Tevatron for LHC:
B pyhsics

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Introduction

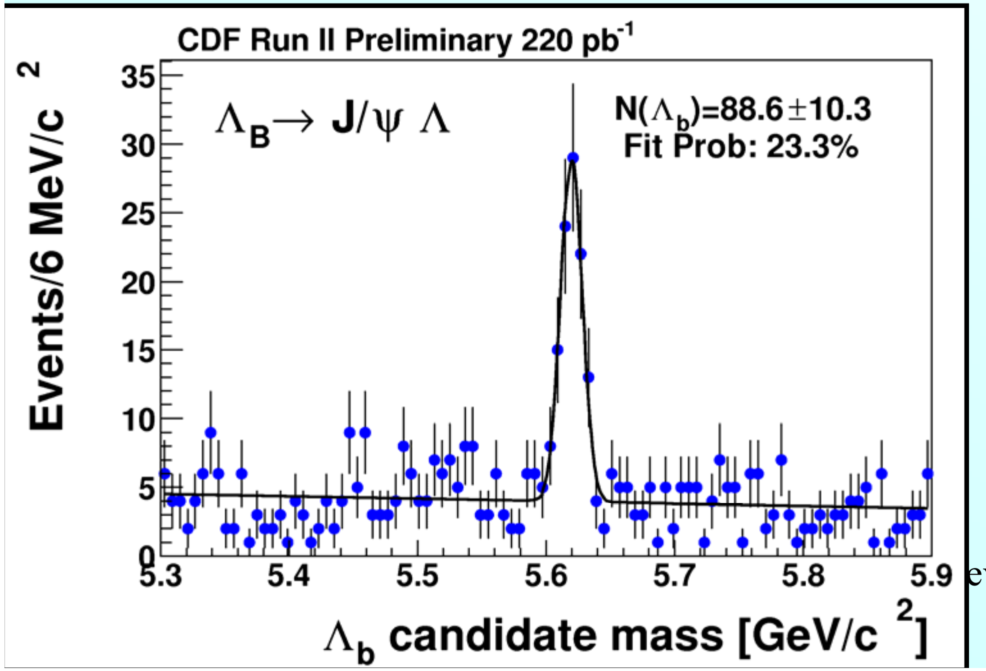
- B physics is a very active subject both in DØ and CDF;
- This direction will be actively exploited in ATLAS and CMS, and it will be the main subject of research for LHCb;
- Both current and future experiments will work in the same environment of hadron collider;
- Technical possibilities for B physics of ATLAS and CMS will be quite close to that of DØ and CDF;
- LHCb, as a dedicated B physics experiment, will be much superior;
- A lot of experience to share, many lessons to learn...

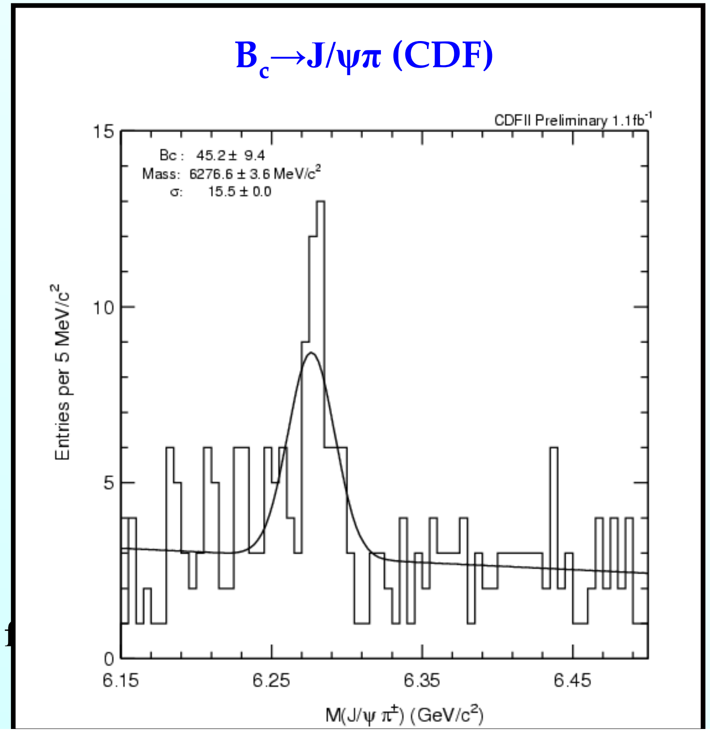
Results of Tevatron in B physics

- **Review of obtained and expected results from Tevatron is useful:**
  - Studies at LHC will be based on the results of Tevatron;
  - LHC will start from the point where Tevatron finished;
  - Experimental program of LHC can be adjusted following the achieved results of Tevatron;
  - Tevatron results provide a real scale estimate of precision expected in the future measurements;

