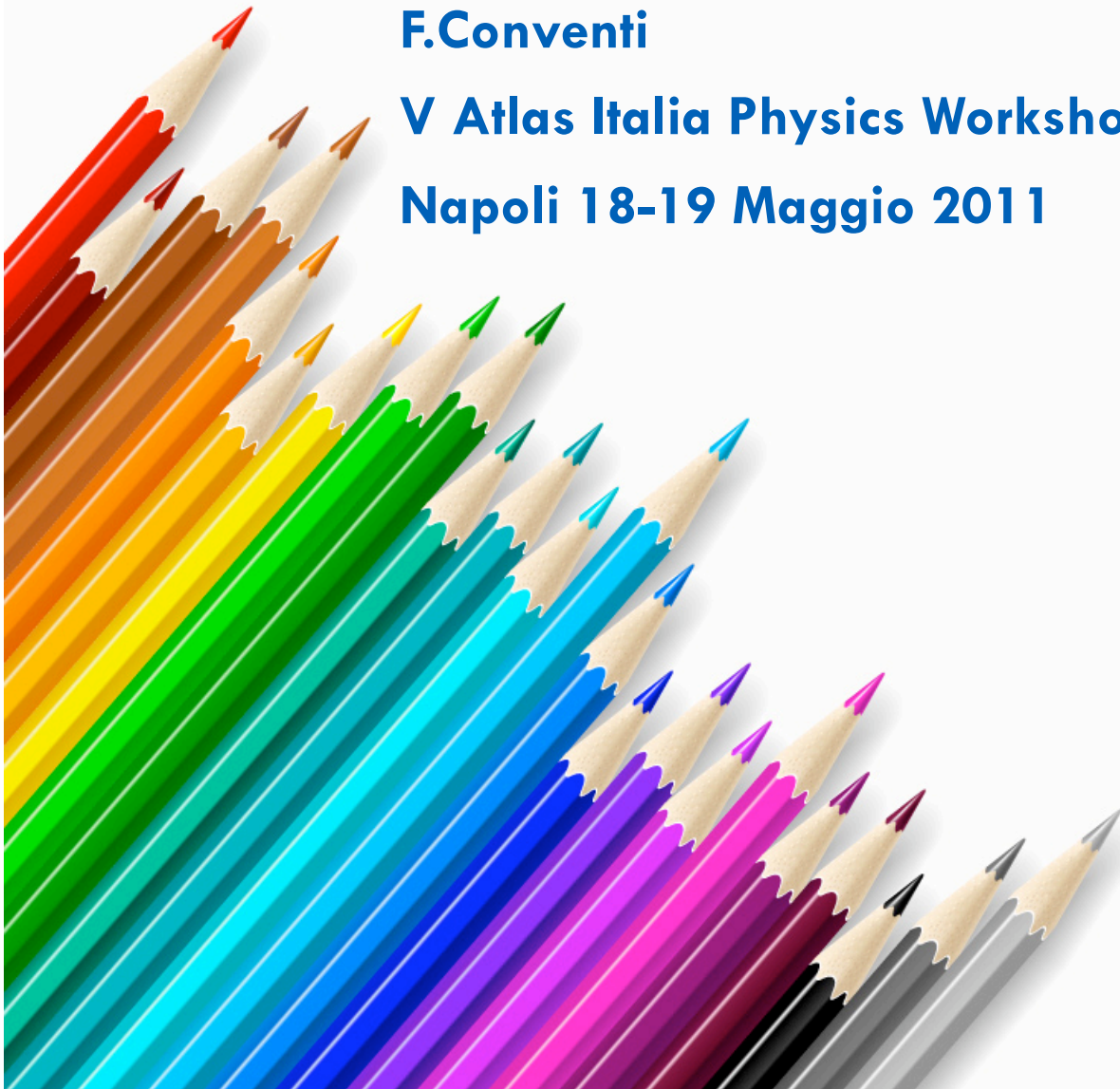


B PHYSICS

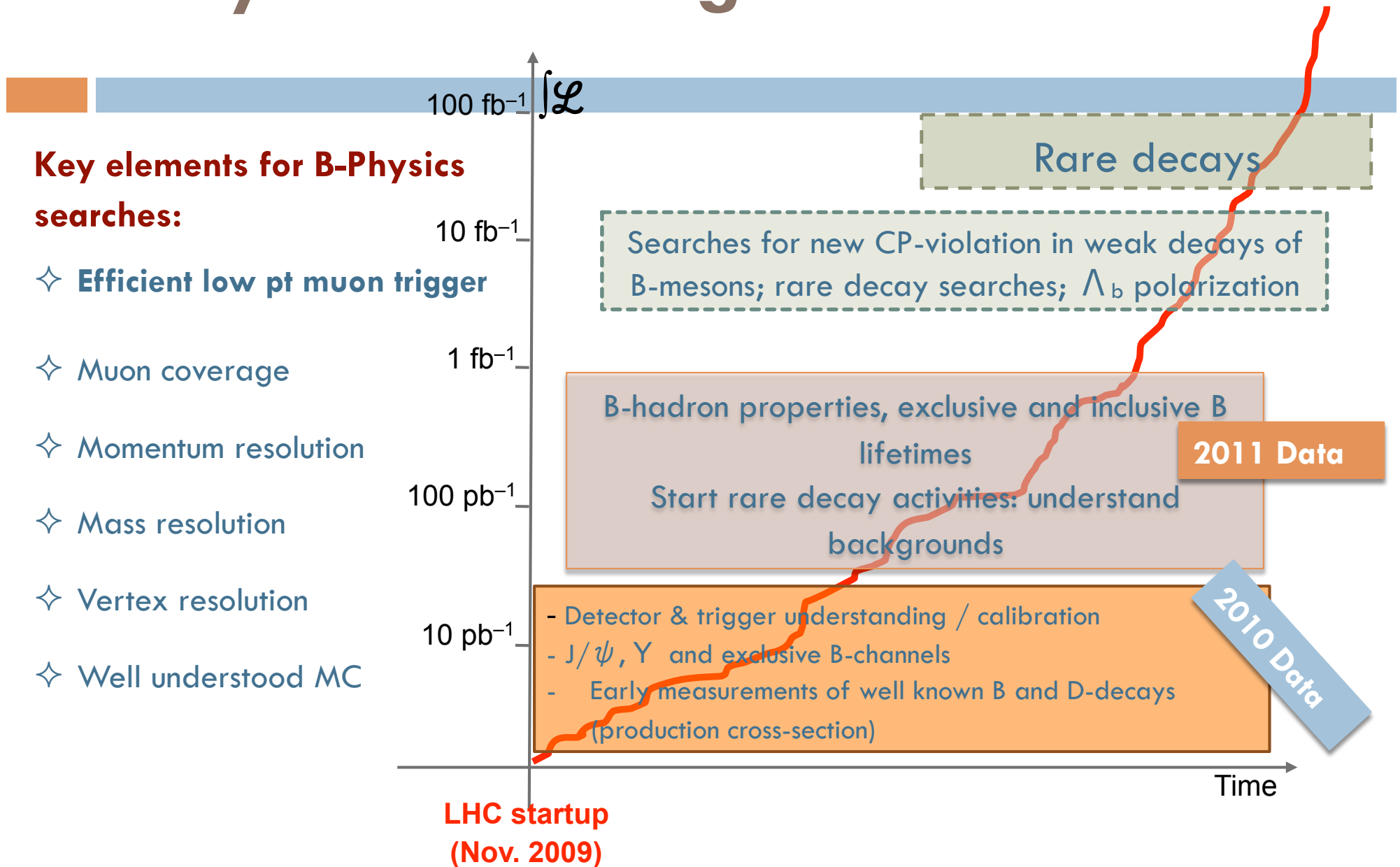
F.Conventi

V Atlas Italia Physics Workshop

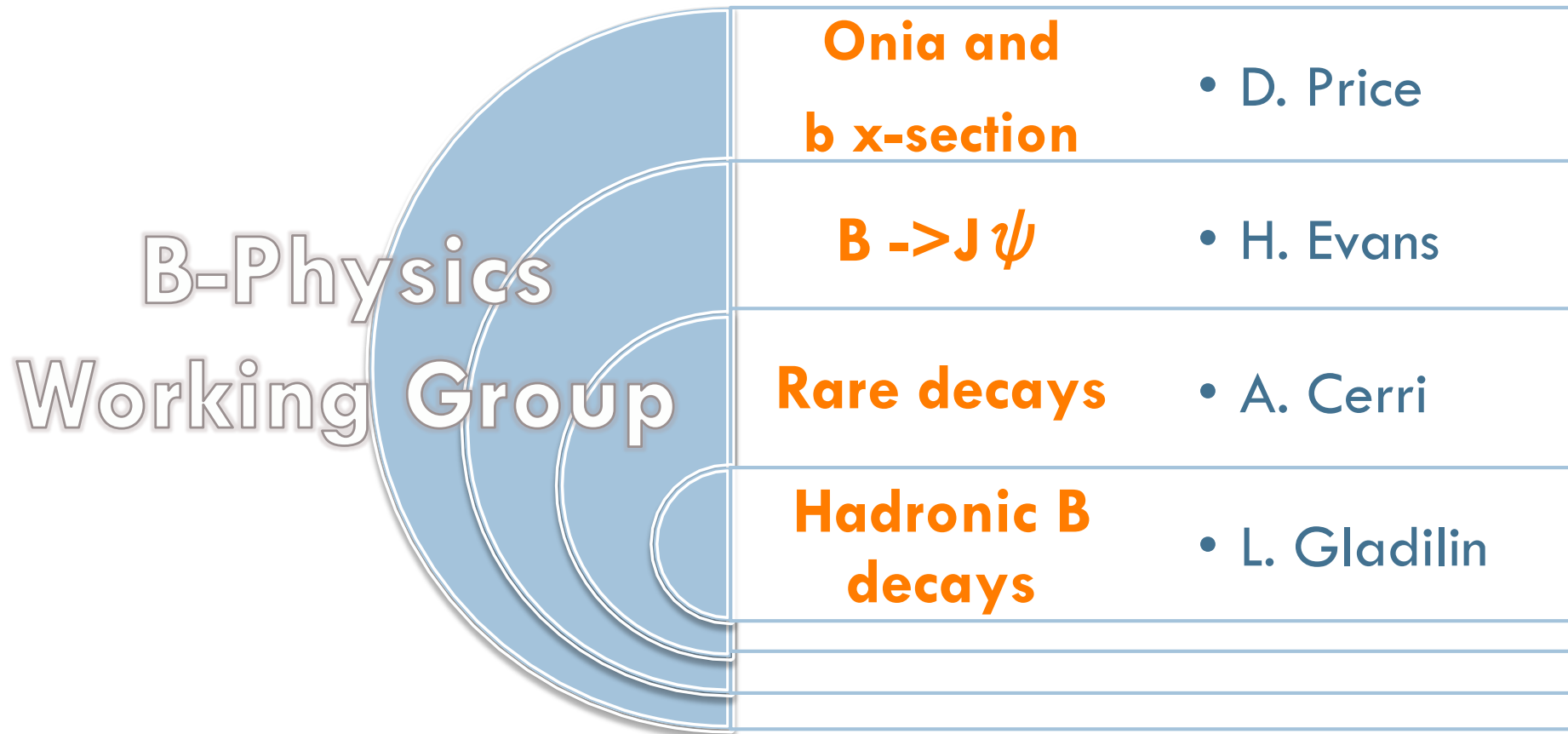
Napoli 18-19 Maggio 2011



Heavy Flavour Program at ATLAS



ATLAS B Physics subgroup organization



Analisi dati 2010

Publications:

