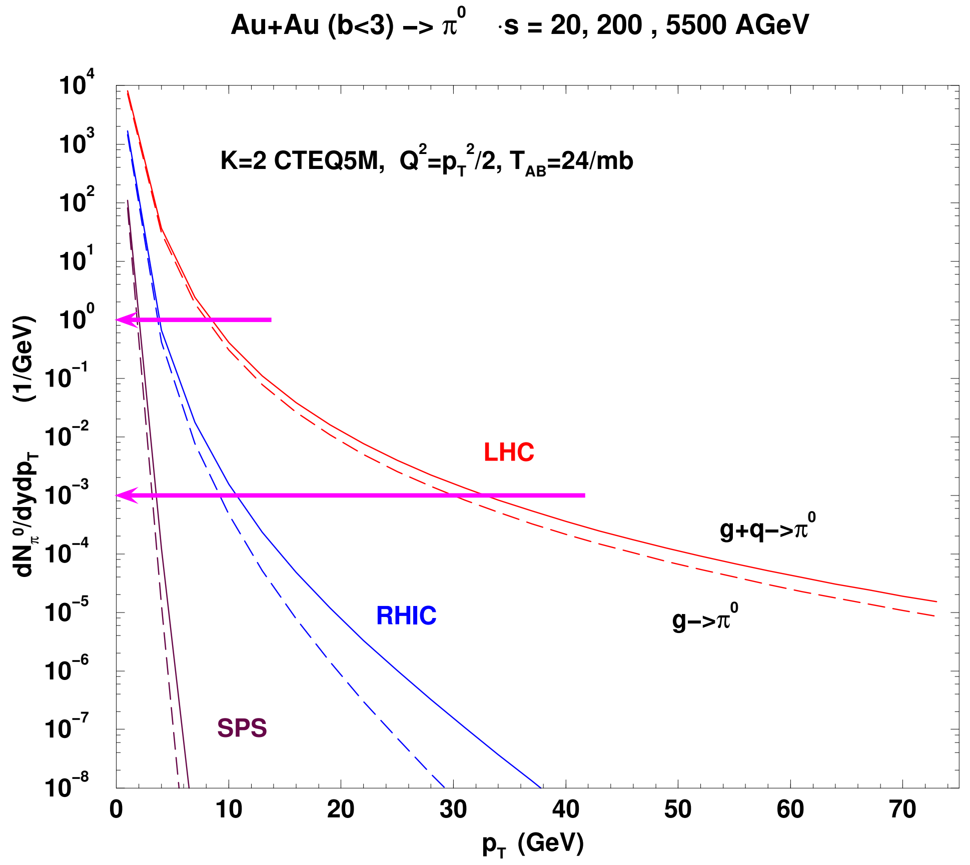
Why SPS → RHIC → LHC?

1. Hard Probes: QCD-calculable



→ tomography

M.Gyulassy

2. Soft – Semihard PartonMatter

copious mini-jets $\to$ "initial conditions": HERA

$$dN_{p_1 p_2 \to 12} = T_{AA}(b)\, \mathcal{K} \sum_{\text{partons}} x_1 x_2\, f_{p_1/A}(x_1, Q^2)\, f_{p_2/A}(x_2, Q^2)\, \frac{d\hat{\sigma}_{12}}{d\hat{t}}\, dp_\perp^2\, dy_1 dy_2$$

mini-jets $\xrightarrow{\textit{rapid thermalization}}$ mini-jet plasma $+$ soft:

	RHIC	LHC
T_i [GeV]	0.544 (334)	1.038
λ_i^g	0.41 (1.2)	0.25
$\frac{dN_\pi}{dy}$	1080	5204