Long living of B hadrons

- **Almost all long living hadrons with b quark (B_s, Λ_b, B_c) are established at Tevatron;**
  - Even though the first claims of B_s and Λ_b were made by LEP experiments, the current precision in parameters of these hadrons dominates by Tevatron results;
- **Observation of the remaining long living B hadrons (Ξ_b, Ω_b) can be expected;**





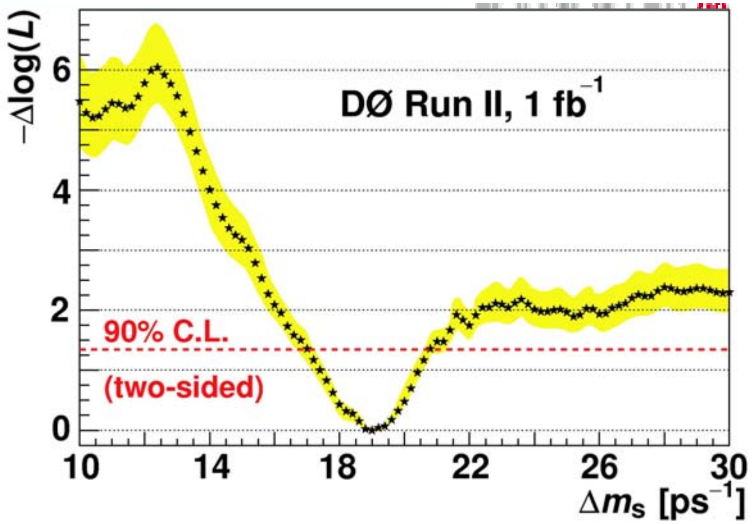
Properties of B_s meson

- **B_s meson is a special object for study at hadron colliders:**
  - No competition with B factories;
  - Interesting properties:
    - mass difference;
    - lifetime difference;
    - Rare decays;
    - CP violation;
  - Potentially high impact of new physics beyond SM;
- **B_s is actively studied at Tevatron, and this exploration will be one of the most important subjects in B physics at LHC;**

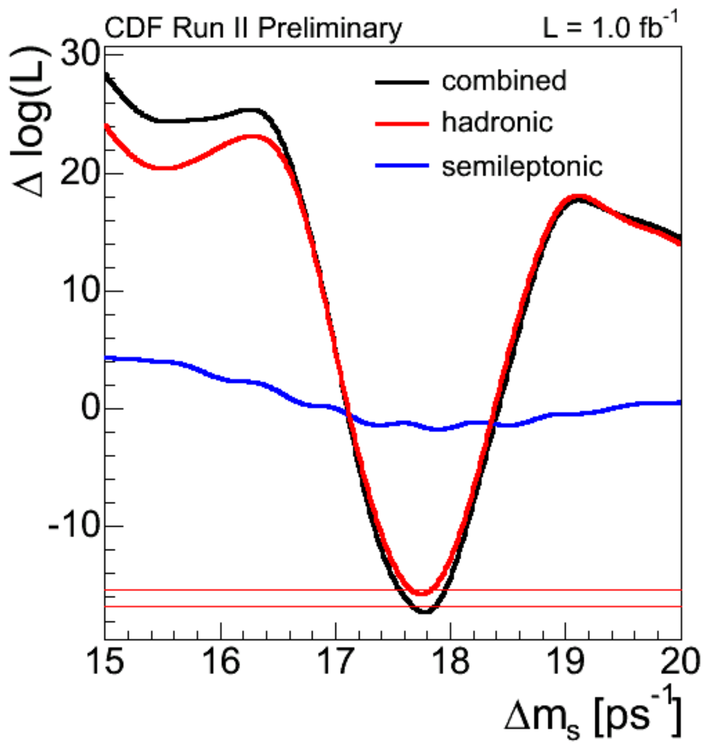
Mass difference of B_s

- **Measurement of mass difference is one of the most important achievements of Tevatron;**
  - First indication of interval given by DØ;
  - First precise measurement of value made by CDF;
- **Obtained value is very precise, main uncertainty in comparing with SM comes from theory;**
- **No additional efforts required from LHC in this direction;**

