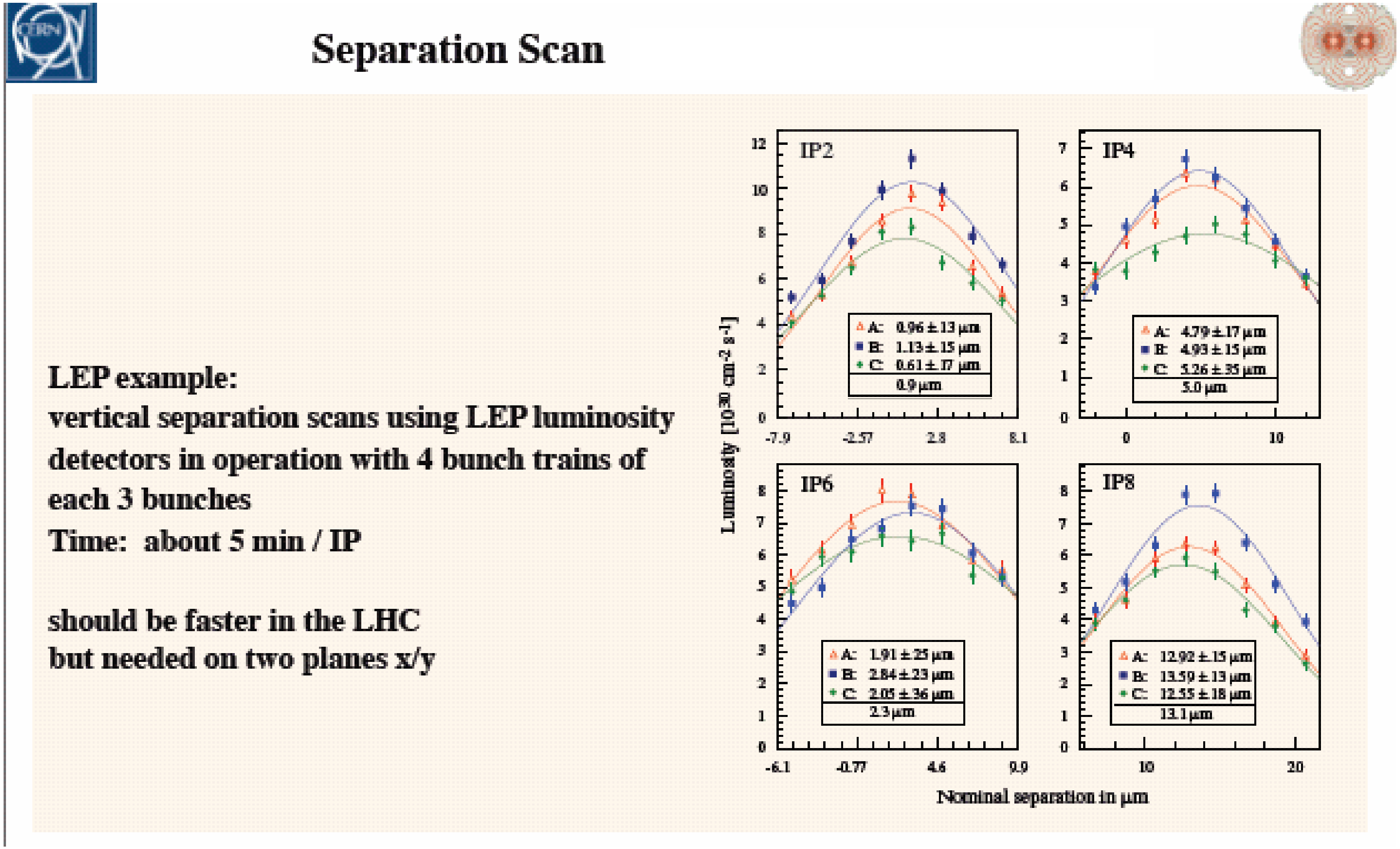
$$\frac{\mathcal{L}}{\mathcal{L}_0} = \exp\left[-\left(\frac{\delta x}{2\sigma_x}\right)^2 - \left(\frac{\delta y}{2\sigma_y}\right)^2\right]$$

$\frac{\delta x}{\sigma_x}$	$\frac{\delta y}{\sigma_y}$	$\frac{\mathcal{L}}{\mathcal{L}_0}$
0	0	1
1/2	0	0.9394
1/2	1/2	0.8825
1	0	0.7788
1	1	0.6065
2	0	0.3679
2	2	0.1353

Commissioning : simple, orthogonal x / y scan



Example LEP



Separation Scan

LEP example:
vertical separation scans using LEP luminosity detectors in operation with 4 bunch trains of each 3 bunches
Time: about 5 min / IP

should be faster in the LHC
but needed on two planes x/y

Summary – Machine parameters

- The special calibration run will improve the precision in the determination of the overlap integral . In addition it is also possible to improve on the measurement of N (number of particles per bunch). Parasitic particles in between bunches complicate accurate measurements. Calibration runs with large gaps will allow to kick out parasitic particles.
- Calibration run with special care and controlled condition has a good potential for accurate luminosity determination. About 1 % was achieved at the ISR.
- Less than ~5 % might be in reach at the LHC (will take some time !)
- Ph.D student in the machine department is working on this (supervisor Helmut Burkhardt)

Optical theorem

Elastic scattering and luminosity

Elastic scattering has traditionally provided a handle on luminosity at colliders.

Can be used in several ways.

The optical theorem relates the total cross section to the forward elastic rate

$$\sigma_{tot} = 4\pi \,\mathrm{Im}\, f_{el}(0) \rightarrow \qquad \boxed{L = \frac{1+\rho^2}{16\pi} \frac{N_{tot}{}^2}{\left.\frac{dN_{el}}{dt}\right|_{t=0}}}$$

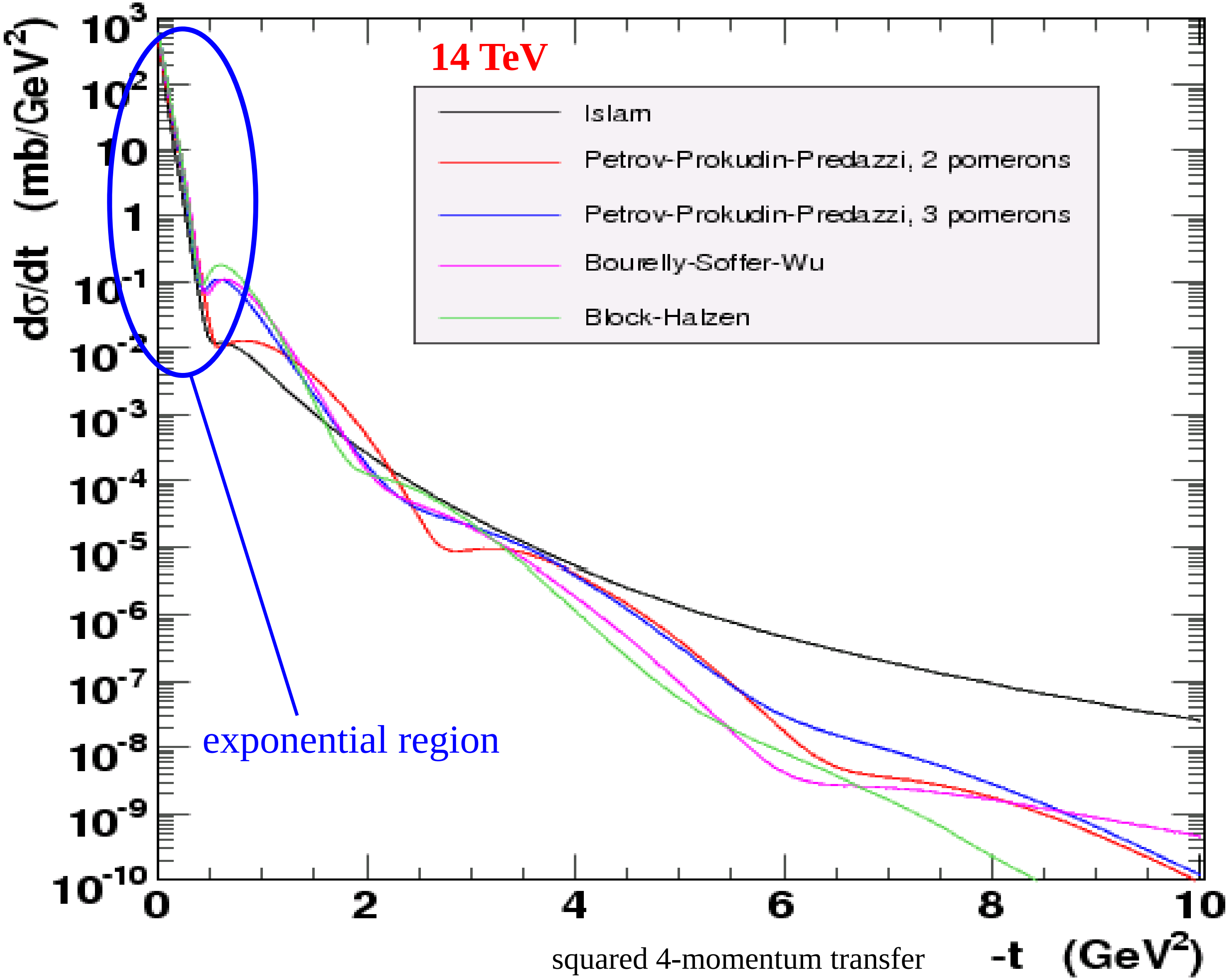
Thus we need

- Extrapolate the elastic cross section to t=o
- Measure the total rate
- Use best estimate of ρ ($\rho \sim 0.13$ +- 0.02 ⇨ 0.5 % in $\Delta L/L$)

Both ATLAS and CMS/TOTEM will use this method. However the η coverage in the forward direction is not optimal for ATLAS and thus this method is more powerful for CMS/TOTEM