with shadowing

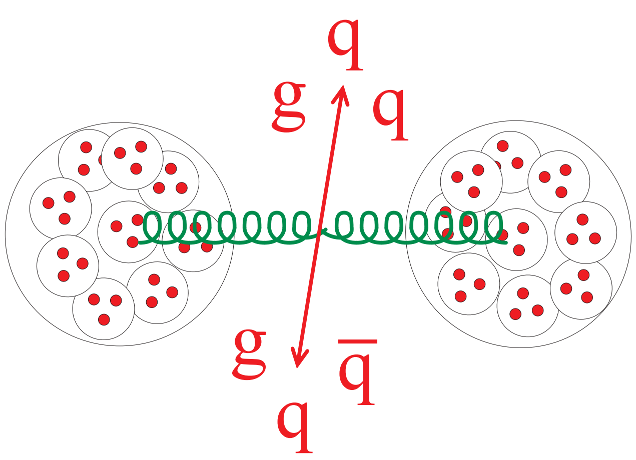
$\lambda_i^q \approx \lambda_i^g$

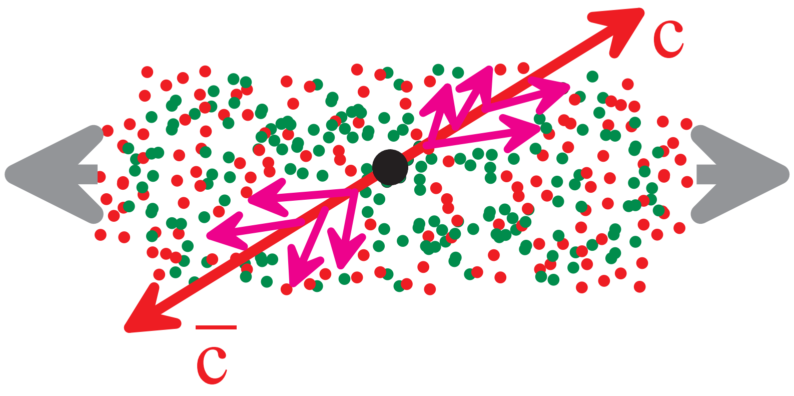
$\tau_i \approx 0.2$ fm/c

$N_c^{\text{hard}} > N_c^{\text{thermal}}$

$N_{l\bar{l}}^{\text{hard}} \sim N_{l\bar{l}}^{\text{thermal}}$

Jet Quenching

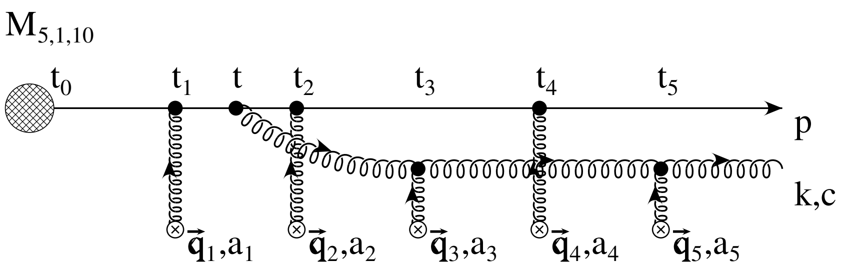




QED: e.m. radiation (small-angle scattering)

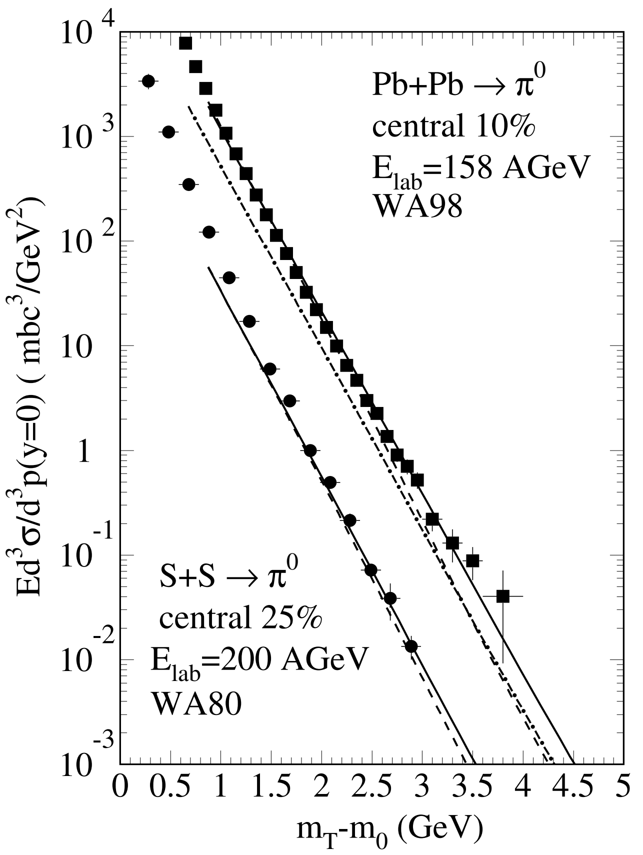
Bethe-Heitler + LPM + TM → destructive interference

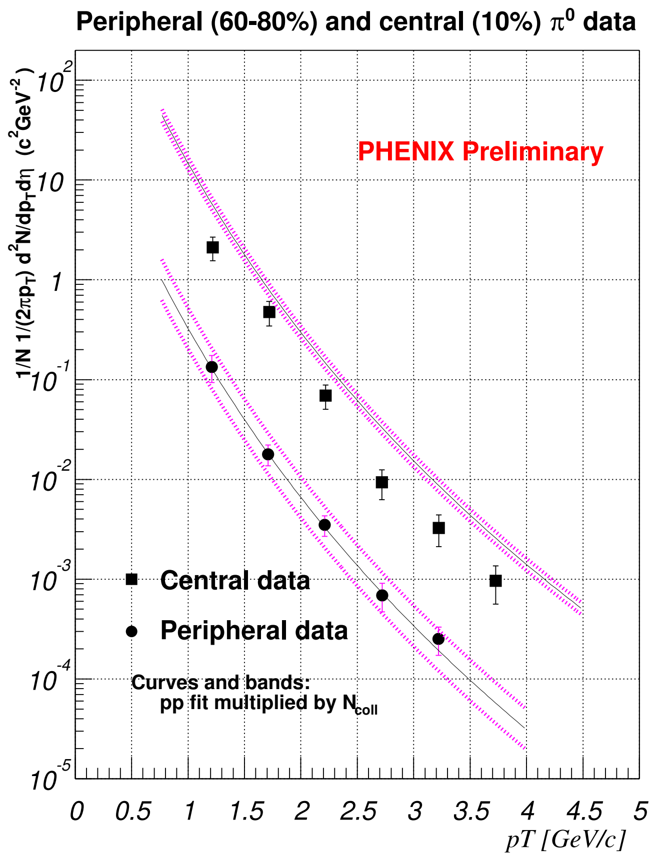
QCD: gluon radiation (color charge transfer on straight trajectories)