DØ 90% CL interval: $17 < \Delta M_s < 21$ ps^{-1}

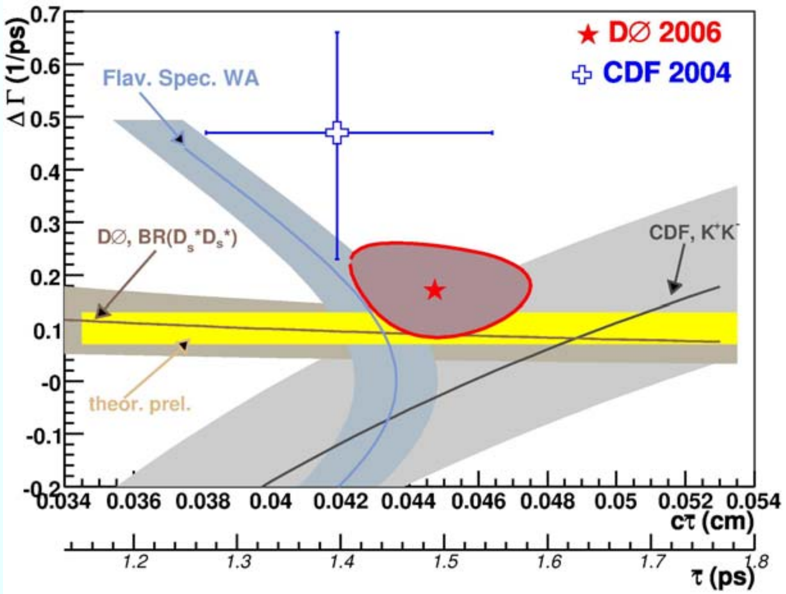


CDF value: $\Delta M_s = 17.77 \pm 0.10 \pm 0.07$ ps^{-1}



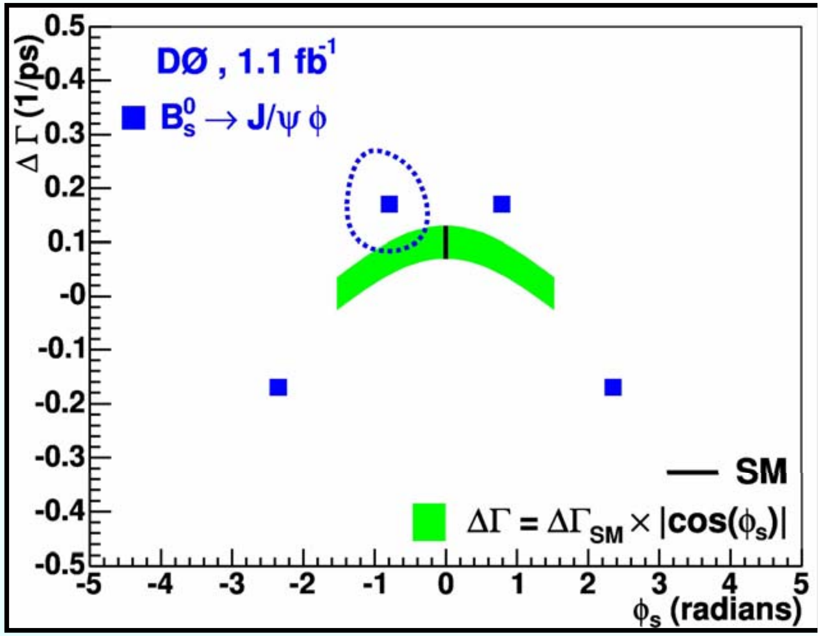
Width difference of B_s

- Another important measurement performed by Tevatron;
- For the moment decay $B_s \to J/\psi\ \varphi$ is studied;
- Other possibilities include measurement of B_s lifetime in CP-specific decays (like $B_s \to K^+K^-$, CDF);
- Obtained precision: $\sigma(\Delta\Gamma) \sim 0.09\ ps^{-1}$;
- Expected precision by the end of Tevatron: $\sigma(\Delta\Gamma_s) \sim 0.025\ ps^{-1}$;
- It can be improved at LHC to test the SM value, currently: $\Delta\Gamma_s(SM) = 0.088 \pm 0.017\ ps^{-1}$;