Optical theorem

Elastic Scattering

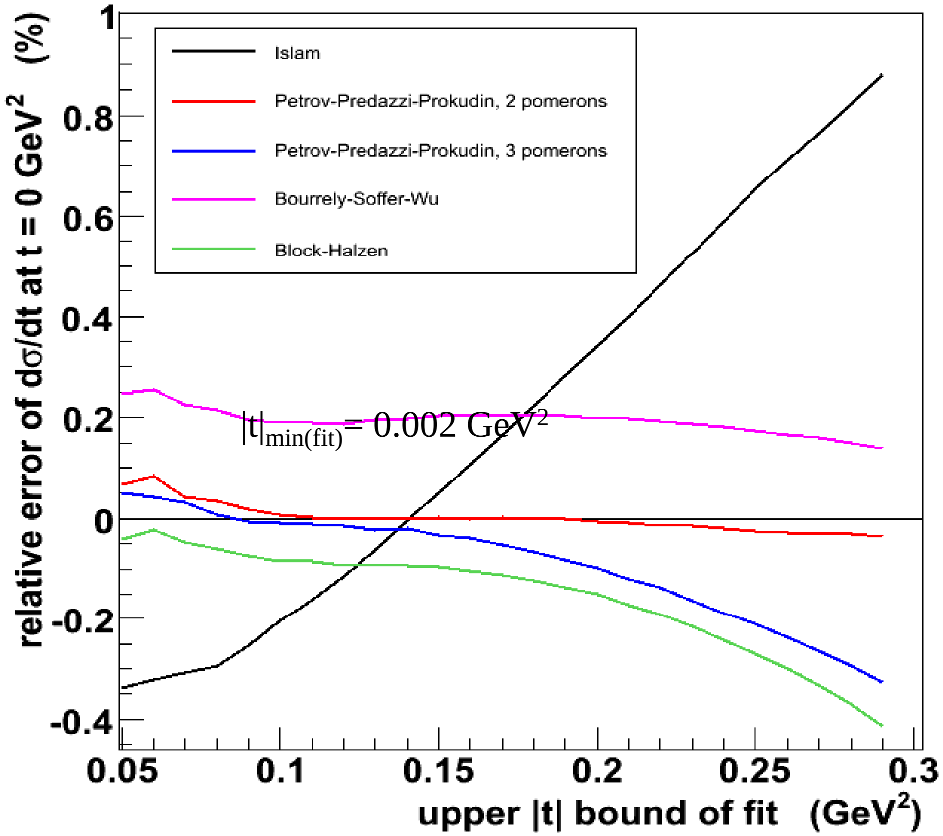


Slide from M.Diele TOTEM

Optical theorem

TOTEM's Baseline Optics: $\beta^* = 1540$ m

Model-dependent systematic error of extrapolation of the elastic cross-section to t = 0:

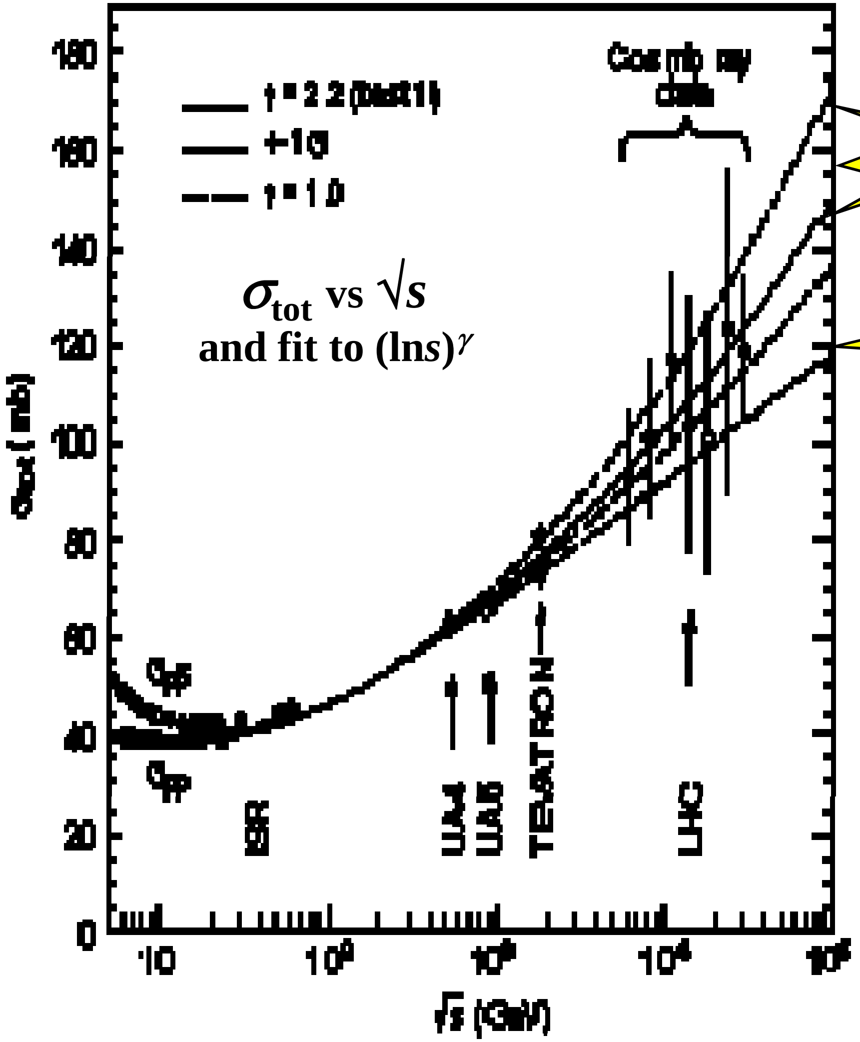


⇒ Uncertainty < 1 % (most cases < 0.2 %)

⊕ experimental systematics: 0.5 – 1 %

Slide from M.Diele TOTEM

The total cross section



σ_{tot} vs $\sqrt{s}$
and fit to $(\ln s)^{\gamma}$

γ=2.2±σ
(best fit)

γ=1.0

Summary – optical theorem

Measurements of the total rate in combination with the t-dependence of the elastic cross section is a well established and potentially powerful method for luminosity calibration and measurement of σ_{tot} .

Error contribution from extrapolation to $t=0$ $<$ 1 % (theoretical and experimental)

Error contribution from total rate ~ 0.8 % → 1.6 % in luminosity

Error from ρ ~ 0 .5 %

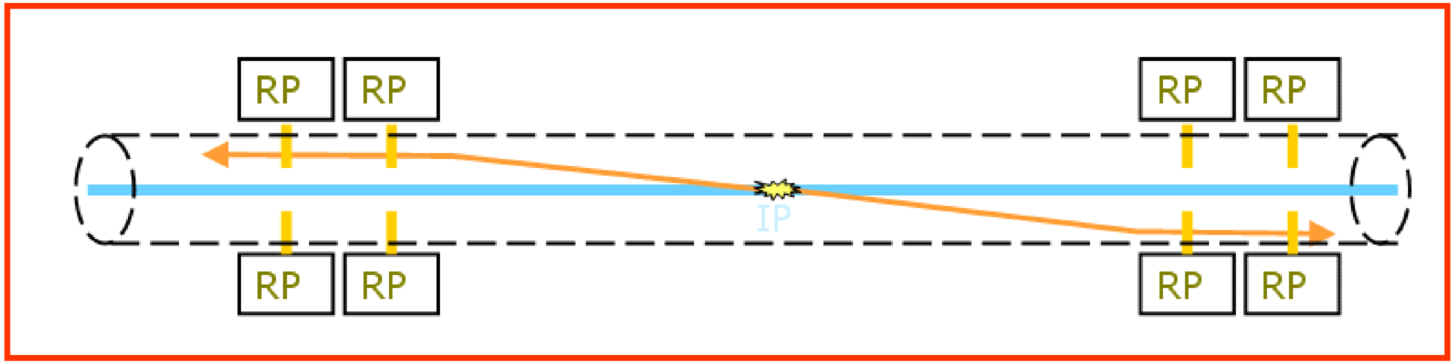
⇨ Luminosity determination of 2-3 % is in reach

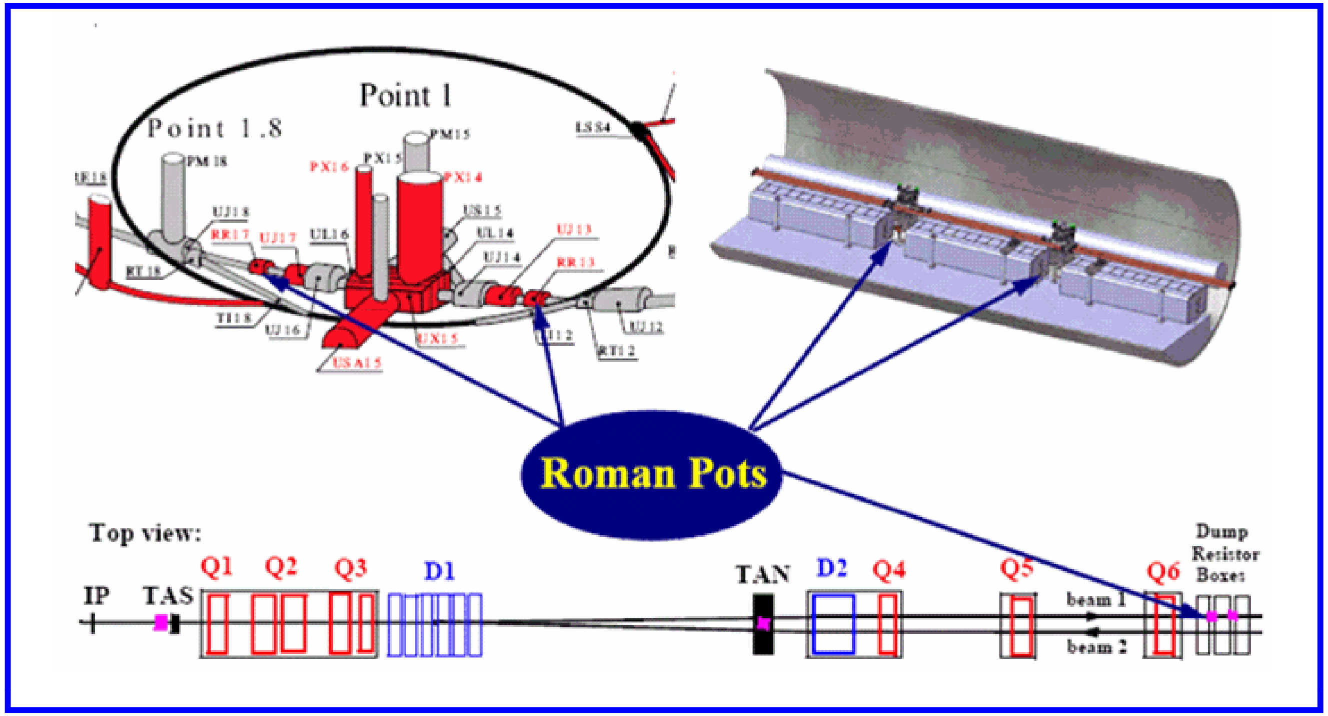
Coulomb

Elastic scattering at very small angles-ATLAS

- Measure elastic scattering at such small t-values that the cross section becomes sensitive to the Coulomb amplitude
- Effectively a normalization of the luminosity to the exactly calculable Coulomb amplitude
- No total rate measurement and thus no additional detectors to cover $\eta > 5$ needed
- UA4 used this method to determine the luminosity to 2-3 %