SPS: −

RHIC: +





Wang

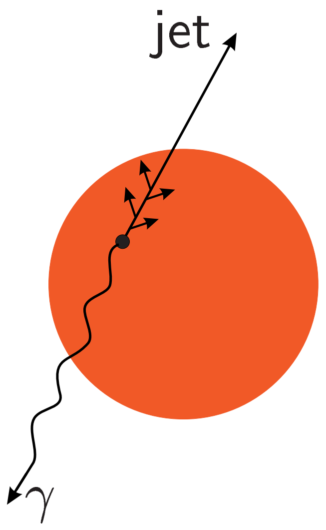
Gyulassy, Levai

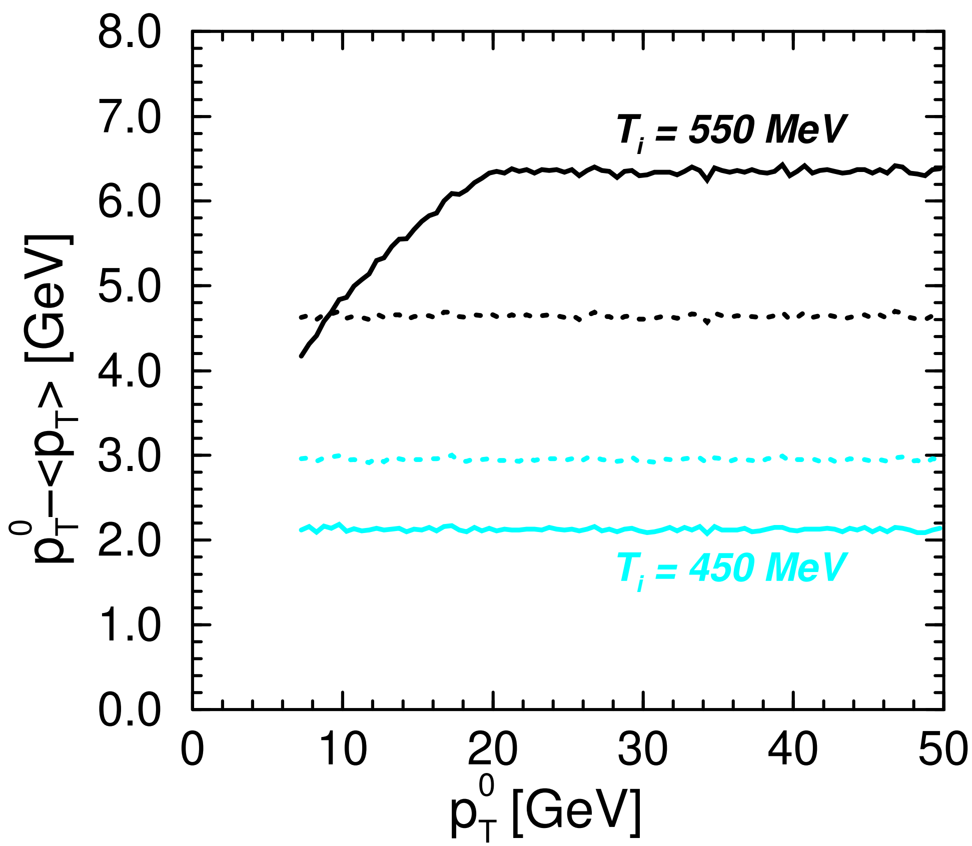
energy loss (BDMPS-Z): $\Delta E(L^{2(1)}, T_f)$, $\Delta E_{\mathrm{plasma}} \gg E_{\mathrm{hadrons}}$