○ Measurement of the differential cross-sections of inclusive, prompt and non-prompt J/ψ production in proton-proton collisions at $\sqrt{s} = 7$ TeV

Submitted to Nuclear Physics B (15 April 2011)

○ Measurement of the centrality dependence of J/ψ yields and observation of Z production in lead-lead collisions with the ATLAS detector at the LHC

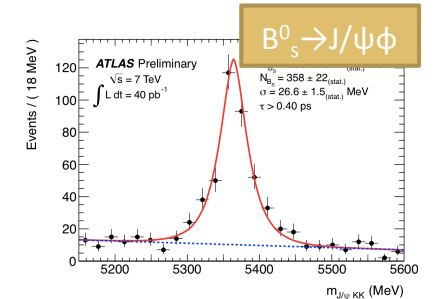
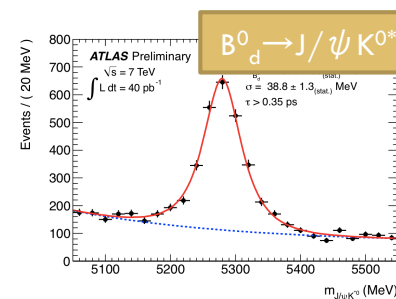
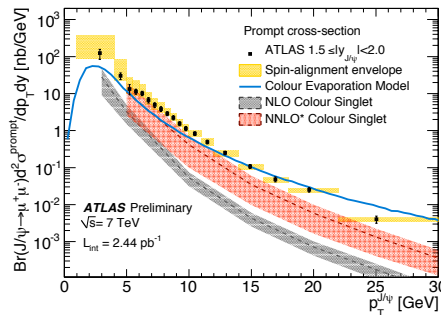
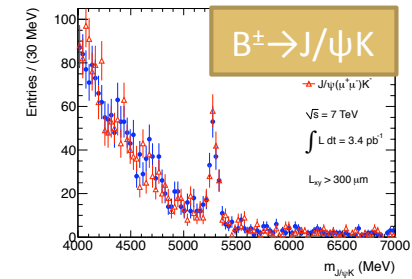
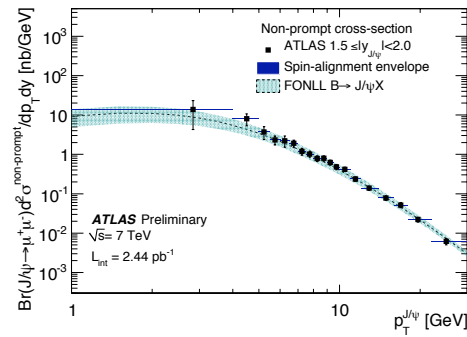
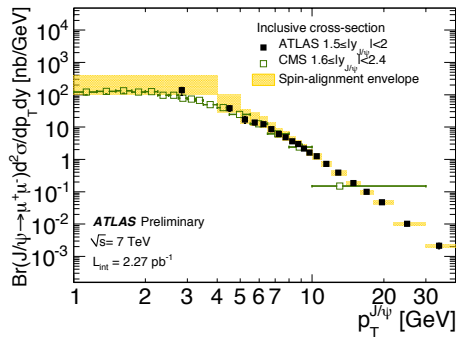
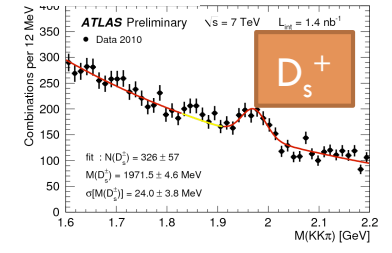
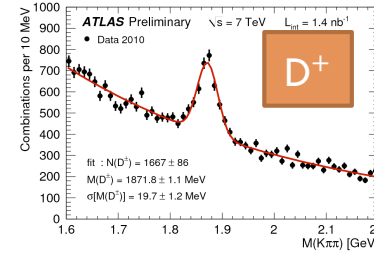
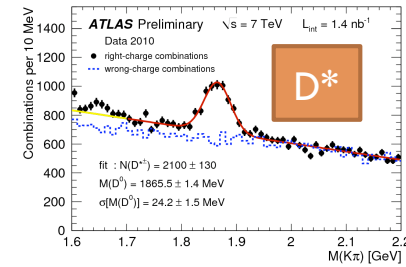
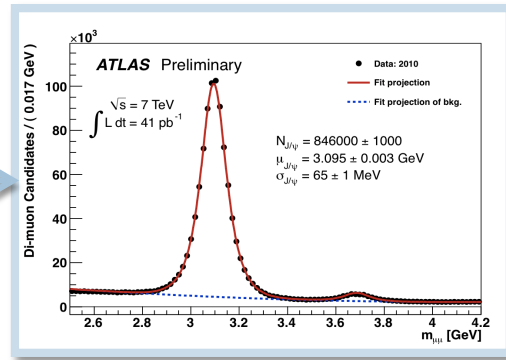
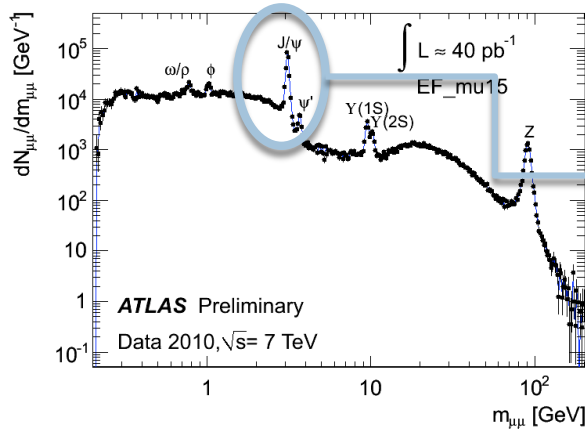
Phys Lett. B697 (2011) 294-312



CONF notes:

D^* mesons reconstruction in pp collisions at $\sqrt{s} = 7$ TeV	0.37nb^{-1}	ATLAS-CONF-2010-034
First observation of the $J/\psi \rightarrow \mu\mu$ resonance	6.4nb^{-1}	ATLAS-CONF-2010-045
Measurement of the $J/\psi \rightarrow \mu\mu$ differential cross section and fraction from B-decays	19.5nb^{-1}	ATLAS-CONF-2010-062
Observation of the B^\pm meson in the decay $B^\pm \rightarrow J/\psi (\mu + \mu^-) K^\pm$	3.4pb^{-1}	ATLAS-CONF-2010-098
Measurement of D^* and D^+ meson production cross sections in ..	1.1nb^{-1}	ATLAS-CONF-2011-017
Observation of the B_d^0 and B_s^0 mesons in the decays $B_d^0 \rightarrow J/\psi K^{0*}$ and $B_s^0 \rightarrow J/\psi \phi$	40pb^{-1}	ATLAS-CONF-2011-050
A measurement of the ATLAS muon reconstruction and trigger efficiency using J/ψ decays	40pb^{-1}	ATLAS-CONF-2011-021

Alcuni plot dalle note 2010



Attività in corso 2011

B → J/ψ + X

- B average lifetime
- $B^{\pm} \rightarrow J/\psi K^{\pm}$ cross section
- $B_d \rightarrow J/\psi K^*$ and $B_s \rightarrow J/\psi \varphi$
- $B_d \rightarrow J/\psi K_s$
- $\Lambda_b \rightarrow J/\psi \Lambda$
- $bb \rightarrow J/\psi \mu$ angular correlations

Hadronic B decays

- Inclusive D^* cross section *ATLAS-CONF-2011-017*
- b/c with $D^{(*)} \mu$ final states *ATLAS-COM-PHYS-2011-179*
- Separation of b/c contributions
- Estimation of fake muon rates (also MCP)
- Tracking efficiency with $D^0 \rightarrow K^- \pi^+$ / $D^0 \rightarrow K^- \pi^+ \pi^+ \pi^-$ (also tracking group)
- $B_s \rightarrow D_s \pi$ and $B_s \rightarrow D_s \mu X$
- Search for $\eta_c \rightarrow K_s^0 K^+ \pi^-$

Onia

- J/ψ cross-section(s) and B-fraction [*Submitted*]
- Upsilon fiducial cross-section [*In collab. review*]
- Upsilon inclusive cross-section + U(nS) ratios
- $\chi_{c-} \rightarrow J/\psi$ gamma [calo+conversions]
- $J/\psi(2S)/J/\psi$ cross-section ratio wrt pT/y
- J/ψ spin-alignment measurement + total xsection
- $\psi(2S), \chi(3872) \rightarrow J/\psi \pi\pi$
- Double J/ψ production studies
- J/ψ in pp @ 2.76 TeV

Rare decays

Updated reach on $B_s \rightarrow \mu \mu$!!

Attività in corso 2011: Atlas-Italia

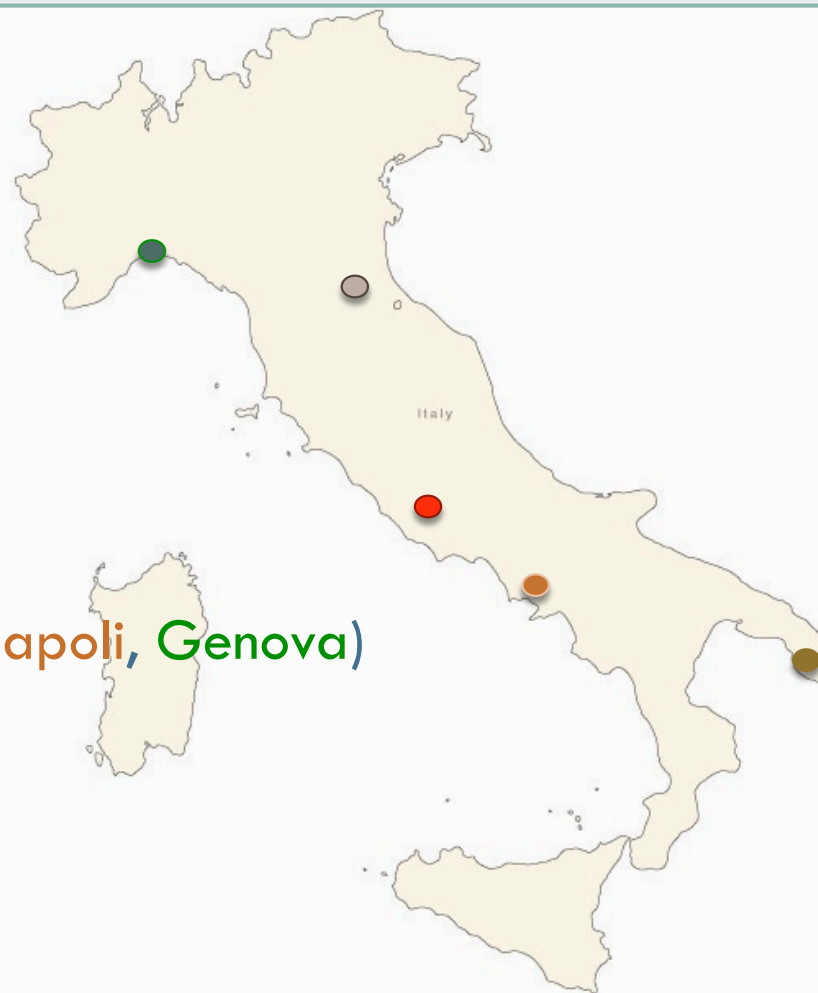
B average lifetime (Roma1)

b/c with $D^{(*)} \mu$ final states (Genova)

$B_s \rightarrow \mu \mu$ (Napoli)