ATLAS Roman Pots

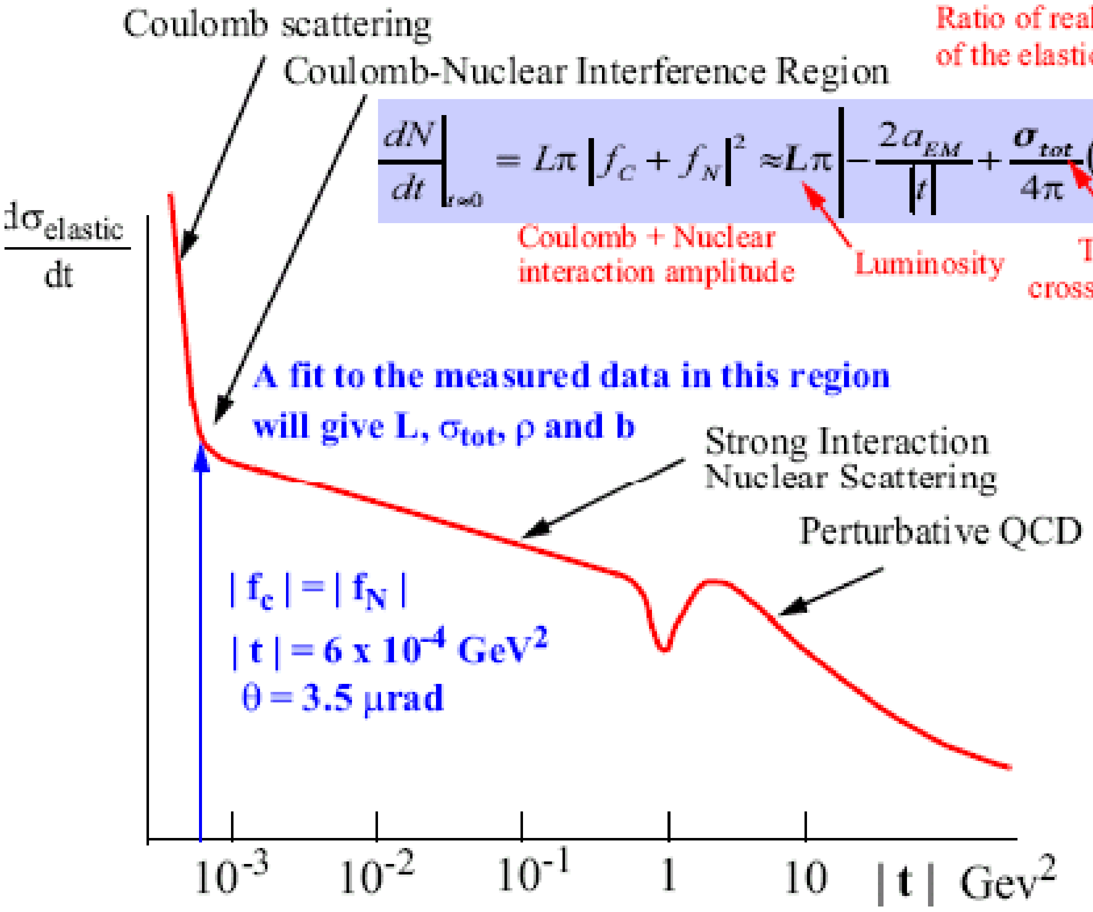




- **A**bsolute
- **L**uminosity
- **F**or
- **ATLAS**

Coulomb

Elastic scattering at very small angles



$$\left.\frac{dN}{dt}\right|_{t\approx 0} = L\pi\left|f_C + f_N\right|^2 \approx L\pi\left|-\frac{2\alpha_{EM}}{|t|} + \frac{\sigma_{tot}}{4\pi}(i+\rho)e^{-b|t|/2}\right|^2$$

Ratio of real to imaginary part of the elastic scattering amplitude

Coulomb + Nuclear interaction amplitude

Luminosity

Total cross section

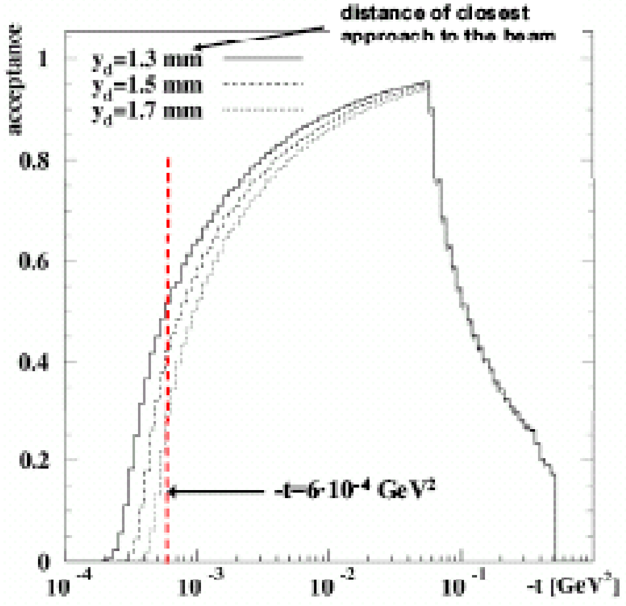
Slope parameter

A fit to the measured data in this region will give L, σ_{tot}, ρ and b

$|f_c| = |f_N|$

$|t| = 6 \times 10^{-4}$ GeV^2

$\theta = 3.5$ µrad



Coulomb

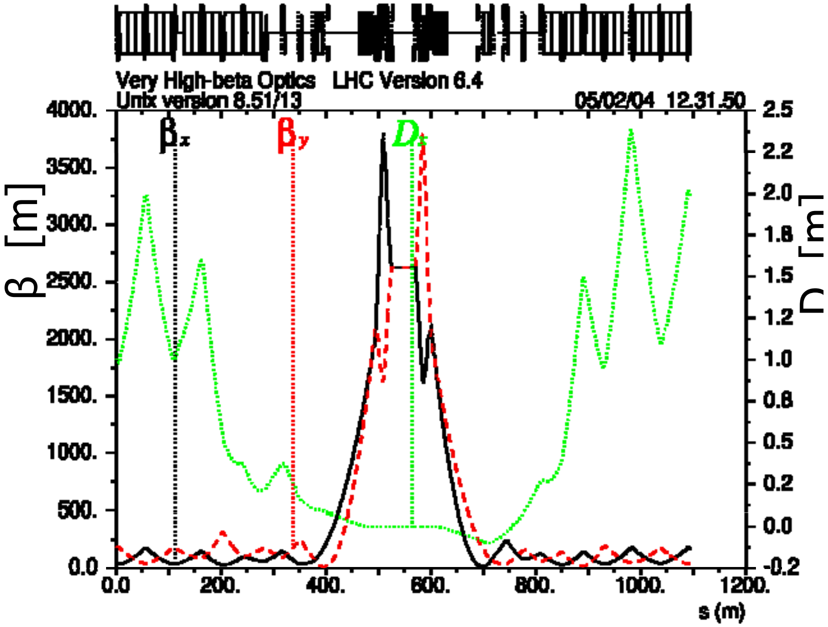
What is needed for small angle elastic scattering measurement?

- Special beam conditions
- "Edgeless" Detector
- Compact electronics
- Precision Mechanics in the form of Roman Pots to approach the beam

Coulomb

The beam conditions

Nominal divergence of LHC is 32 μrad
We are interested in angles ~ x 10 smaller
⇨ high beta optics and small emittance
(divergence $\propto \sqrt{\varepsilon} / \sqrt{\beta^*}$)

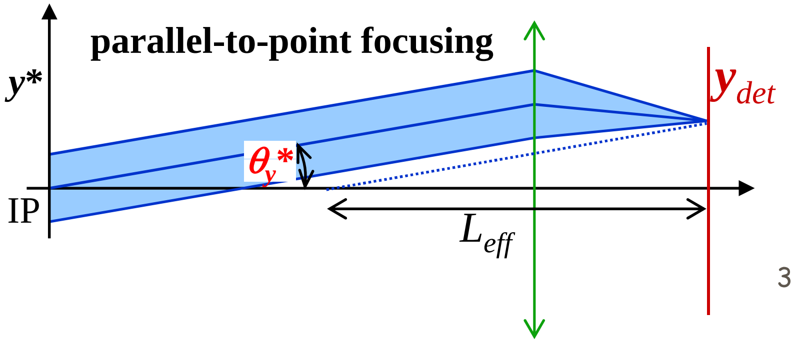


To reach the Coulomb interference region we will use an optics with β^* ~ 2.6 km and ε_N ~ 1 μm rad