gluon emission needs time $\rightarrow$ no explicit sensitivity on T_i

but: geometry $\rightarrow$ $L(T_i)$

γ tagged jets $\rightarrow$ imbalance $\sim T_i$ at τ_i fixed





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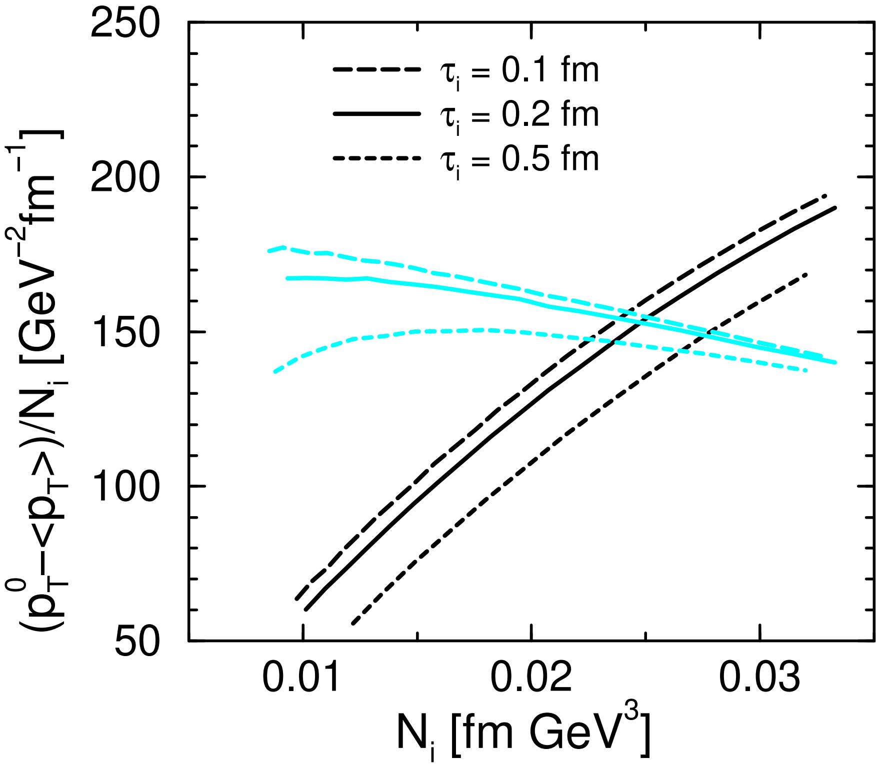
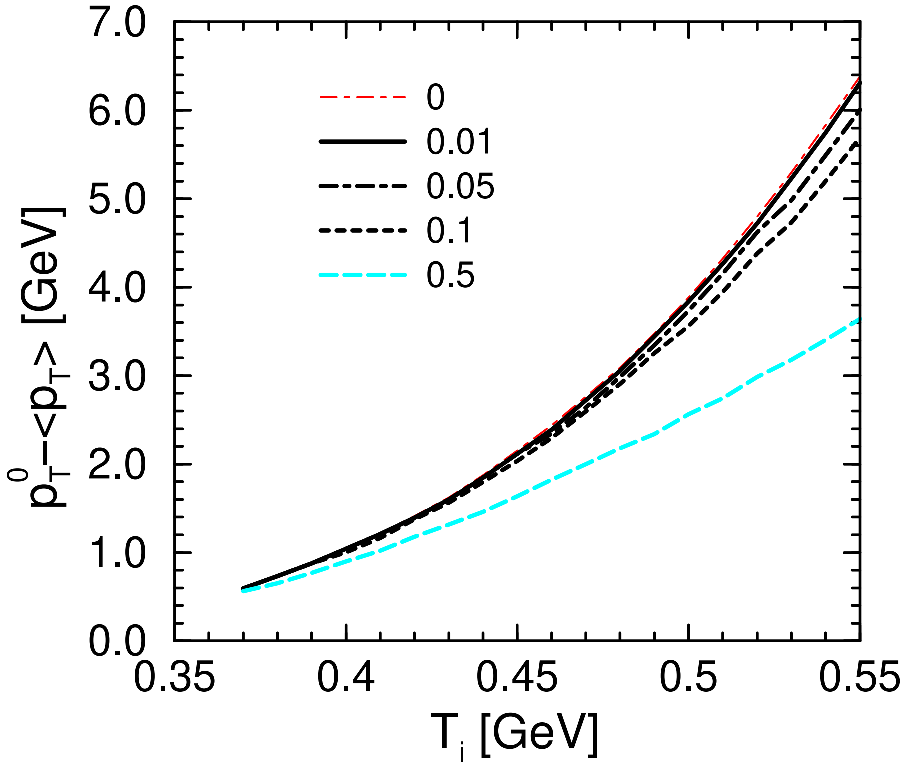
imbalance $\sim N \equiv T_i^3 \tau_i$