J/ψ polarization (Bologna)

Tracking and trigger efficiency (Lecce, Napoli, Genova)



B Inclusive Lifetime

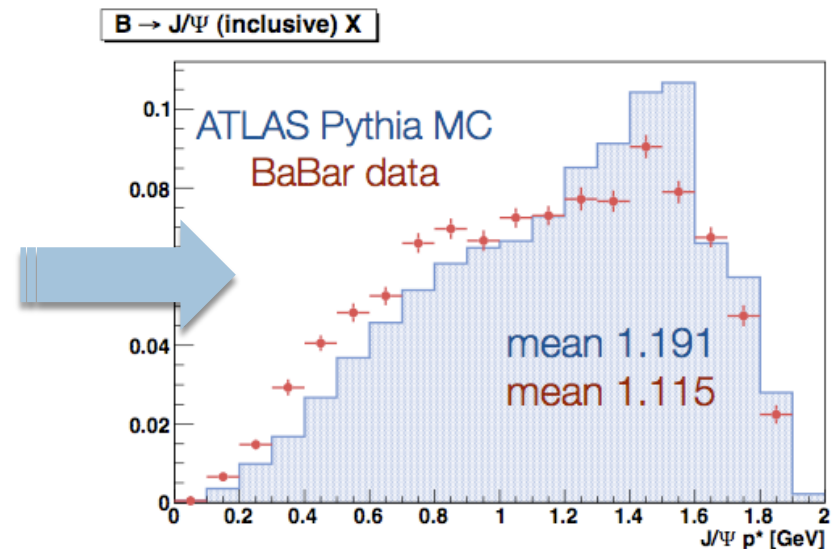
Misura di rilievo per lo studio della ricostruzione delle tracce e dei vertici
Precede le misure di lifetime “esclusive”

Obiettivo della misura è $\tau = \frac{L_{xy} m^B}{p_T^B}$ ma viene misurato $\tau = \frac{L_{xy} m^{J/\Psi}}{p_T^{J/\Psi}}$

Per passare da una quantità all'altra viene calcolato da MC il fattore K di correzione:

$$k = \frac{(\beta\gamma)_T^B}{(\beta\gamma)_T^{J/\Psi}}$$

- E' stata applicata una procedura di reweighting del MC sui dati di BaBar al fine di riprodurre lo spettro di p^* atteso.
- Dati Babar ricorretti per effetti di efficienza e accettazione
- Campione MC di B^\pm e B^0



B Inclusive Lifetime

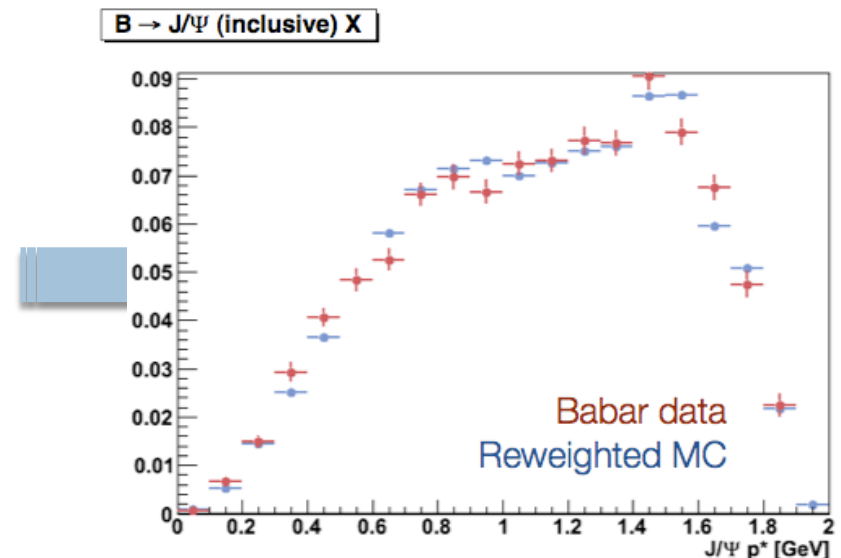
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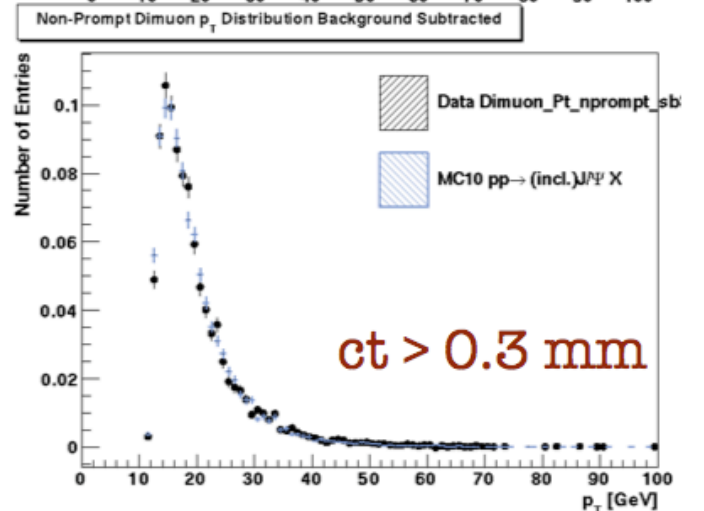
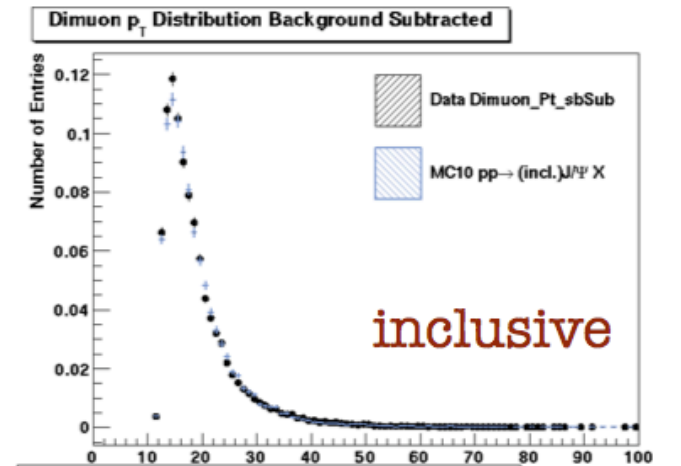
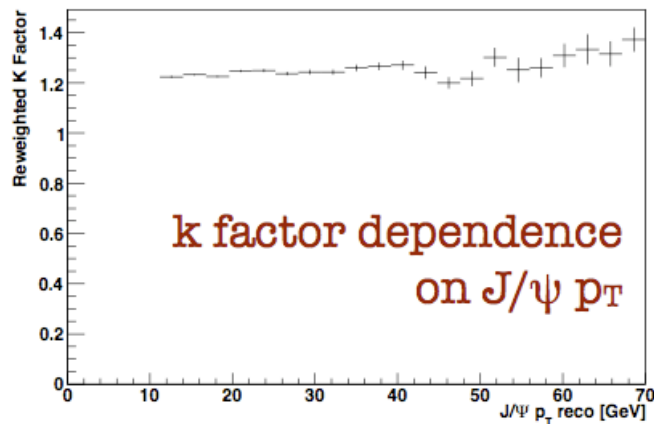
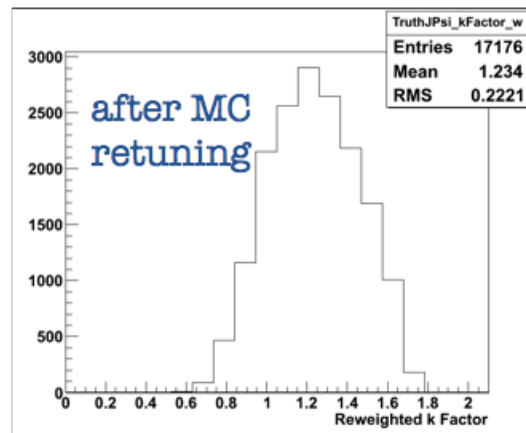
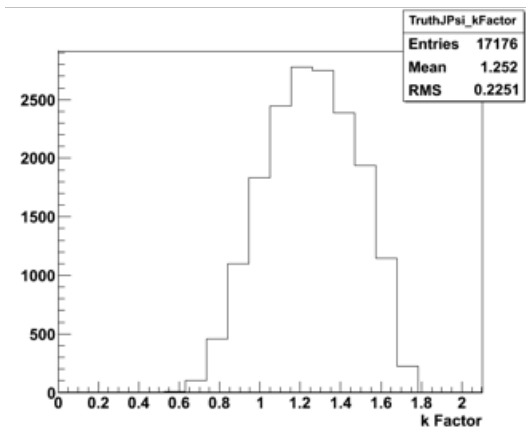
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B Inclusive Lifetime

$$k = \frac{m^B}{p_T^B} \cdot \frac{p_T^{J/\Psi}}{m^{J/\Psi}} \cdot \frac{1}{\cos(\Delta\phi^{J/\Psi-B})}$$



B Inclusive Lifetime

Unbinned maximum likelihood fit doppio nel range $[\text{mean} - 10\sigma, \text{mean} + 10\sigma]$ intorno al picco della J/ψ

Pseudo-Proper Time Model

Signal: Delta function plus exponential convolved with a gaussian with per-event error

k factor correction:

Si applica alla sola componente non-prompt!!
Convoluzione della PDF per il fattore k con la componente non-prompt

$$\int dk H(k) \cdot e^{\frac{-ct^* \cdot K}{\tau}} \otimes \text{Gauss}(ct^*, \sigma(ct^*))$$