Zero crossing angle ⇨ fewer bunches

High β^* and few bunches ⇨ low luminosity

Insensitive to vertex smearing
large effective lever arm L_{eff}



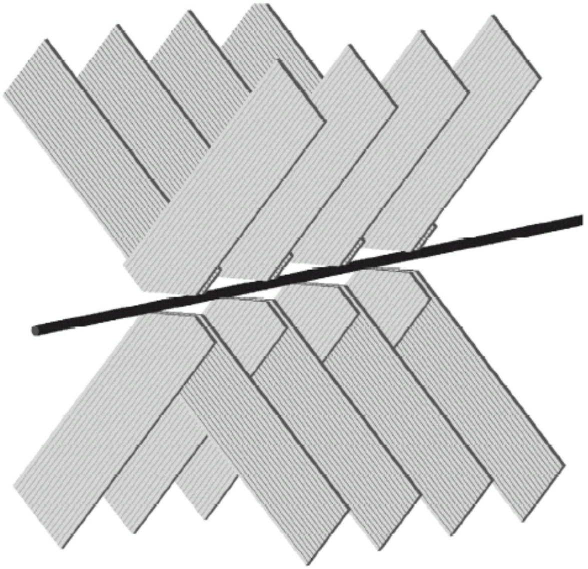
The detectors-fiber tracker

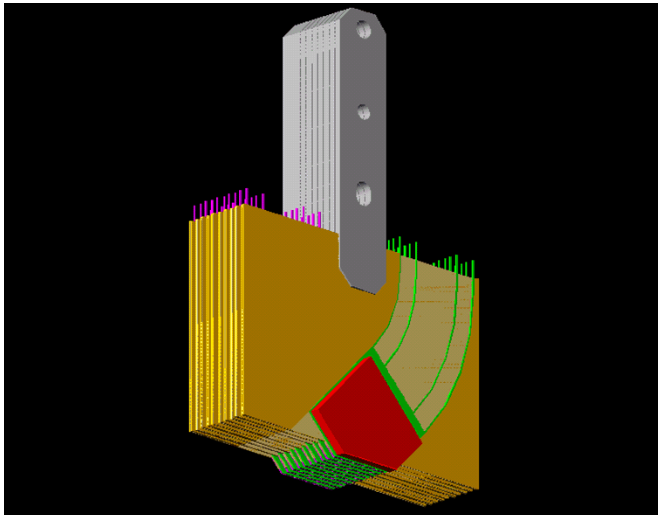
Choice of technology:

- minimum dead space
- no sensitivity to EM induction from beam
- resolution $\sigma \sim 30\ \mu m$

Concept

- 2x10 U planes
  2x10 V planes
- Scintillating fibers
  0.5 mm^2 squared
- Staggered planes
- MAPMT readout

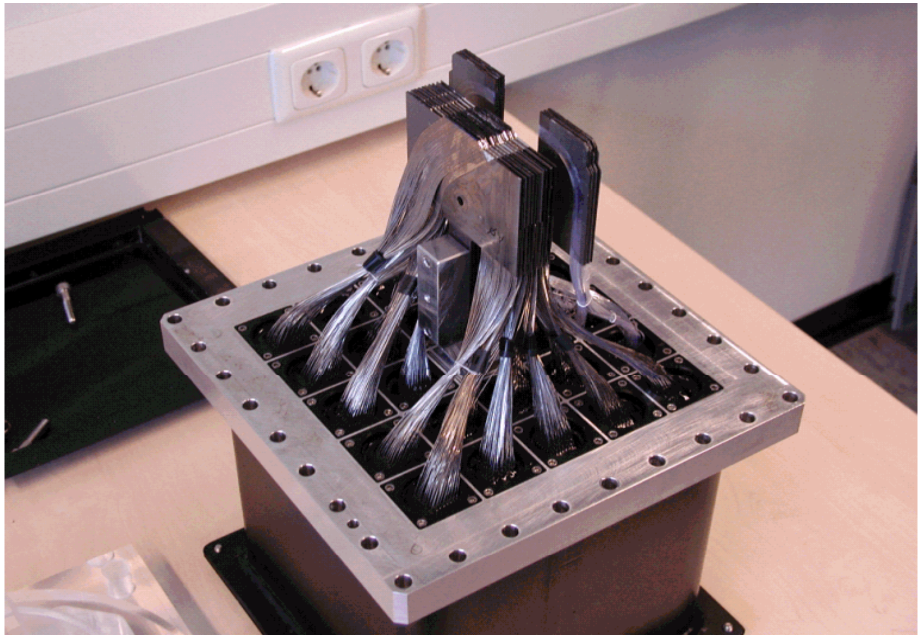


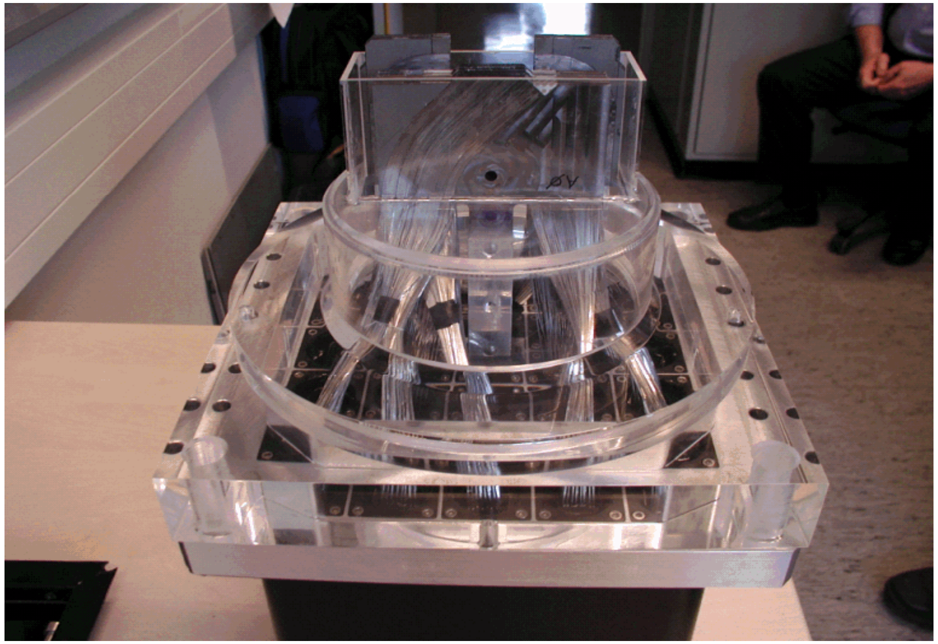


Coulomb

Test beam-this summer

Complete detector for one Roman Pot i.e. 1460 channels





Summary - Coulomb

- Getting the Luminosity through Coulomb normalization will be extremely challenging due to the small angles and the required closeness to the beam.
- Main challenge is not in the detectors but rather in the required beam properties
- Will the optics properties of the beam be know to the required precision?
- Will it be possible to decrease the emittance as much as we need?
- Will the beam halo allow approaches in the mm range?

No definite answers before LHC start up

- UA4 achieved a precision using this method at the level of 2-3 %
  but at the LHC it will be harder .....

Luminosity measurement only interesting if there is luminosity to be measured !

Parameter evolution and rates

$$L = \frac{N^2 k_b f \gamma}{4\pi \varepsilon_n \beta^*} F$$

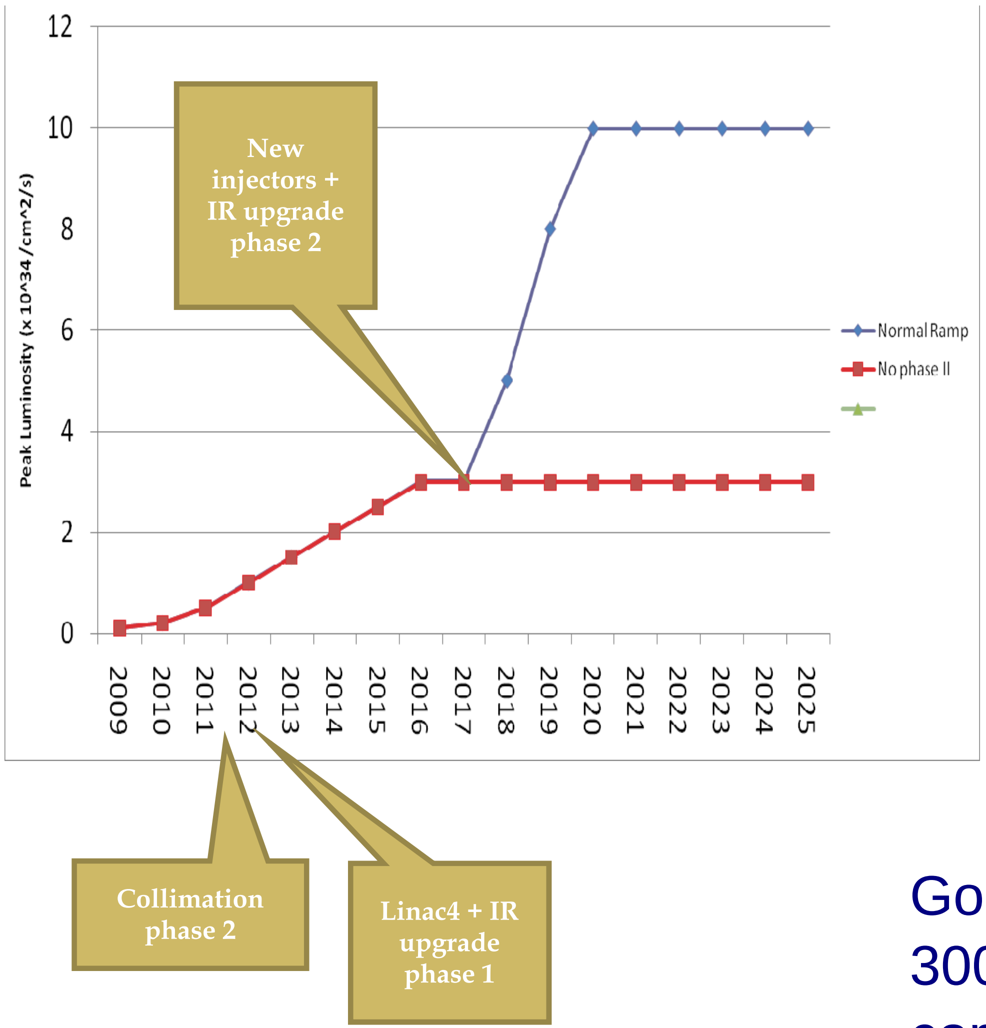
$$Eventrate / Cross = \frac{L \sigma_{TOT}}{k_b f}$$

All values for nominal emittance, 10m β^* in points 2 and 8

All values for 936 or 2808 bunches colliding in 2 and 8 (not quite right)