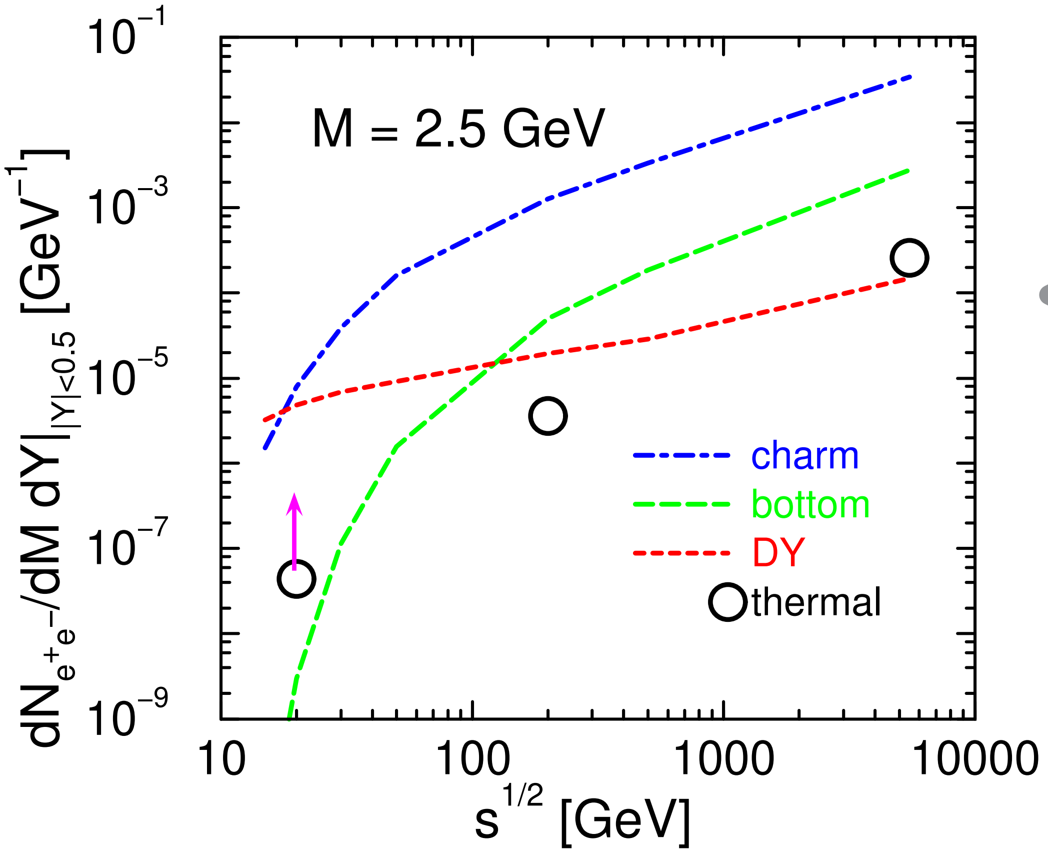


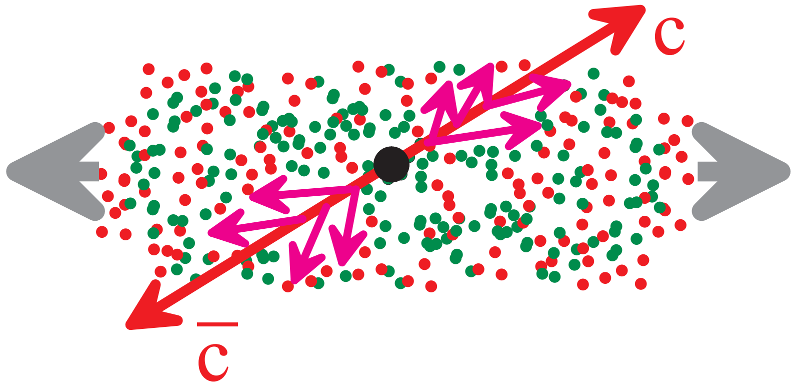
importance of jet cone selection

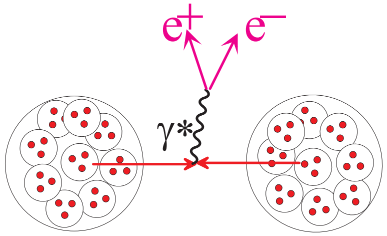


$\rightarrow$ discriminate scenarios

Dileptons & Charm Stopping

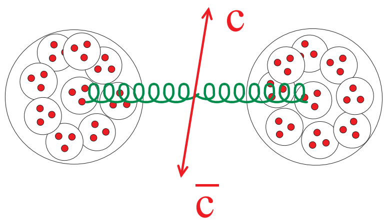






Drell-Yan: $q\bar{q} \to \gamma^* \to e^+e^-$

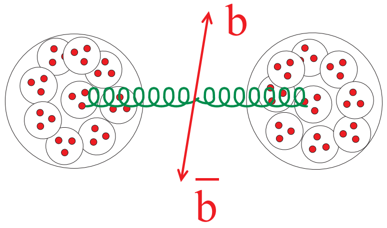
correlated decays