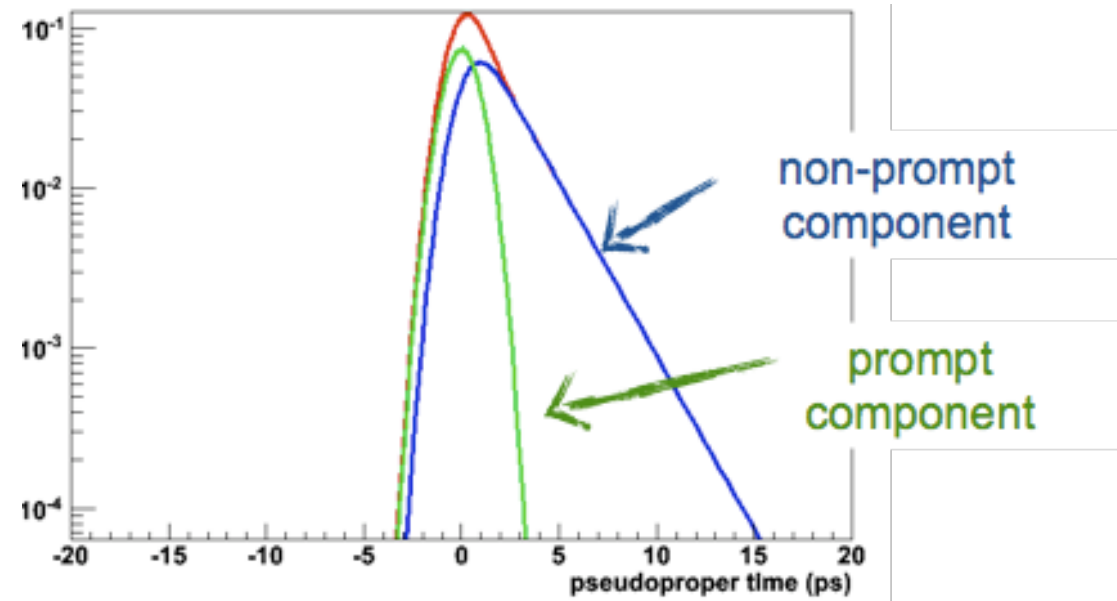
Mass Model

Signal: Crystalball function with a per-event error

Background: Chebichev 1st order polynomial

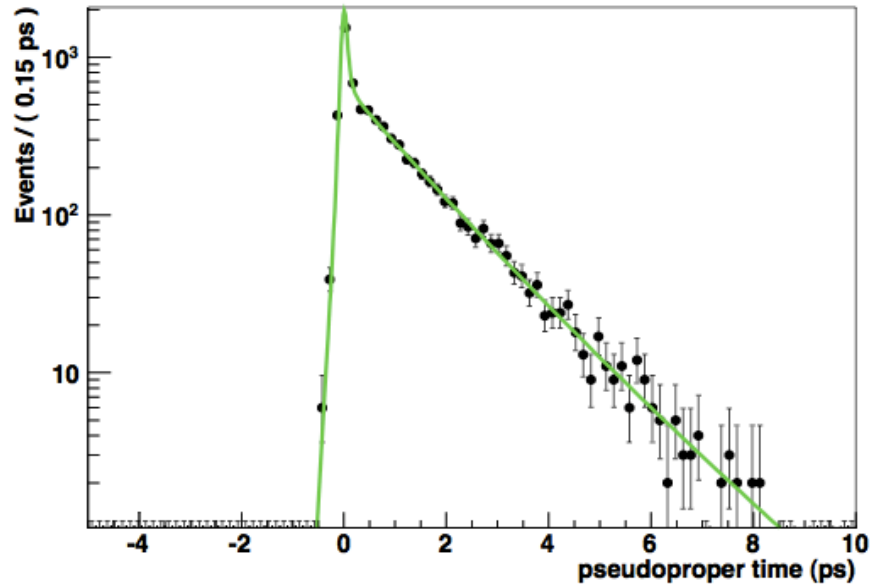
Two lifetime components:

- **prompt:** $ct = 0$
- **non-prompt:** $ct > 0$



B Inclusive Lifetime

$p_T(\mu_1) > 6 \text{ GeV} \ \&\& \ p_T(\mu_2) > 6 \text{ GeV}$
 $\eta(\mu_1) < 1.05 \ \&\& \ \eta(\mu_2) < 1.05$



Background: -> (dalle sidebands)

Symmetric positive and negative exponentials plus a positive exponential all convoluted with a gaussian with per-event error

Pseudo-Proper Time Error

PDFs Models Built using templates

Validazione procedura di fit sul MC:
 $bb \rightarrow J/\psi \ X$ mixed with $pp \rightarrow (\text{direct}) J/\psi \ X$

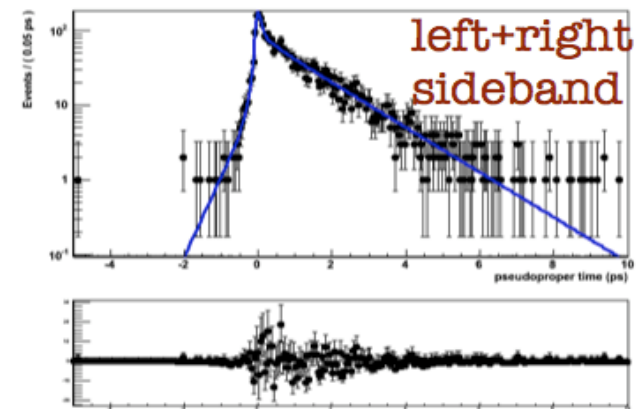
Complete signal sample:

○ true lifetime:

$$\tau_{\text{truth}}(\text{B}) = 1.53 \text{ ps}$$

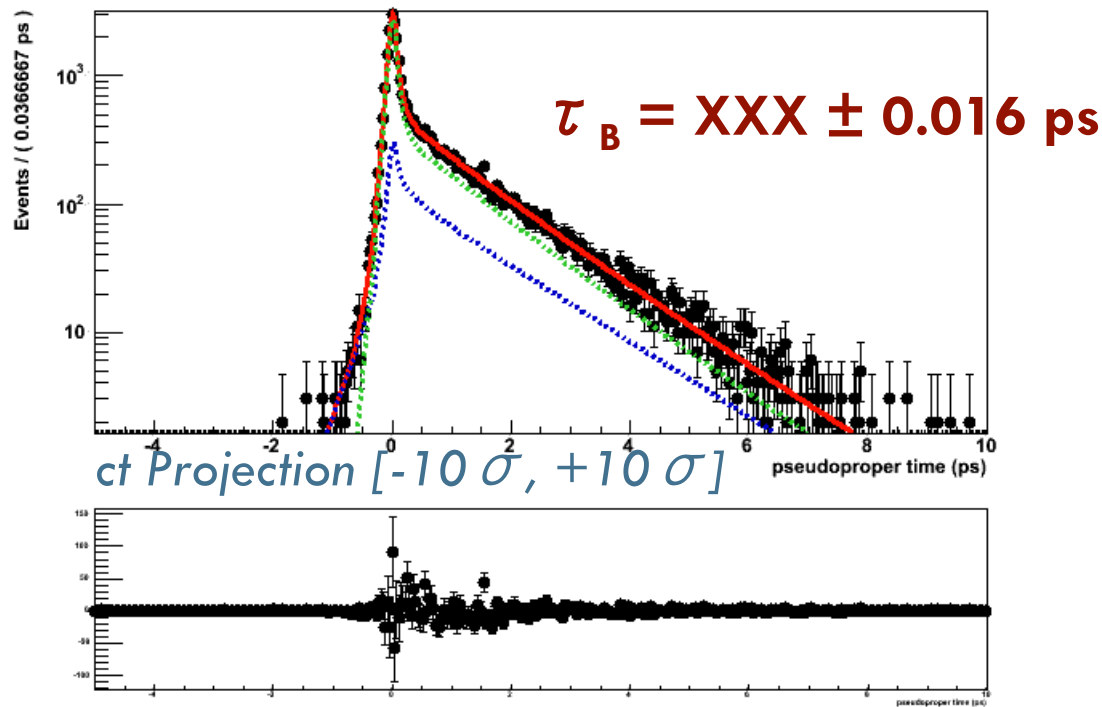
○ Lifetime from fit:

$$\tau_{\text{fit}}(\text{B}) = 1.53 \pm 0.02 \text{ ps}$$

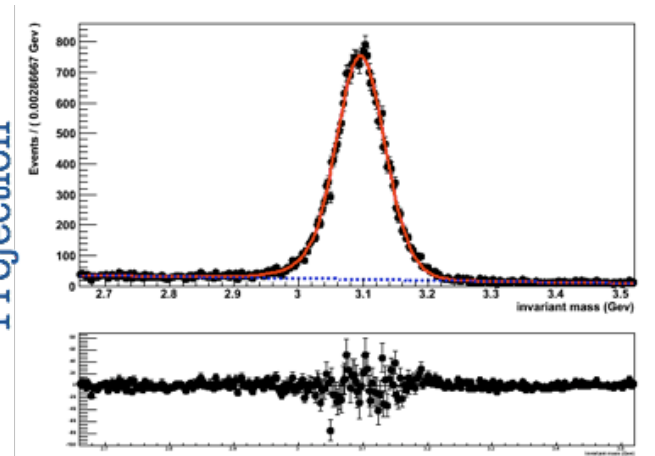


B-Physics group approval within one or two weeks
 A Conf-Note is being written to go public fast

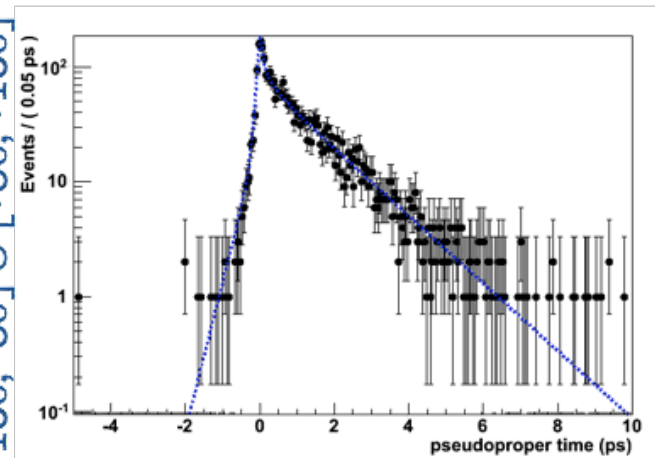
B Inclusive Lifetime



Invariant Mass Projection



Background Projection $[-10\sigma, -6\sigma] \cup [+6\sigma, +10\sigma]$



Systematic studies on...

K-factor extraction $\rightarrow \Delta \tau_B \sim 0.003 \text{ ps}$

ct resolution model $\rightarrow \Delta \tau_B \sim 0.002 \text{ ps}$

ct and mass background models $\rightarrow \Delta \tau_B \sim 0.037 \text{ ps}$

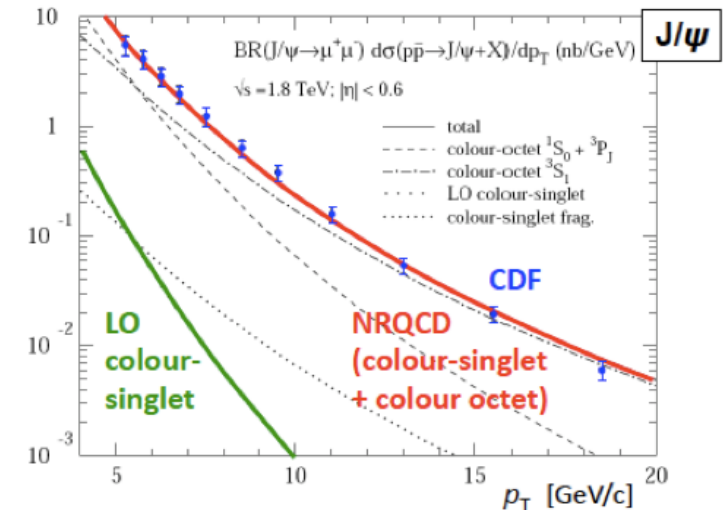
Alignment \rightarrow sul misaligned MC

Polarizzazione J/ψ

Modelli teorici recenti mostrano un buon accordo nella descrizione della sezione d'urto differenziale...

- ⊙ Color Singlet Model (CSM)
- ⊙ Color Octet Mechanism (COM) / NRQCD
- ⊙ Color Evaporation Model

..ma non nel caso della polarizzazione!