Mixing phase of B_s

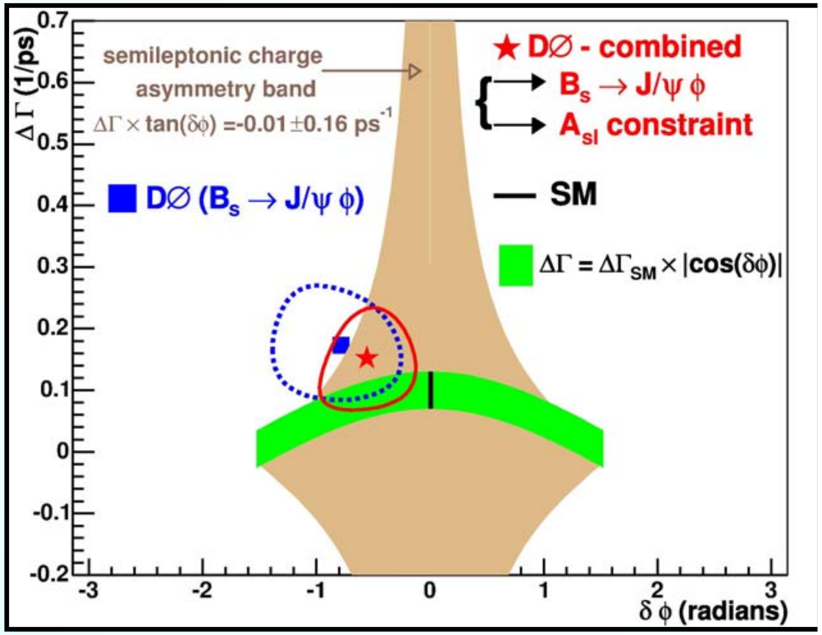
- Nonzero mixing phase ϕ_s of B_s would result in the CP violation in mixing;
- Very small value in SM, but can be considerably increased by contributions of the new physics;
- DØ experiment just released the first pioneer measurements of this phase in $B_s \to J/\psi\ \varphi$ decay: $\phi_s = -0.79 \pm 0.56 \pm 0.01$;



- Essential development of analysis technique: extract the mixing phase without the flavour tagging of initial state;
- Phase ϕ_s can be measured in untagged sample provided $\Delta\Gamma_s$ is non-zero;

Mixing phase of B_s

- Other measurements of the phase ϕ_s are possible, e.g. from the semileptonic charge asymmetry (also first made in DØ);
- Combination of these results improves precision of ϕ_s;
- Study will continue with the new statistics, but the big progress can be achieved at LHC;
- It is a very promising direction in B physics, both for ATLAS/CMS and LHCb;



Rare decays

- **The most interesting decay is $B_s \to \mu^+ \mu^-$;**
- **Recent results from CDF: $Br(B_s \to \mu^+ \mu^-) < 1 \times 10^{-7}$ (95% CL);**
- **Similar limit can be expected from DØ soon;**
- **SM prediction for this decay: $\sim 4 \times 10^{-9}$;**
- **New physics can significantly change this value;**
- **The SM rate is achievable at LHC, both CMS/ATLAS and LHCb can do it;**