open charm: $gg \to c\bar{c} \xrightarrow{fragmentation} D\bar{D}$

$e^-\bar{X}$ 12%

e^+X 12%



open bottom: $gg \to b\bar{b} \xrightarrow{fragmentation} B\bar{B}$

$e^-\bar{X}$ 10%

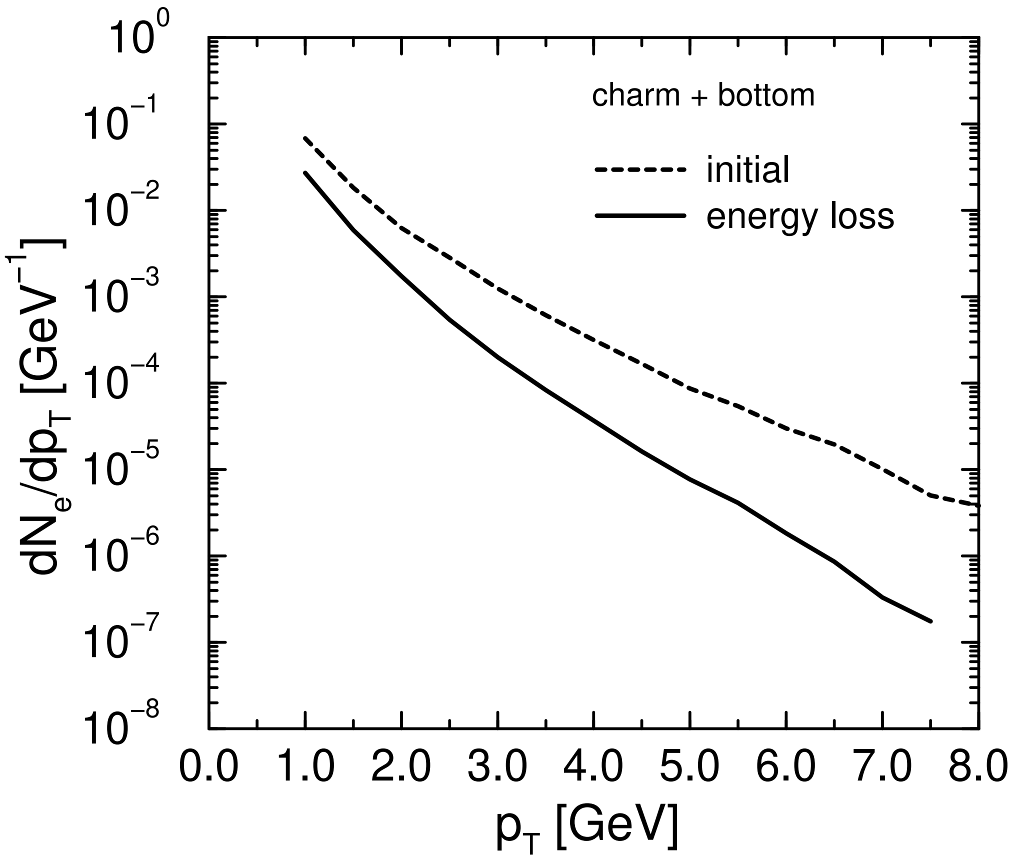
e^+X 10%

$B^0 \to e^+D^-X$ 2%

$e^-\bar{X}$ 17%

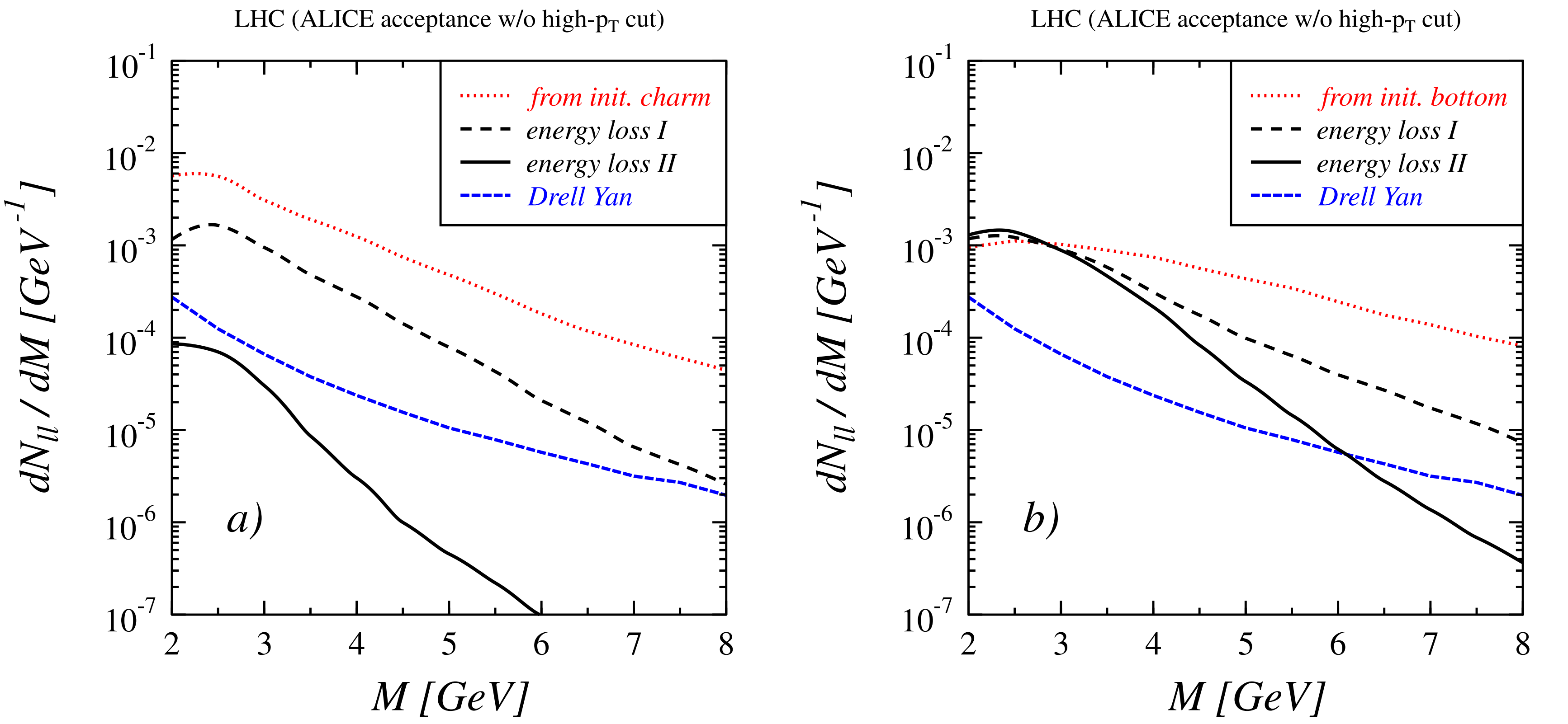
$$B^0 \xrightarrow{4\%} e^+D^{*-}_{2010}X \xrightarrow{100\%} \bar{D}^{0/-}x \xrightarrow{7/17\%} e^-X'$$