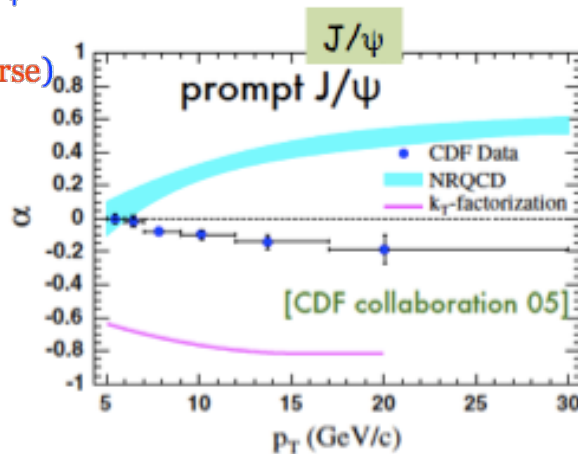


NRQCD (octet mechanism) →
transverse polarization of J/ψ



$J_z = \pm 1$ (transverse)
 λ_θ (high p_T) → 1

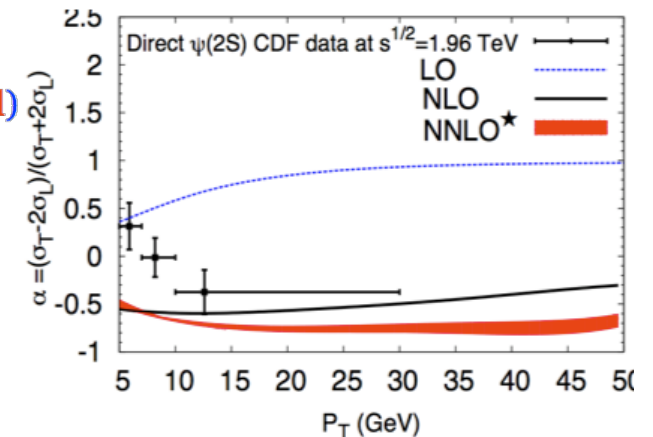
In helicity frame



NLO calculation of CSM →
longitudinal polarization

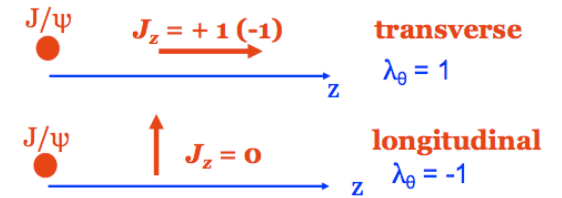


$J_z = 0$ (longitudinal)
 λ_θ (high p_T) → -1



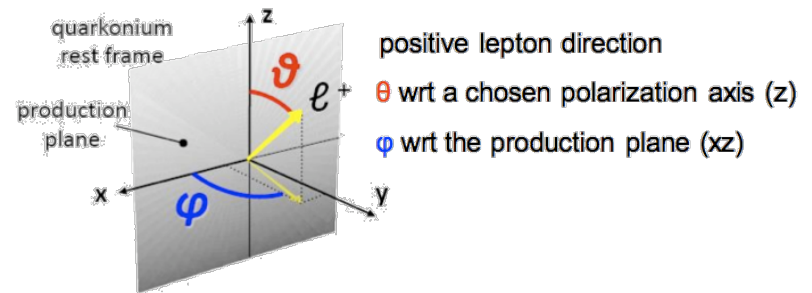
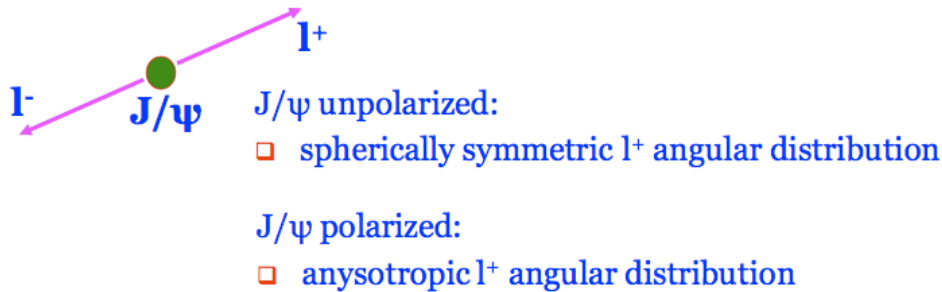
Polarizzazione J/ψ

If J/ψ has $J_z = \pm 1$ is said **transverse** polarized



Polarizzazione misurata a partire dalla distribuzione angolare delle particelle provenienti dal decadimento della J/ψ .

Nel sistema di riferimento in cui la J/ψ è a riposo si ha:



Asse di polarizzazione

helicity (HX) J/ψ direction in hadron ($h_1 + h_2$) CM frame



Gottfried-Jackson (GJ) direction of h_1 or h_2 in quarkonium rest frame

Collins-Soper (CS) bisector between h_1 and $(-h_2)$ directions in quarkonium rest frame \rightarrow \sim direction of relative momentum of colliding partons



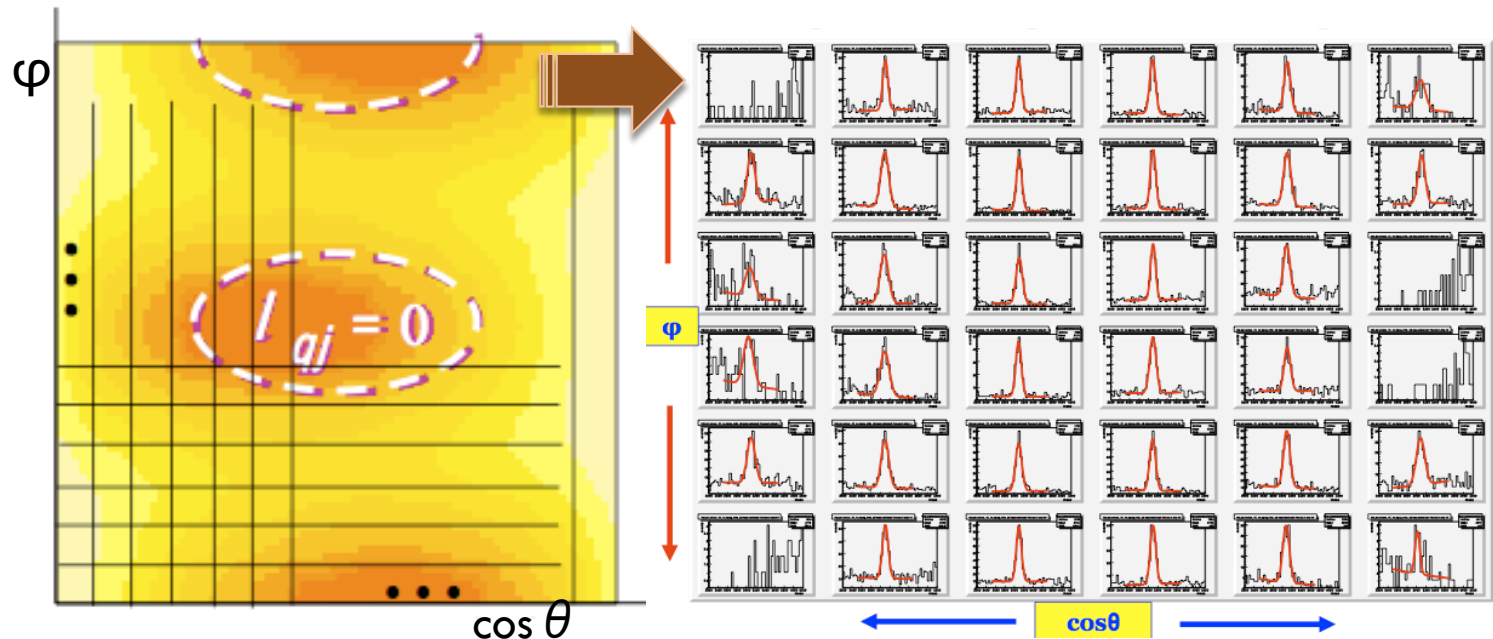
Polarizzazione J/ψ

- La distribuzione angolare dileptonica dipende da 3 parametri

$$W(\cos\theta', \varphi') = \frac{3}{4\pi(3 + \lambda'_\theta)} (1 + \lambda'_\theta \cos^2\theta' + \lambda'_\varphi \sin^2\theta' \cos 2\varphi' + \lambda'_{\theta\varphi} \sin 2\theta' \cos \varphi')$$

- Diversi metodi implementati per estrarre λ_θ , λ_φ e $\lambda_{\theta\varphi}$:
 - ▣ Fit bidimensionale o proiezione monodimensionale
 - ▣ Asimmetria
 - ▣ sidebands

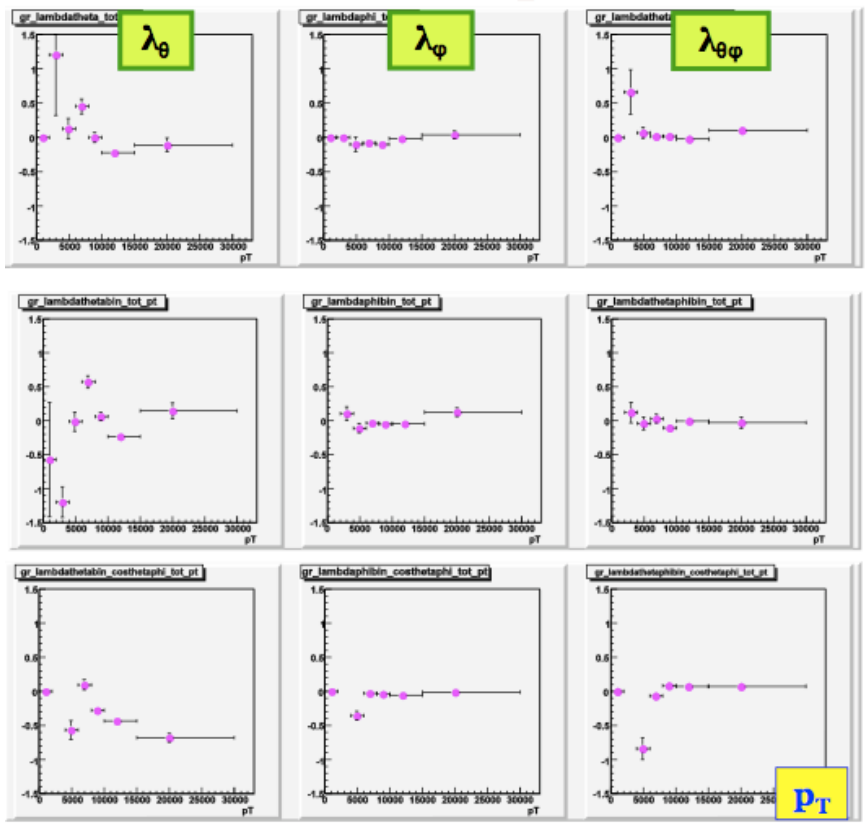
Per ogni bin p_T - y si effettua un fit della massa invariante della J/ψ ripesato per l'efficienza



Polarizzazione J/ψ : stato e prospettive

All methods: all periods summed, HX

45



asym

projection

bidimensional

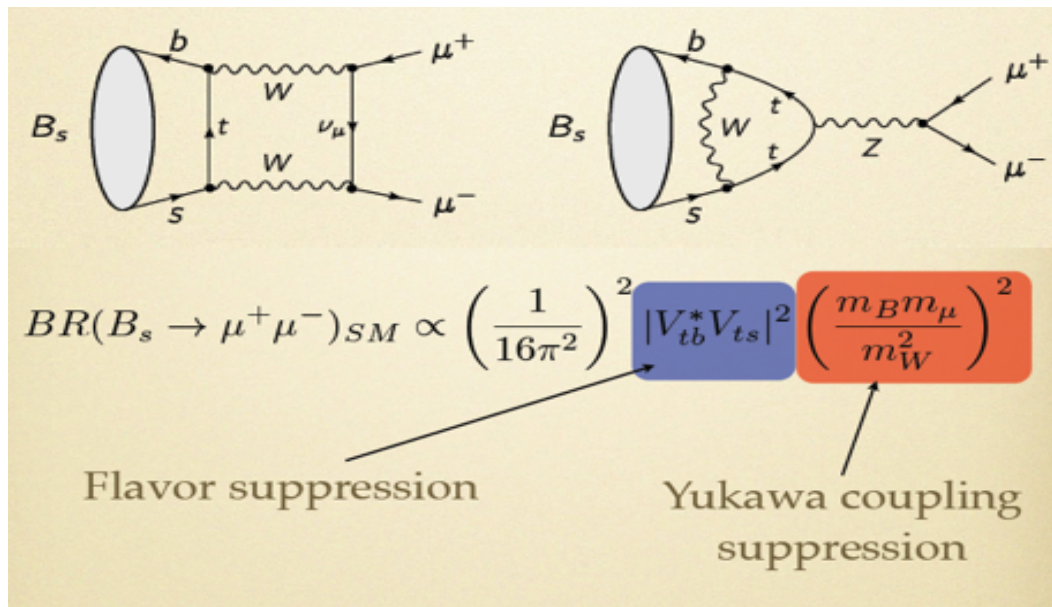
- Tool di analisi pronti!
- Aumentare la statistica processando i nuovi dati 2011.
- Studio approfondito dei trigger dimuonici
- Separazione J/ψ prompt e non prompt.