	Parameters			Beam levels		Rates in 1 and 5		Rates in 2 and 8	
	k_b	N	β^* 1,5 (m)	I_{beam} proton	E_{beam} (MJ)	Luminosity ($cm^{-2}s^{-1}$)	Events/ crossing	Luminosity ($cm^{-2}s^{-1}$)	Events/ crossing
5 TeV	43	4 10^{10}	11	1.7 10^{12}	1.4	8.0 10^{29}	<< 1	Depend on the configuration of collision pattern	
	43	4 10^{10}	3	1.7 10^{12}	1.4	2.9 10^{30}	0.36		
	156	4 10^{10}	3	6.2 10^{12}	5	1.0 10^{31}	0.36		
	156	9 10^{10}	3	1.4 10^{13}	11	5.4 10^{31}	1.8		
7 TeV	936	4 10^{10}	11	3.7 10^{13}	42	2.4 10^{31}	<< 1	2.6 10^{31}	0.15
	936	4 10^{10}	2	3.7 10^{13}	42	1.3 10^{32}	0.73	2.6 10^{31}	0.15
	936	6 10^{10}	2	5.6 10^{13}	63	2.9 10^{32}	1.6	6.0 10^{31}	0.34
	936	9 10^{10}	1	8.4 10^{13}	94	1.2 10^{33}	7	1.3 10^{32}	0.76
	2808	4 10^{10}	11	1.1 10^{14}	126	7.2 10^{31}	<< 1	7.9 10^{31}	0.15
	2808	4 10^{10}	2	1.1 10^{14}	126	3.8 10^{32}	0.72	7.9 10^{31}	0.15
	2808	5 10^{10}	1	1.4 10^{14}	157	1.1 10^{33}	2.1	1.2 10^{32}	0.24
	2808	5 10^{10}	0.55	1.4 10^{14}	157	1.9 10^{33}	3.6	1.2 10^{32}	0.24

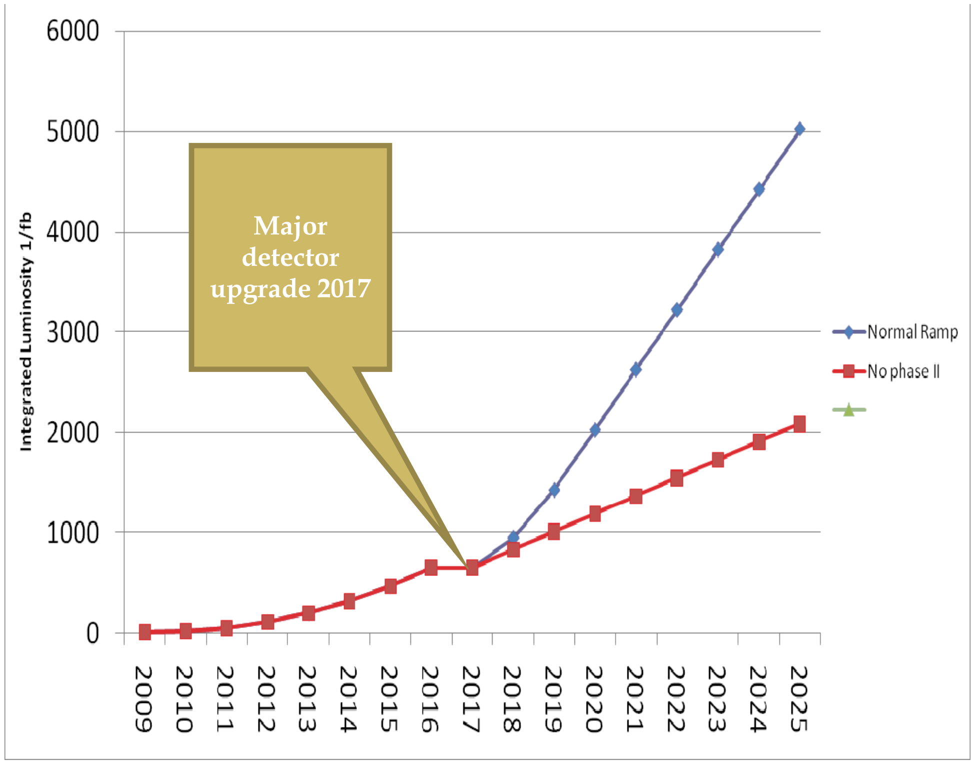
Peak and Integrated Luminosity



New injectors + IR upgrade phase 2

Collimation phase 2

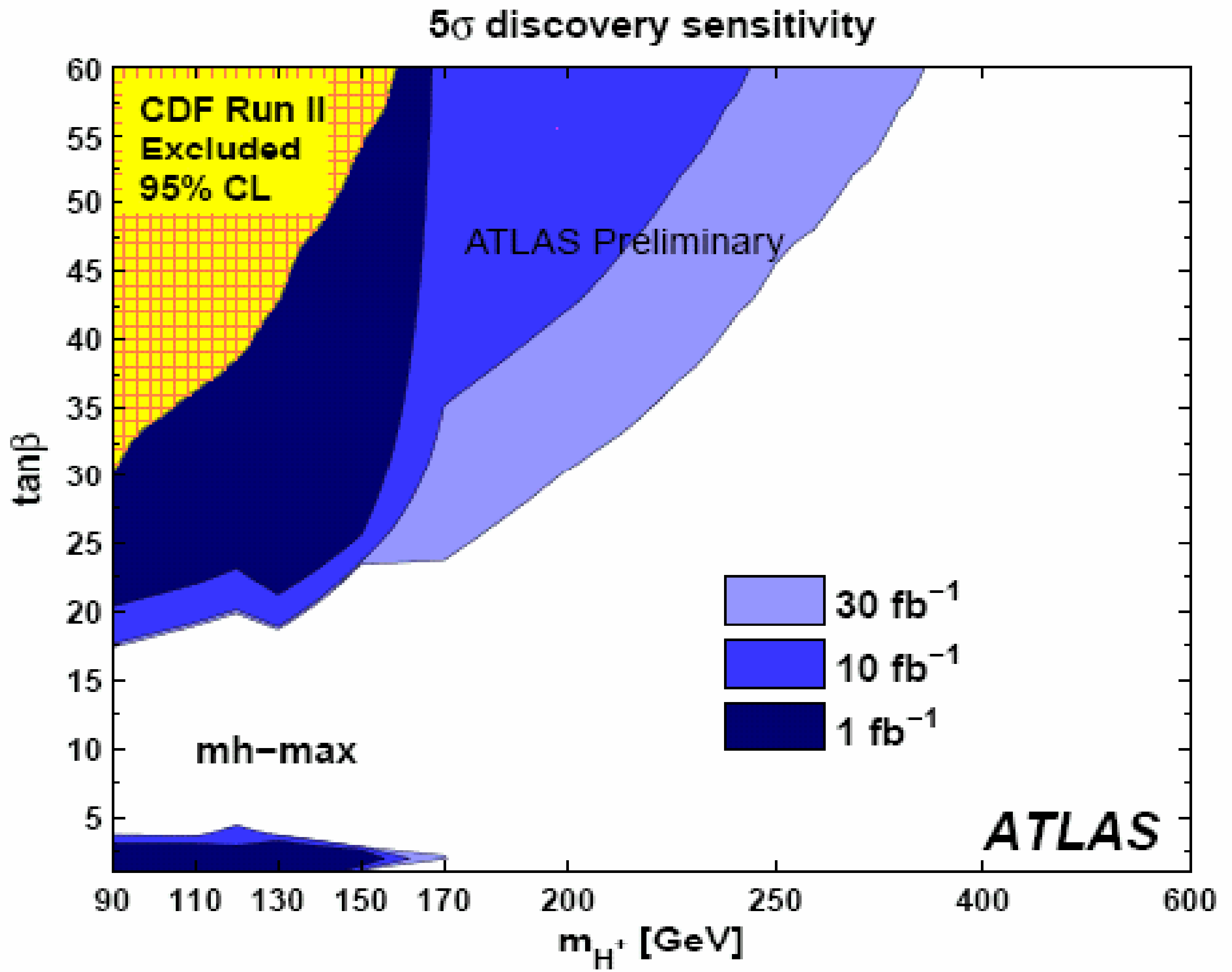
Linac4 + IR upgrade phase 1



Major detector upgrade 2017

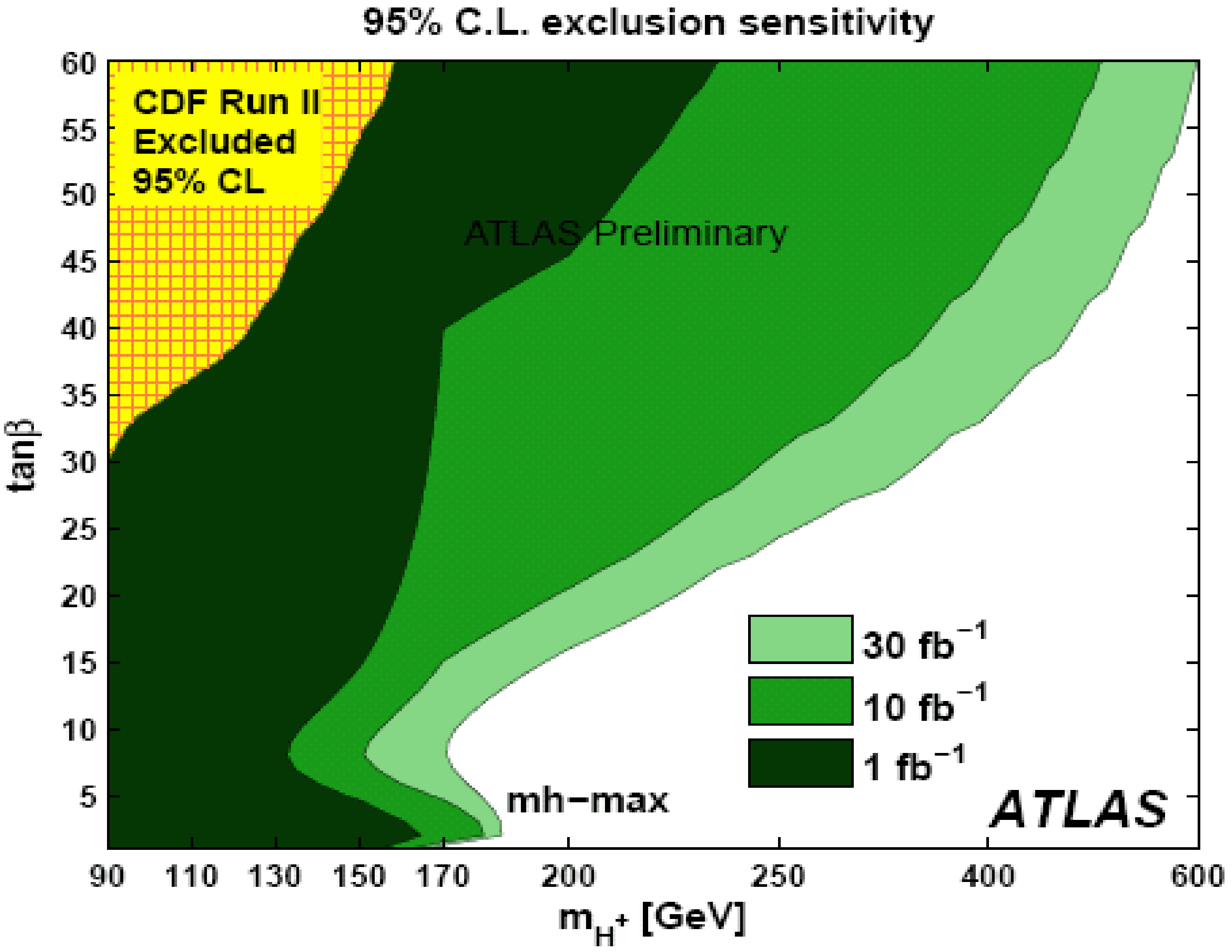
Goal for ATLAS Upgrade:
3000 fb^{-1} recorded
cope with ~400 pile-up events each BC