(i) energy loss $\rightarrow$ modified e^- spectrum:

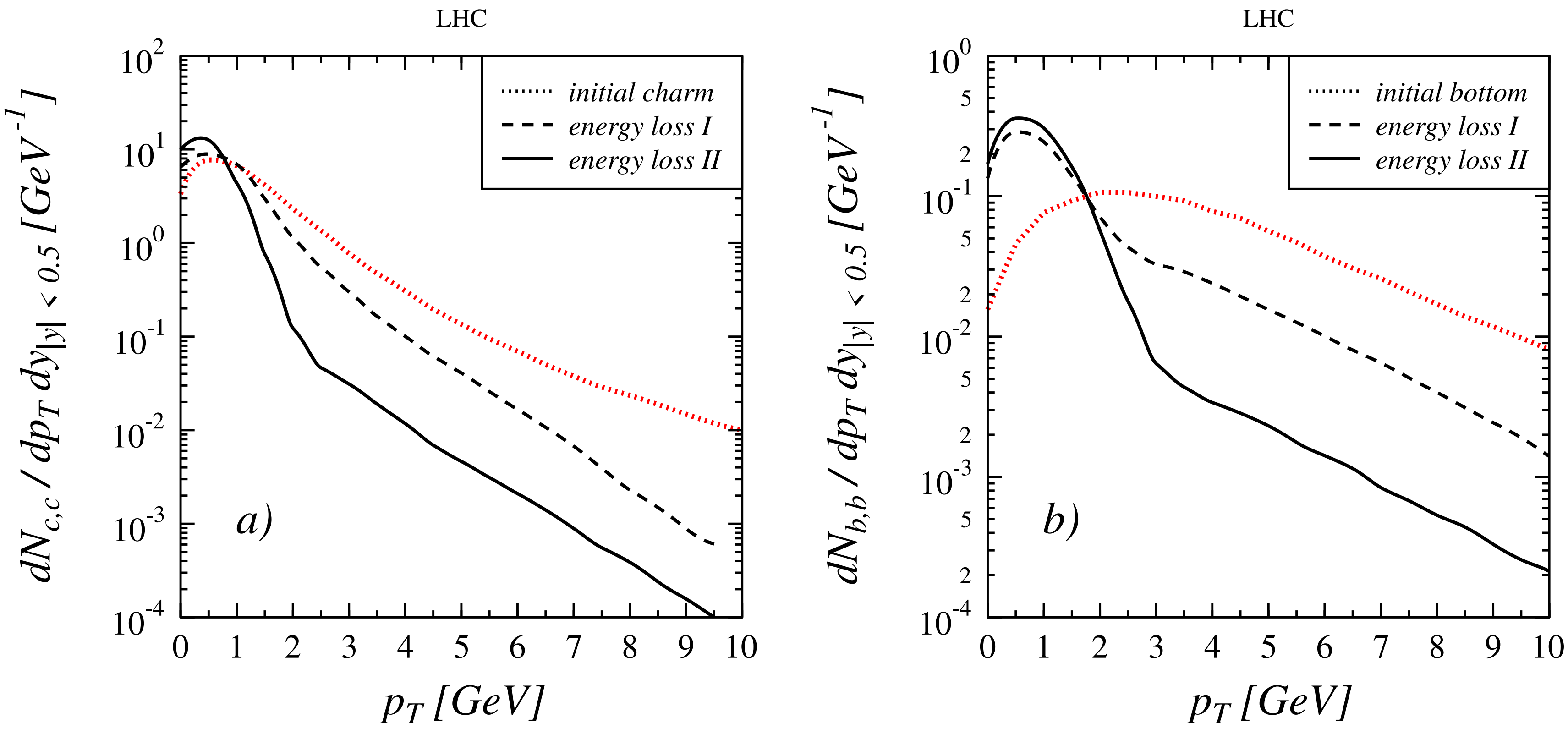


$\rightarrow$ ALICE + TRD