Risultati preliminari (dati 2010)

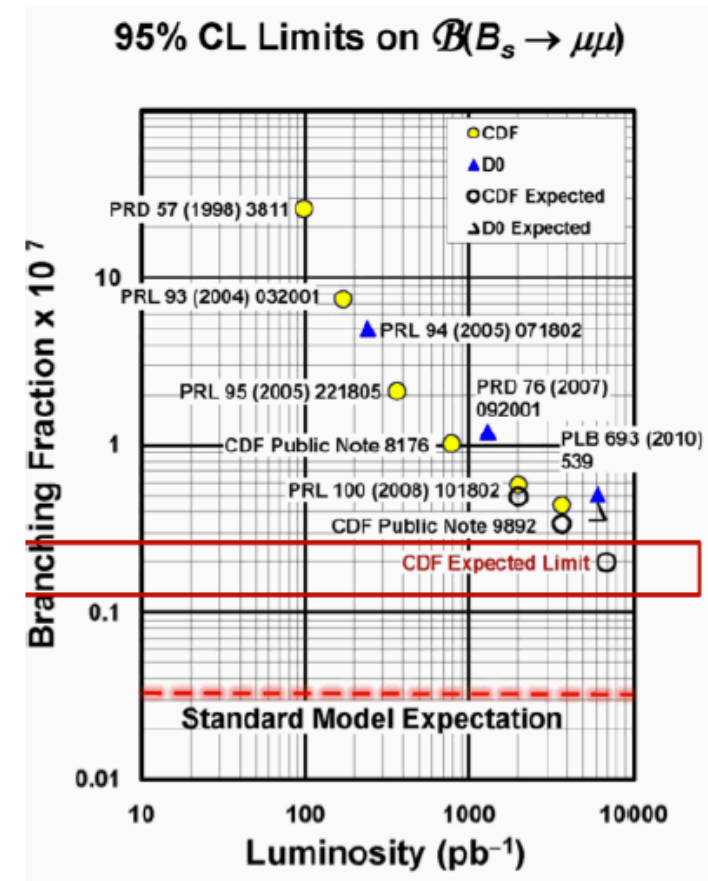


SM predicts $BR(B_s \rightarrow \mu\mu) \sim 3.8 \times 10^{-9}$

- Deviazioni dal valore previsto dal MS \rightarrow indicazione nuova fisica oltre MS (principalmente Minimum Flavor Violating models poichè limite sperimentale $O(MS)$)



Limite attuale PDG: $<4.7 \times 10^{-8}$



$B_s \rightarrow \mu\mu$: Strategia di analisi

Rare decays workshop: <https://indico.cern.ch/conferenceDisplay.py?ovw=True&confId=132275>

Misura del BR rispetto ad un canale di riferimento ben noto in modo da evitare misura assoluta di sezione d'urto. Inoltre si ottiene una cancellazione di alcune sistematiche.

Canale di riferimento: $B^+ \rightarrow J/\psi K^+$

$$\mathcal{B}(B_s \rightarrow \mu^+ \mu^-) = \frac{N_{B_s}}{N_{B^+}} \frac{\alpha_{B^+}}{\alpha_{B_s}} \frac{\epsilon_{B^+}}{\epsilon_{B_s}} \frac{1}{\epsilon_N} \frac{f_u}{f_s} \mathcal{B}(B^+ \rightarrow J/\psi K^+) \cdot \mathcal{B}(J/\psi \rightarrow \mu^+ \mu^-)$$

Our reference:

$B^+ \rightarrow J/\psi K^+$

Pros:

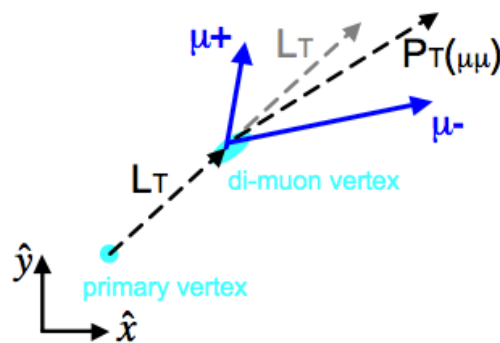
• BR: $(1.014 \pm 0.034) \cdot 10^{-3} \times (5.93 \pm 0.06) \cdot 10^{-2} \rightarrow \pm 3.7\%$

Cons:

• $(\alpha\epsilon)_{B_s}/(\alpha\epsilon)_{ref}$ has absolute reconstruction term (K^+)

• Higher statistics (BR=5.98E-5)

• $f_u/f_s = 3.71 \pm 0.47 \rightarrow \pm 12\%$



Very clean experimental signature:

- Final state fully reconstructed, $M_{\mu\mu} = M(B_s)$
- Long B_s lifetime ($c\tau = 483 \mu\text{m}$) \rightarrow large $\lambda = cL_T$
- $M_{\mu\mu}/P_T(\mu\mu)$
- L_T and $P_T(\mu\mu) \sim$ collinear \rightarrow small Pointing Angle

.....but the main challenge is to estimate the background!!

$B_s \rightarrow \mu\mu$: Strategia di analisi

Ntuple di gruppo rare-decays :

(<https://twiki.cern.ch/twiki/bin/view/AtlasProtected/BPhysicsWorkingGroupDataRare>)

Le attività del gruppo consistono principalmente:

- Studio delle efficienze di trigger per $B_s \rightarrow \mu\mu$.
più in generale studio delle efficienze per i trigger dimuonici (cfr talk di A. Ventura)

- MC re-weighting technique

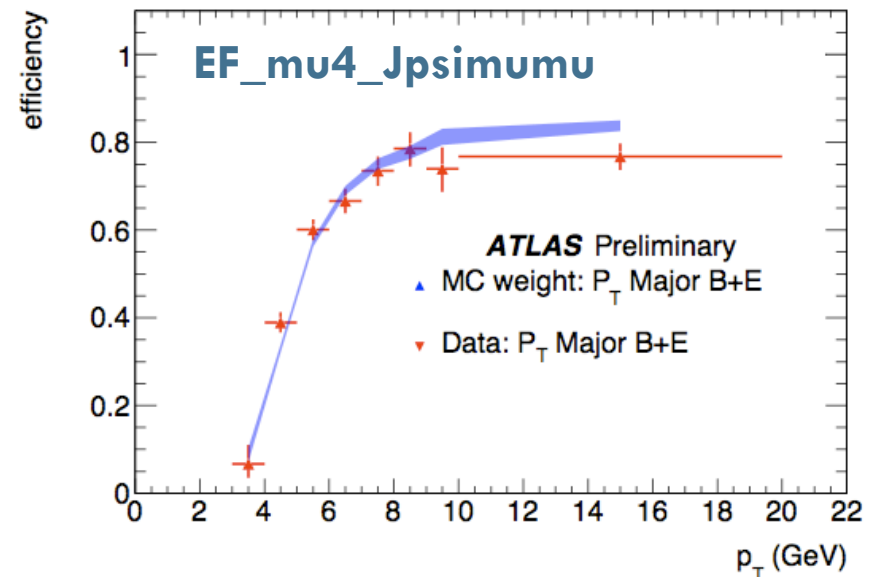
- Misura/limite al BR:

- studio sistematiche per i tagli di isolamento sul B_s

- validazione variabili likelihood per il reference channel (data vs MC)

- Definizione template distribuzioni di fondo (dalle sidebands)

- Definizione template per il segnale (dal MC)



$B_s \rightarrow \mu\mu$: Strategia di analisi

Ntuple di gruppo rare-decays :

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Reference channel:

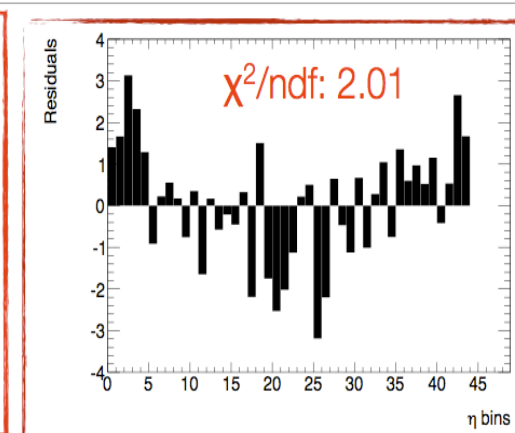
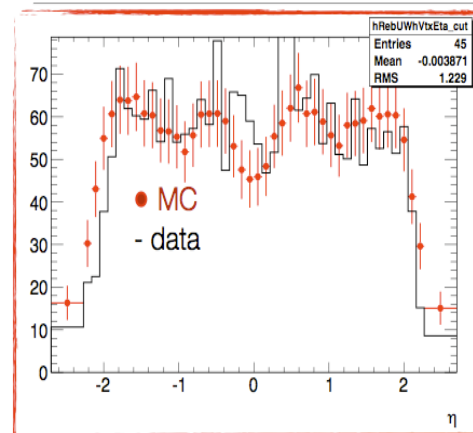
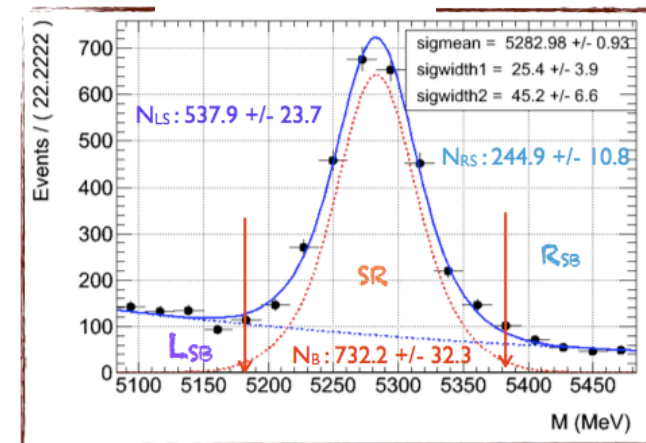
Re-weighting dal canale $B \rightarrow J/\psi(\mu\mu)K$

(2010 data)

→ re-weight of the $B^+ \rightarrow J/\psi(\mu\mu)K^+$
(MC)

No reweight

B^+ yield



$B_s \rightarrow \mu\mu$: Strategia di analisi

Ntuple di gruppo rare-decays :

(<https://twiki.cern.ch/twiki/bin/view/AtlasProtected/BPhysicsWorkingGroupDataRare>)

Le attività del gruppo consistono principalmente:

□ Studio delle efficienze di trigger per $B_s \rightarrow \mu\mu$.
più in generale studio delle efficienze per i trigger dimuonici (cfr talk di A. Ventura)

□ MC re-weighting technique

Reference channel:

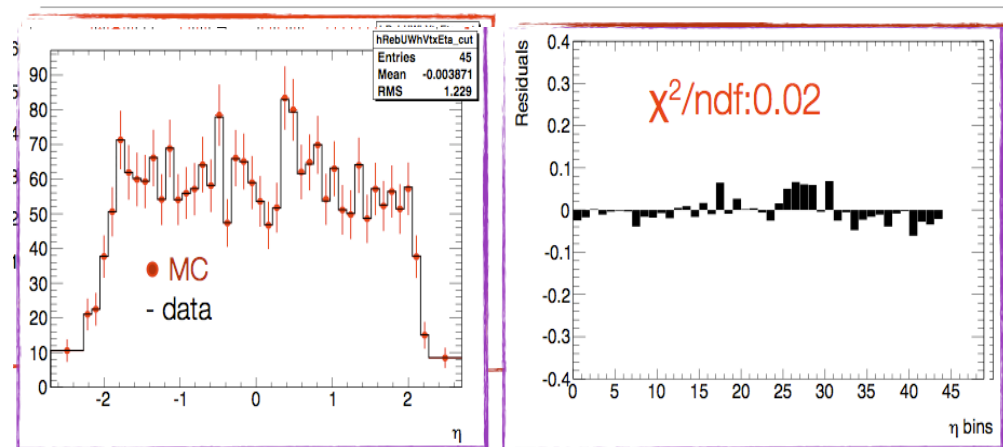
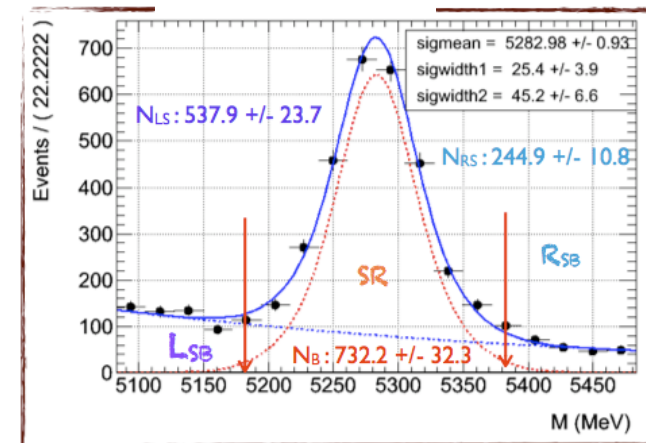
Re-weighting dal canale $B \rightarrow J/\psi(\mu\mu)K$

(2010 data)

→ re-weight of the $B^+ \rightarrow J/\psi(\mu\mu)K^+$
(MC)

1st iteration

B^+ yield



$B_s \rightarrow \mu\mu$: Sviluppi futuri

- Produzione di una sensitivity curve (SES) in 2 settimane

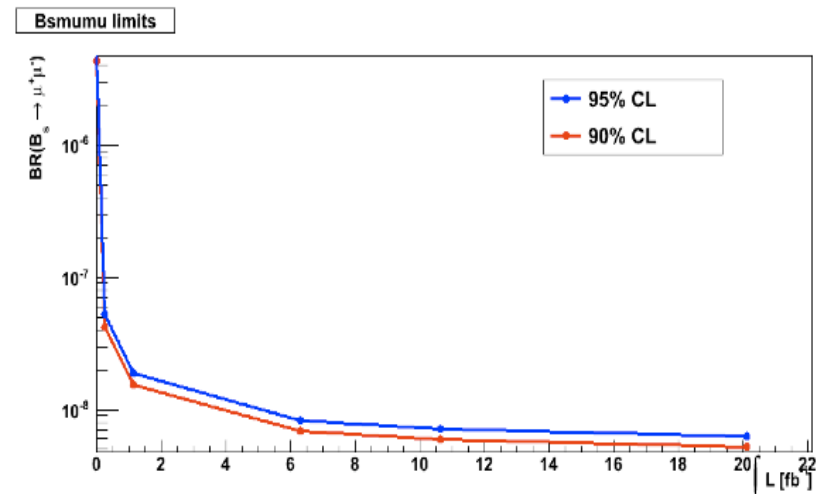
$$SES = \frac{1}{\alpha_{B_s} \epsilon_{B_s}^{tot}} \cdot \frac{\alpha_{reference} \epsilon_{reference}^{tot}}{N_{reference}} \cdot \frac{f_{reference}}{f_s} \cdot BR(reference)$$

Measured by LHCb

Limite attuale PDG: $<4.7 \times 10^{-8}$

- Ottimizzazione delle variabili di selezione
> Isolamento, pointing angle, massa invariante, L_{xy}
- Limite al BR basato sulla statistica 2010-2011 entro 1 mese (contributo studio delle sistematiche)
- Fine tuning dell'analisi (entro sei mesi).

BR atteso (limite) $\approx 4-6 \cdot 10^{-8}$

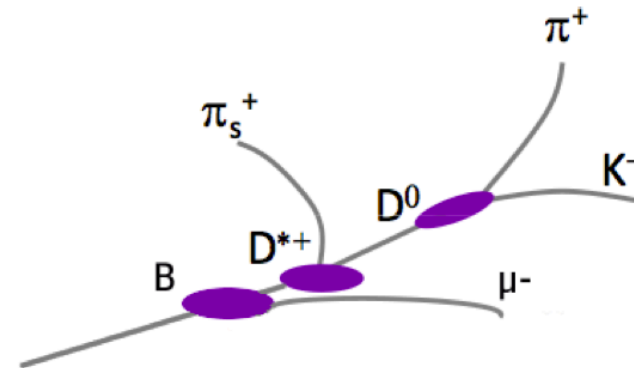


B production cross section with $D^{*\pm} \mu^{\mp} X$ final states

Articolo in preparazione:

<http://cdsweb.cern.ch/record/1330662>

Dati ATLAS 2010 periodi E-G ($L=3.4 \text{ pb}^{-1}$)



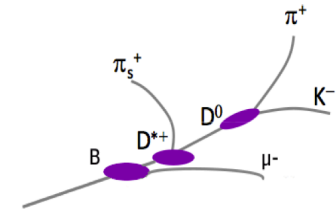
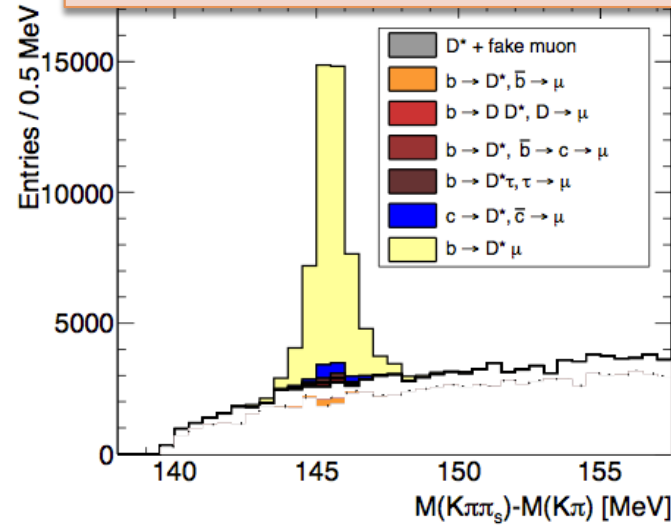
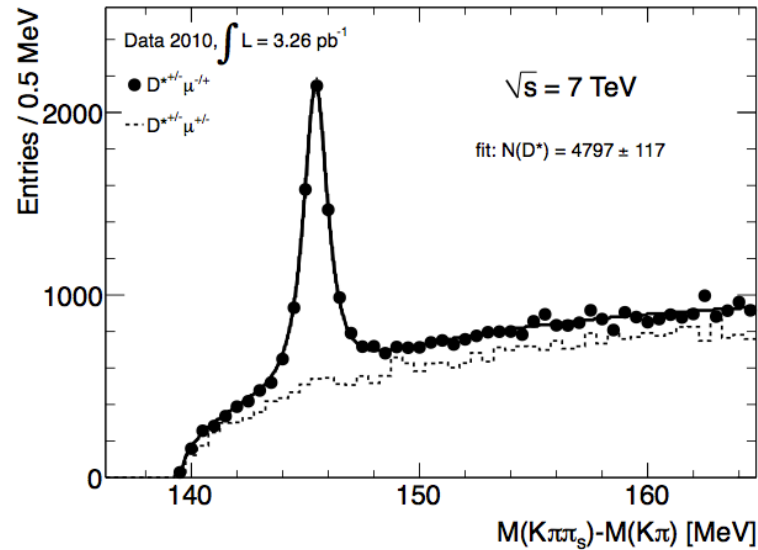
Perché lo stato finale $D^{*} \mu X$?

- Branching ratio complessivo sufficientemente elevato
 $b \rightarrow D^{*} \mu X$ (2.75%)
- Facilmente triggerabile (singolo muone)
- Mesone D^{*} facile da ricostruire (3 tracce ID, cinematica particolare)
- Eccellente purezza del campione (basse contaminazioni non provenienti da singolo b)

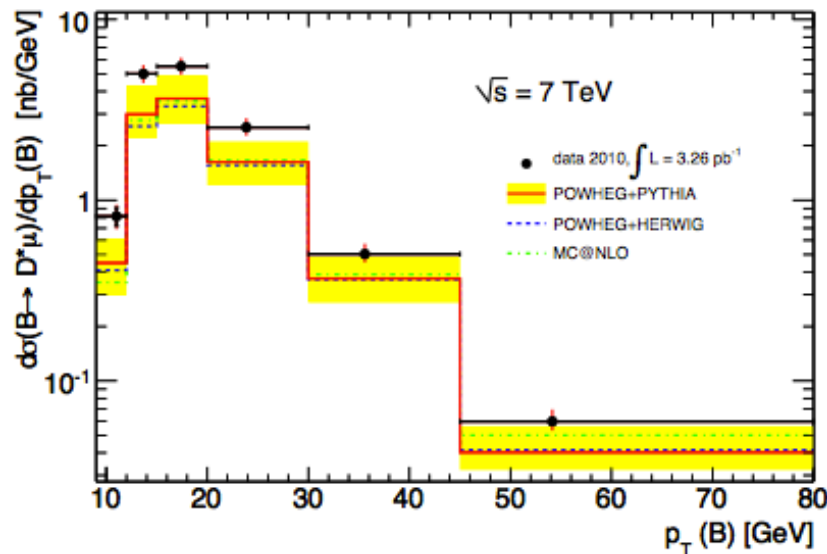
Ulteriori informazioni nel talk "b- e c-tagging, b cross section" di F. PARODI (GE)