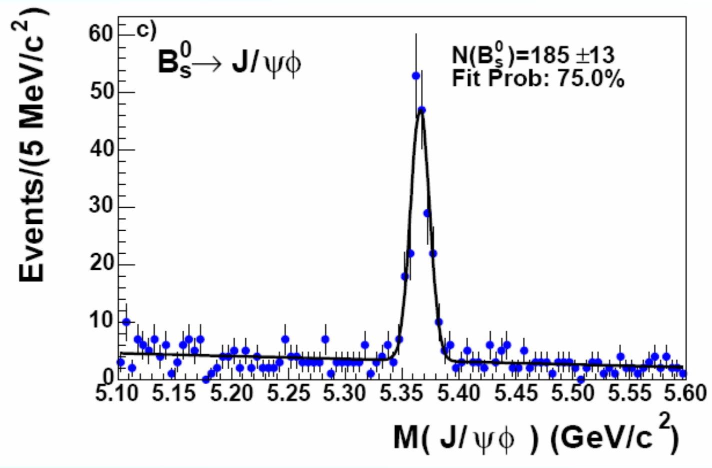
CP violation studies

- **CP violation studies at Tevatron are limited, comparing to the results from B factories;**
- **The most important achievements:**
  - dimuon same sign charge asymmetry (DØ);
  - CP asymmetry in $B \to h^+h^-$ decays (CDF);
- **These results can be improved at LHC:**
  - dimuon charge asymmetry does not require special triggers, but need a good understanding of detector;
  - To select $B \to h^+h^-$ decays, special triggers are required;

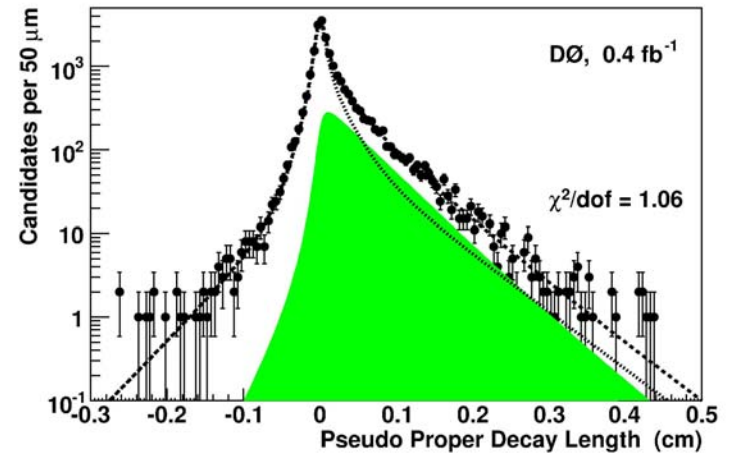
Properties of B hadrons

- **Tevatron measured precisely masses and lifetimes of long living B hadrons;**
- **Tevatron results dominate in the current precision in masses and lifetimes of all B hadrons except B^0 and B^+:**
- **$\sigma(M(B_s))$ ~ 0.7 MeV (CDF), ~2.4 MeV (World);**
- **$\sigma(\tau(B_s))$ ~ 0.051 ps (DØ), ~0.059 ps (World);**
- **Statistics of Tevatron in B_c, Ξ_b, Ω_b will not be high, and the precise measurement of their lifetimes can be done at LHC;**