ATLAS MSSM H^+ Discovery Potential $(m_h - max)$



ATLAS MSSM H^+ discovery potential for 1, 10 and 30 fb^{-1}

ATLAS MSSM H^+ Exclusion Potential ($m_h - max$)



ATLAS MSSM H^+ exclusion potential for 1, 10 and 30 fb^{-1}

(Shown by R Garoby at the
LHCC meeting on 1st July)

Basic expectations

Collimation phase 2

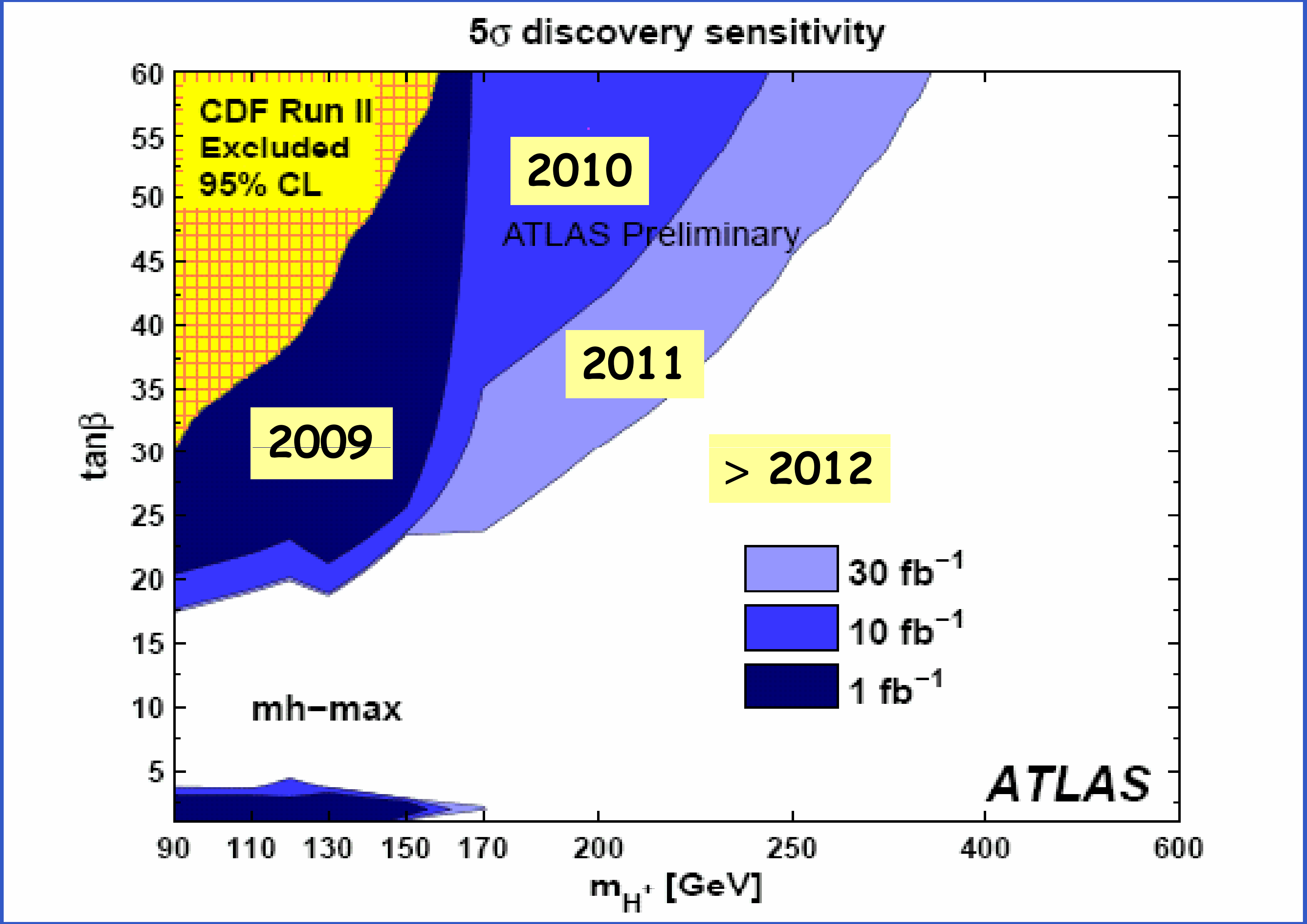
Linac4 + IR upgrade phase 1

New injectors + IR upgrade phase 2

Radiation damage limit ???

	Normal Ramp			No phase II		
Year	Peak Lumi (x 10^{34})	Annual Integrated (fb^{-1})	Total Integrated (fb^{-1})	Peak Lumi (x 10^{34})	Annual Integrated (fb^{-1})	Total Integrated (fb^{-1})
2009	0.1	6	6	0.1	6	6
2010	0.2	12	18	0.2	12	18
2011	0.5	30	48	0.5	30	48
2012	1	60	108	1	60	108
2013	1.5	90	198	1.5	90	198
2014	2	120	318	2	120	318
2015	2.5	150	468	2.5	150	468
2016	3	180	648	3	180	648
2017	3	0	648	3	0	648
2018	5	300	948	3	180	828
2019	8	420	1428	3	180	1008
2020	10	540	2028	3	180	1188
2021	10	600	2628	3	180	1368
2022	10	600	3228	3	180	1548
2023	10	600	3828	3	180	1728
2024	10	600	4428	3	180	1908
2025	10	600	5028	3	180	2088

ATLAS MSSM H^+ Discovery Potential $(m_h - max)$



ATLAS MSSM H^+ discovery potential for 1, 10 and 30 fb^{-1}

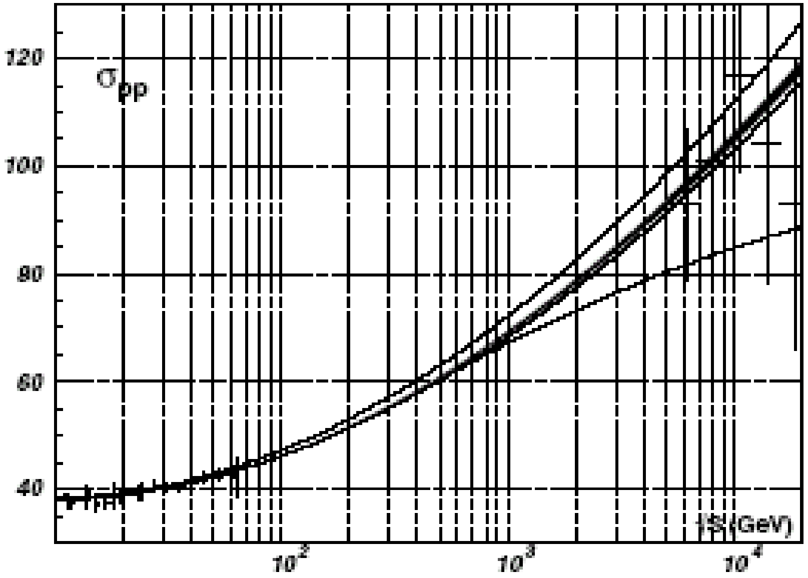
Overall conclusions

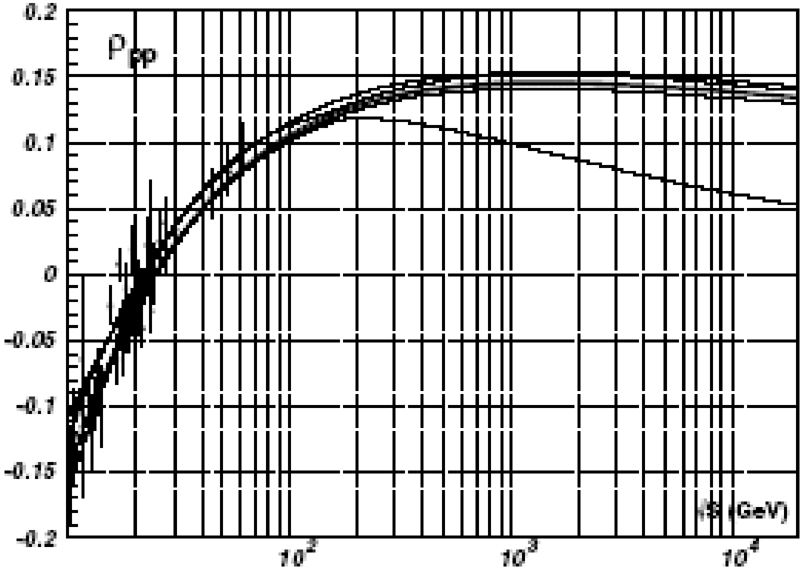
- We have looked at the principle methods for luminosity determination at the LHC
- Each method has its weakness and its strength
- Accurate luminosity determination is difficult and will take time (cf Tevatron). First values will be in the 20 % range.
  Aiming to a precision well below 5 % after some years.
- We better exploit different options in parallell

Back up

The ρ parameter

- ρ = Re F(0)/Im F(0) linked to the total cross section via dispersion relations
- ρ is sensitive to the total cross section beyond the energy at which ρ is measured $\Rightarrow$ predictions of σ_{tot} beyond LHC energies is possible
- Inversely :Are dispersion relations still valid at LHC energies?