Sezione d'urto differenziale $B \rightarrow D^* \mu X$

Monte Carlo: bbmu4X e ccmu4X



Sezione d'urto differenziale $B \rightarrow D^* \mu X$



Regione cinematica:

$$|\eta(D^*)| < 2.5$$

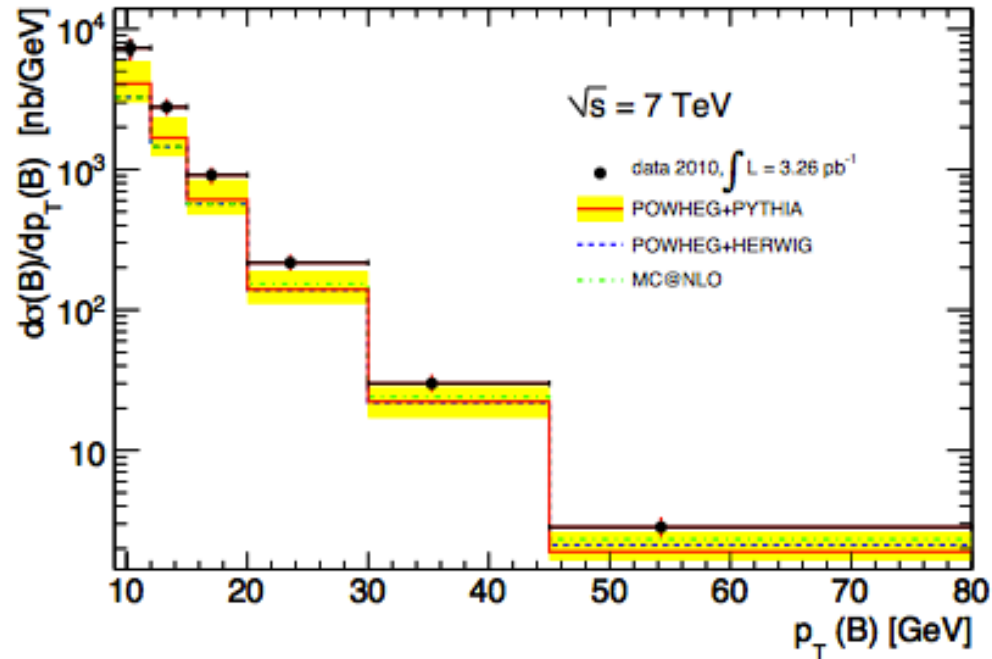
$$|\eta(\mu)| < 2.4$$

$$p_{TD^*} > 4.5 \text{ GeV}$$

$$p_{T\mu} > 6 \text{ GeV}$$

Sezione d'urto differenziale del B

Regione
cinematica:
 $|\eta_B| < 2.5$
 $p_{TB} > 9 \text{ GeV}$



La banda gialla rappresenta le incertezze teoriche delle predizioni. I dati sono presentati con l'errore statistico in nero ed errore statistico + sistematico in rosso.

Entro la regione cinematica la sezione d'urto integrata è:

$$\sigma(pp \rightarrow BX) = 33.9 \pm 1.0|_{stat}^{+3.4}_{-4.3}|_{syst} \pm 2.5|_B \pm 1.2|_{\mathcal{L}} \mu b$$

Risultati CMS (arXiv:1104.2892, arXiv:1101.0131)

$$\sigma(pp \rightarrow B^0 X) = 33.2 \pm 2.5|_{stat} \pm 3.5|_{syst} \mu b_{(p_T(B) > 5 \text{ GeV}, |y(B)| < 2.2)}$$

$$\sigma(pp \rightarrow B^+ X) = 28.1 \pm 2.4|_{stat} \pm 2.0|_{syst} \pm 3.1|_{\mathcal{L}} \mu b_{(p_T(B) > 5 \text{ GeV}, |y(B)| < 2.4)}$$

In situ Muon Performance JPSI T&P

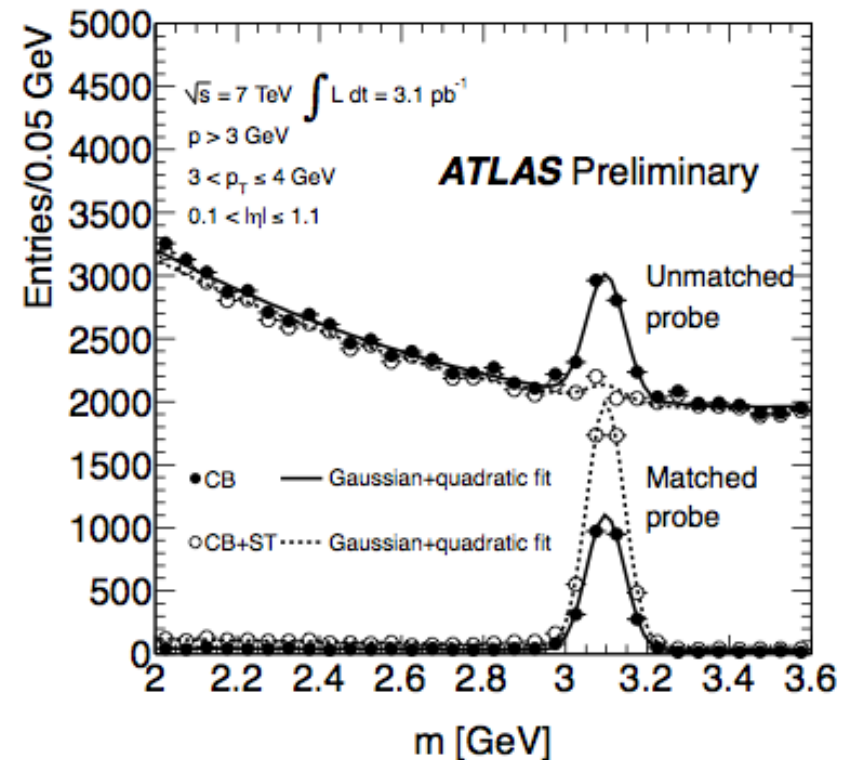
<https://twiki.cern.ch/twiki/bin/view/AtlasProtected/JpsiMuMuExtraInfo>

□ Efficienze di ricostruzione per i muoni di basso pT:

cfr. ATL-COM-PHYS-2011-082

□ Attività svolta nel “Low-pT performance group”:
“Measurement of the ATLAS muon reconstruction and trigger efficiency using J/ψ decays” - ATLAS-CONF-2011-021 (3pb⁻¹)

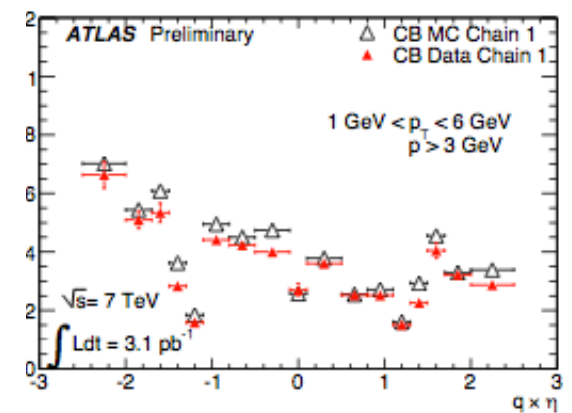
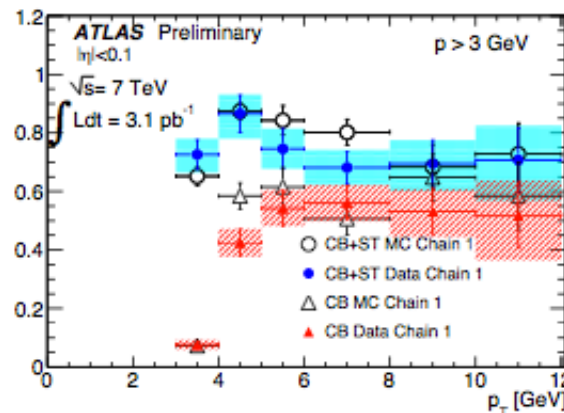
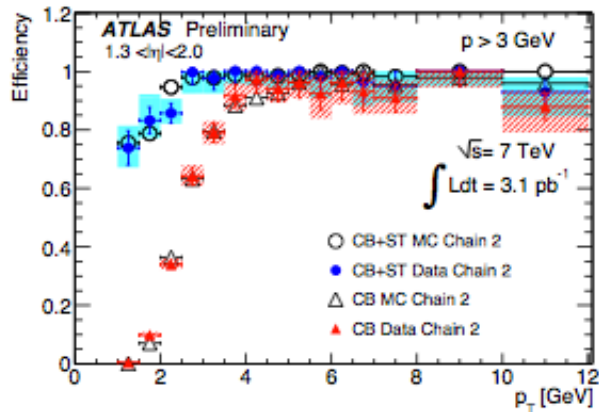
□ Il tool di analisi sviluppato è stato utilizzato per il reprocessing dei dati 2010 con rel 16.6.x.y ed è il tool ufficiale ATLAS per lo studio delle efficienze di ricostruzione con i dati 2011



Efficienza di ricostruzione è ottenuta dal rapporto tra il numero di eventi sotto al picco nella distribuzione dei “matched probe” ed il numero totale di eventi. Applicato un χ^2 fit simultaneo.

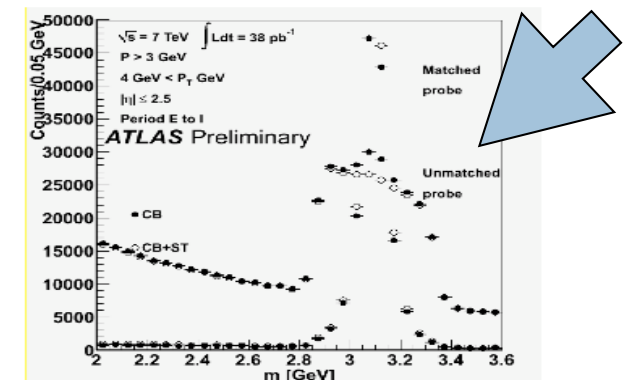
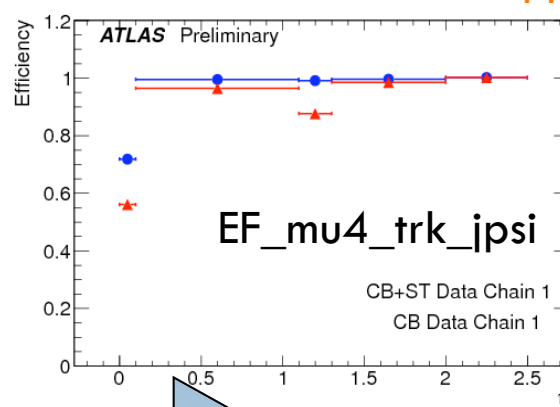
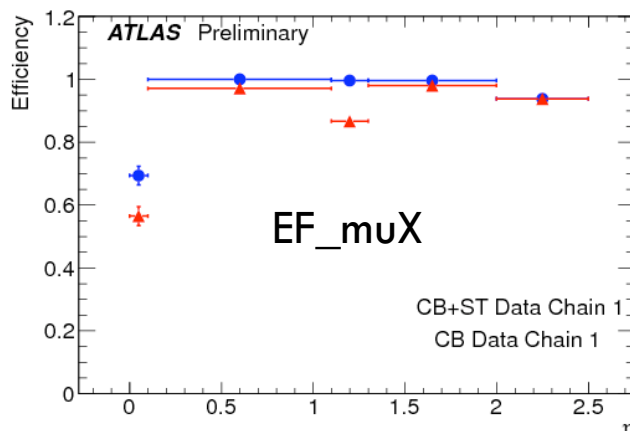
InsituMuonPerformace JPSI T&P

from ATLAS-CONF-2011-021 (per. A-F, highest thr. unprescaled μ trigger mu6)

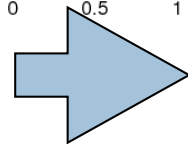


Analisi ripetuta con rel 16 (35pb⁻¹)

- Di-muon triggers to increase statistics
- Probe + calomuon to remove BG



from per. G low acceptance for J/ψ selection



need of dedicated triggers

Conclusioni

- Focus delle primi analisi del 2010 su J/ψ (misura sezione d'urto di produzione, calibrazione, performance ricostruzione e del trigger)
- Evoluzione nelle analisi in corso nel 2011 in linea con il programma previsto della b-physics (misure di lifetime, decadimenti esclusivi, misure di sezione d'urto, decadimenti rari)
- Contributo dei gruppi italiani in tutti i sottogruppi di analisi per il 2011
- Attività legate allo studio delle performance del trigger ed alla ricostruzione confermate per il 2011