Measurement of B_s mass in CDF

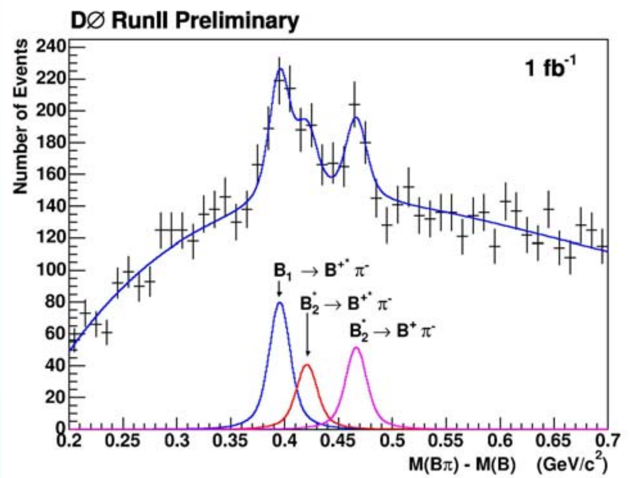


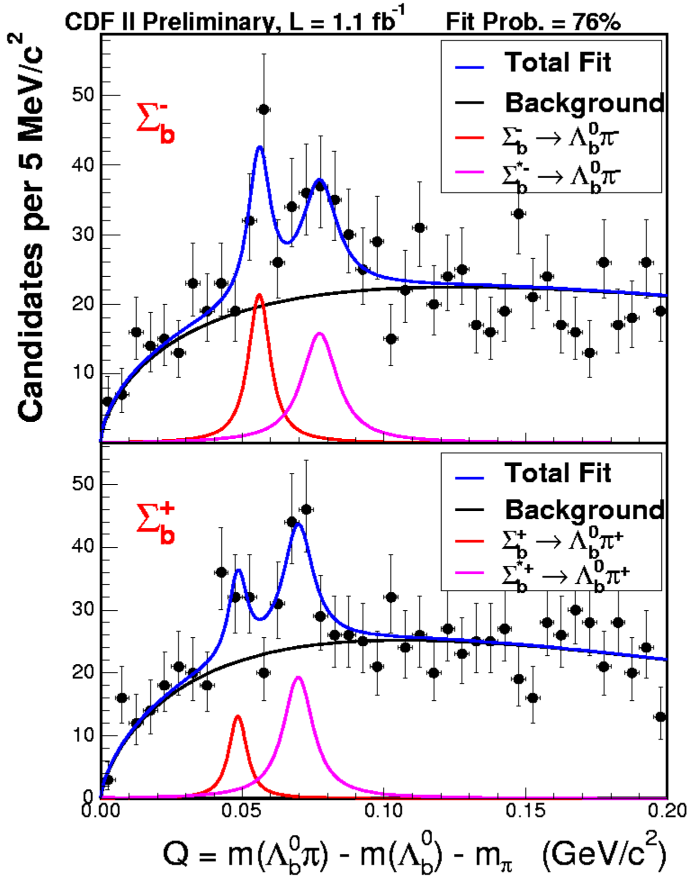
Measurement of B_s lifetime in DØ



B hadron spectroscopy

- **Tevatron provided a precise information on some excited states:**
  - B^{**} (B_1 and B_2^*);
  - B_s^{**} (B_{s1} and B_{s2}^*);
  - Σ_b and Σ_b^*;
- **Only easiest states are observed;**
- **Systematic study of B hadron spectroscopy can be performed at LHCb;**
- **Will be very useful for developing theory of quark bound states;**





Decays of B hadrons

- **Very limited number of results from Tevatron;**
- **Some highlights of measured branching rates:**
  - $B_s \to D_s(3\pi)$ (CDF);
  - $B_s \to K^+K^-$ (CDF);
  - $B_s \to \mu\nu D_s^{**}$ (DØ);
  - $B_s \to D_s^{(*)} D_s^{(*)}$ (DØ);
  - $B_s \to D_s D_s$ (CDF);
- **Mainly results for B_s, not too much;**
- **Some of these channels are very interesting to study CP violation in B_s system (e.g. $B_s \to K^+K^-$, $B_s \to D_s D_s$);**
- **Other B hadrons will not be studied at Tevatron;**
- **Good possibility for LHCb; to do it in ATLAS/CMS, dedicated SV triggers required;**

Technical aspects

- **Experience of Tevatron clearly showed that B physics can be successfully explored in a difficult environment of hadron collisions:**
  - high background from QCD;
  - high track mutiplicity;
  - overlay of many interactions;
- **Essential for B physics:**
  - special dedicated triggers, like SV trigger of CDF or high performance muon trigger of DØ;
  - Excellent and efficient tracking (both DØ and CDF demonstrated this capability);
  - Particle ID (it helps a lot in many measurements of CDF);

Algorithms and analysis techniques

- **Tevatron experience in many B physics studies can be used directly at LHC:**
  - Flavor tagging: both CDF and DØ developed very powerful methods;
  - Analysis of the untagged $B_s \rightarrow J/\psi\varphi$ sample still provides the measurement of CP violating phase ϕ_s;
  - Multivariate techniques of analysis (e.g. selection of decay $B_s \rightarrow \mu\nu D_s$ in DØ or the search for $B_s \rightarrow \mu^+\mu^-$ decay in CDF);

Conclusions

- **Tevatron clearly demonstrated the possibility of successful B physics program at hadron collider;**
- **Tevatron provides a better vision of possibilities and limitations of making B physics at hadron collider;**
- **Some directions (Bs oscillation, long living B hadrons) will be fully covered by Tevatron; others (e.g. CP violation in B_s) show excellent possibilities to continue study at LHC;**
- **Tevatron demonstrated the importance of triggers and particle ID for the successful B physics program;**
- **Many algorithms and ideas of analysis were developed at Tevatron, they can be applied for studies at LHC;**