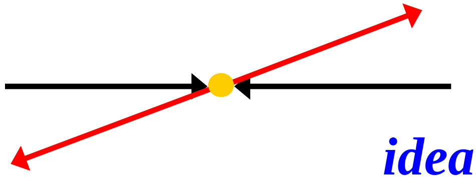




t-resolution

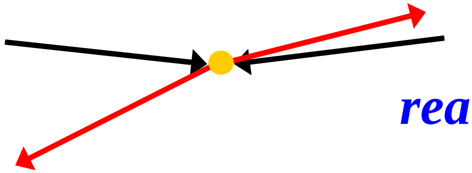
The *t*-resolution is dominated by the divergence of the incoming beams.

σ’=0.23 μrad

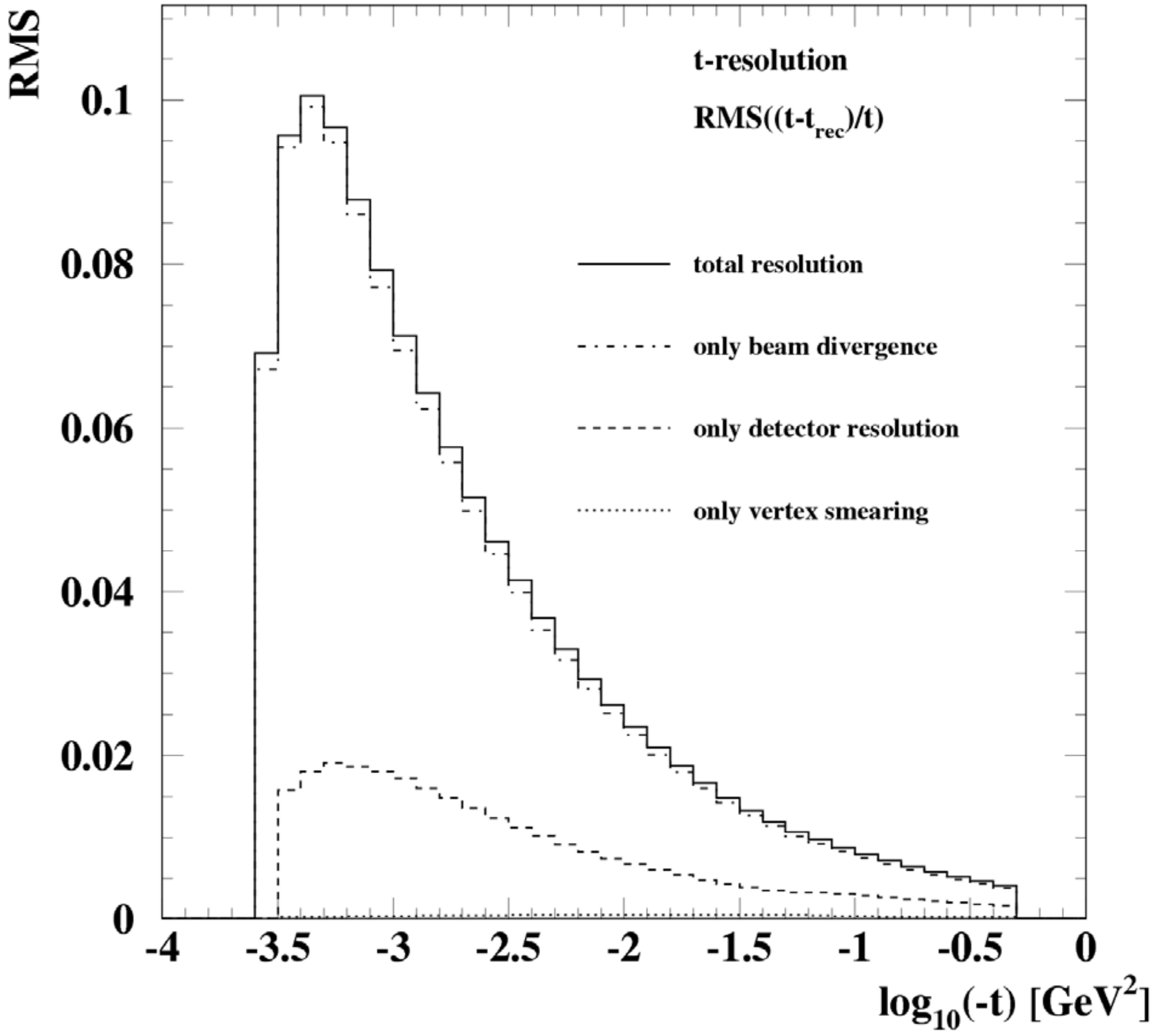


ideal case

$$-\hat{t} = (p_1 - p_3)^2 \approx (p\theta^*)^2$$

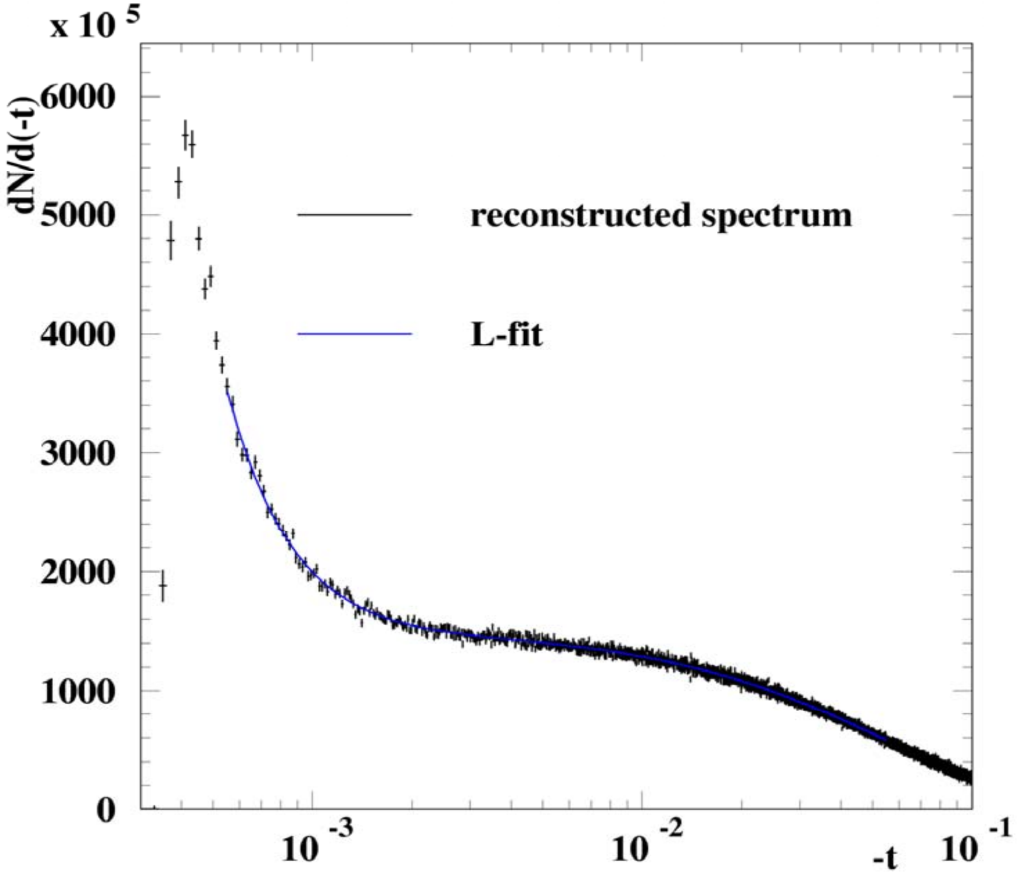


real world



L from a fit to the t-spectrum

$$\frac{dN}{dt} = L\pi\left|F_C + F_N\right|^2$$
$$= L\left(\frac{4\pi\alpha^2(\hbar c)^2}{|t|^2} - \frac{\alpha\rho\sigma_{tot}e^{-B|t|/2}}{|t|} + \frac{\sigma_{tot}^2\left(1+\rho^2\right)e^{-B|t|}}{16\pi(\hbar c)^2}\right)$$

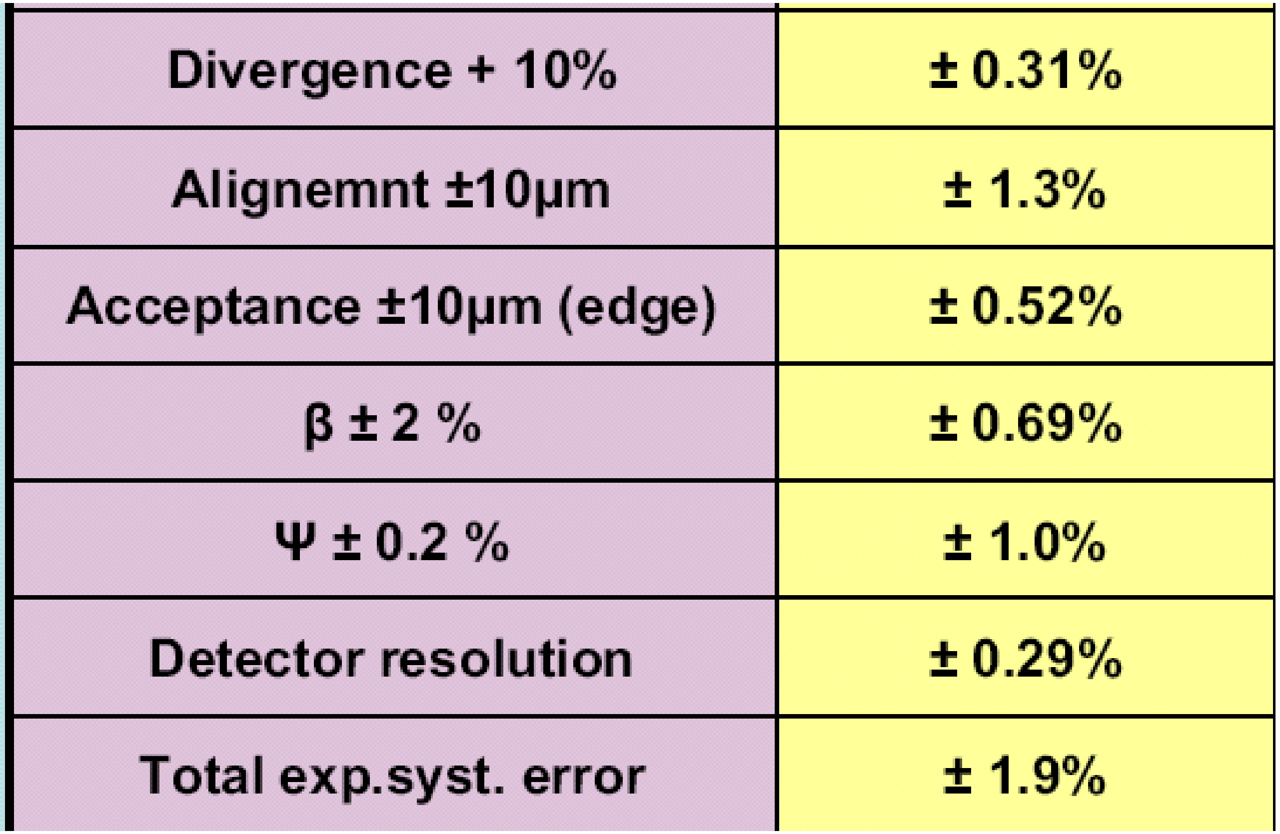


Simulating 10 M events,
running 100 hrs
fit range 0.00055-0.055

	input	fit	error	correlation
L	8.10 10^{26}	8.151 10^{26}	1.77 %	
σ_{tot}	101.5 mb	101.14 mb	0.9%	-99%
B	18 Gev^{-2}	17.93 Gev^{-2}	0.3%	57%
ρ	0.15	0.143	4.3%	89%

large stat.correlation between
L and other parameters

Systematic errors

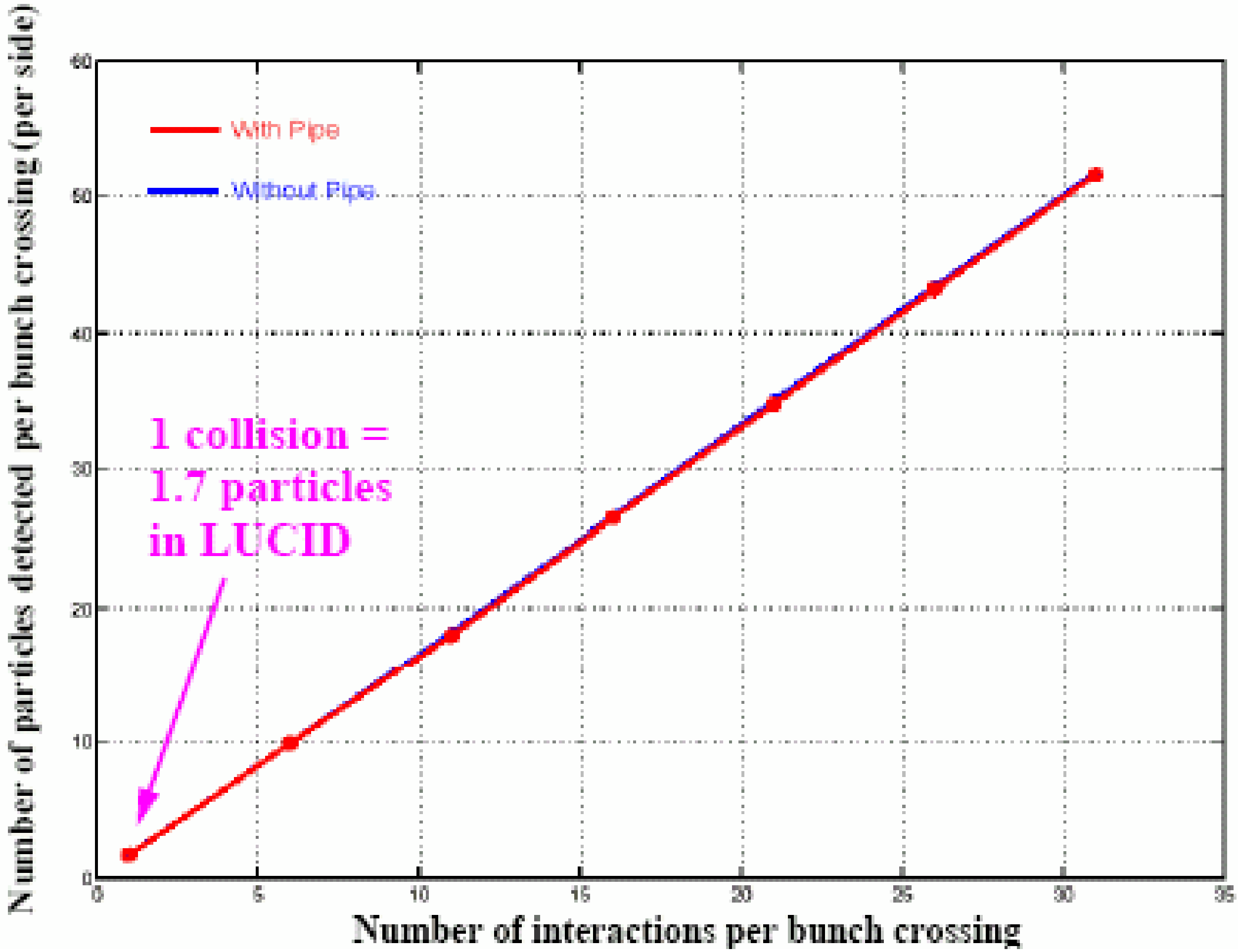


Divergence + 10%	± 0.31%
Alignemnt ±10µm	± 1.3%
Acceptance ±10µm (edge)	± 0.52%
β ± 2 %	± 0.69%
Ψ ± 0.2 %	± 1.0%
Detector resolution	± 0.29%
Total exp.syst. error	± 1.9%

Background subtraction ~ 1%

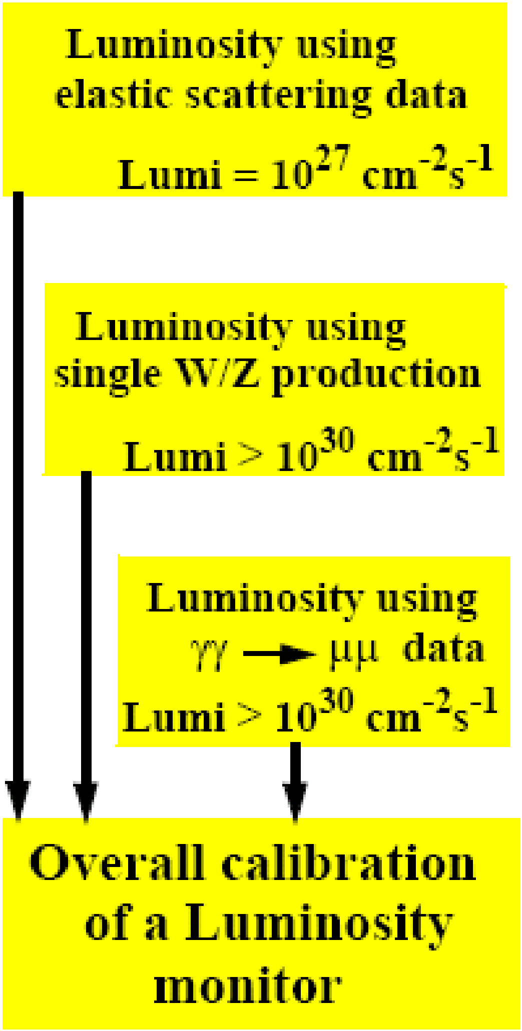
LUCID: Principle

Simulations shows a perfectly linear relationship between the number of particles measured in LUCID and the luminosity.



1 collision = 1.7 particles in LUCID

V. Hedberg



Luminosity using elastic scattering data

Lumi = 10^{27} cm^{-2}s^{-1}

Luminosity using single W/Z production

Lumi > 10^{30} cm^{-2}s^{-1}

Luminosity using $\gamma\gamma \rightarrow \mu\mu$ data

Lumi > 10^{30} cm^{-2}s^{-1}

Overall calibration of a Luminosity monitor

Roman Pots equipped with scintillating fibre detectors will be used to measure the protons in elastic scattering events.

The rate of $W \rightarrow l\nu$ is expected to be 60 Hz at high luminosity

The uncertainty in the rate of W/Z events is currently about 4%

QED process

About 10k events/day at high lumi if $P_T > 3$ GeV (1.5k if $P_T > 6$ GeV)

LUCID: A detector consisting of Cherenkov tubes that surrounds the beampipe. No absolute luminosity measurement !

Luminosity transfer 10^{27}-10^{34} cm^{-2} sec^{-1}

- Bunch to bunch resolution ⇒ we can consider luminosity / bunch

⇒ ~ 2 x10^{-4} interactions per bunch to 20 interactions/bunch

⇓

- Required dynamic range of the detector ~ 20
- Required background < < 2 x10^{-4} interactions per bunch
  - main background from beam-gas interactions
  - Dynamic vacuum difficult to estimate but at low luminosity we will be close to the static vacuum.
  - Assume static vacuum ⇒ beam gas ~ 10^{-7} interactions /bunch/m
  - We are in the process to perform MC calculation to see how much of this will affect LUCID

How to select events and eliminate background(N-BG)

- QCD background and heavy quarks
- $Z \rightarrow e^+e^-$ where the second lepton is not identified

  $Z \rightarrow \tau^+\tau^-$ where one τ decay in the electron channel
- ttbar background
- $W \rightarrow \tau \rightarrow l$; τ decaying in the electron channel

- Pseudorapidity $\eta < 2.4$ (no bias at edge)
- $P_t > 25$ GeV (efficient electron ident)
- Missing $E_t > 25$ GeV
- No jets with $P_t > 30$ GeV (QCD background)