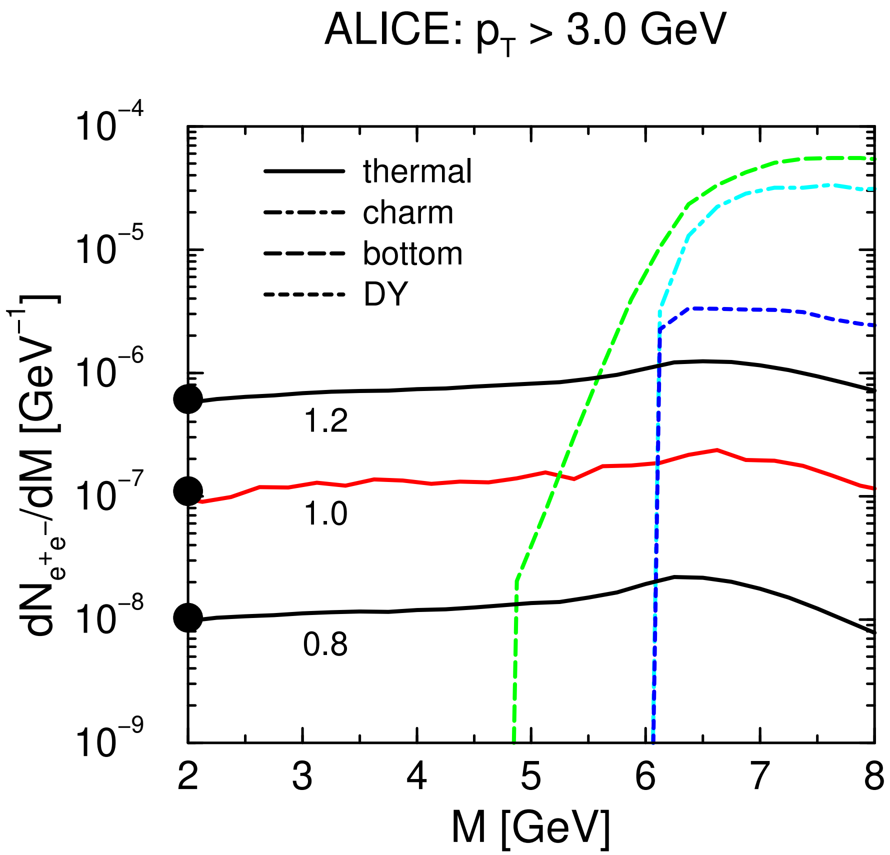
(ii) energy loss $\rightarrow$ modified e^+e^- spectrum:

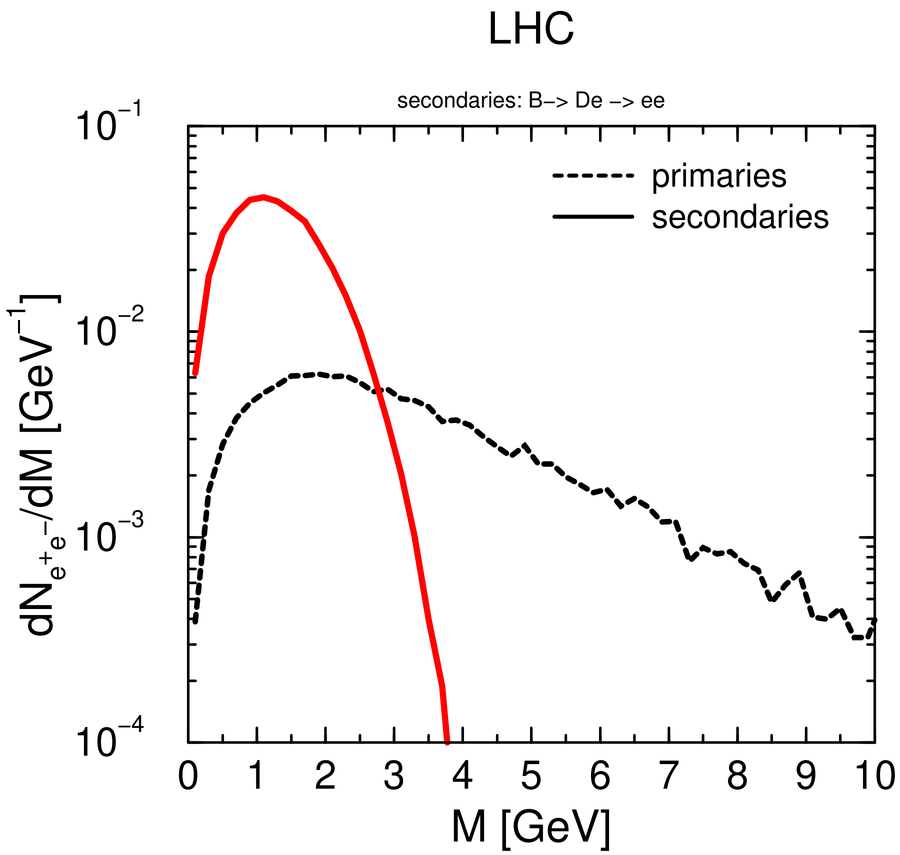


w/o acceptance

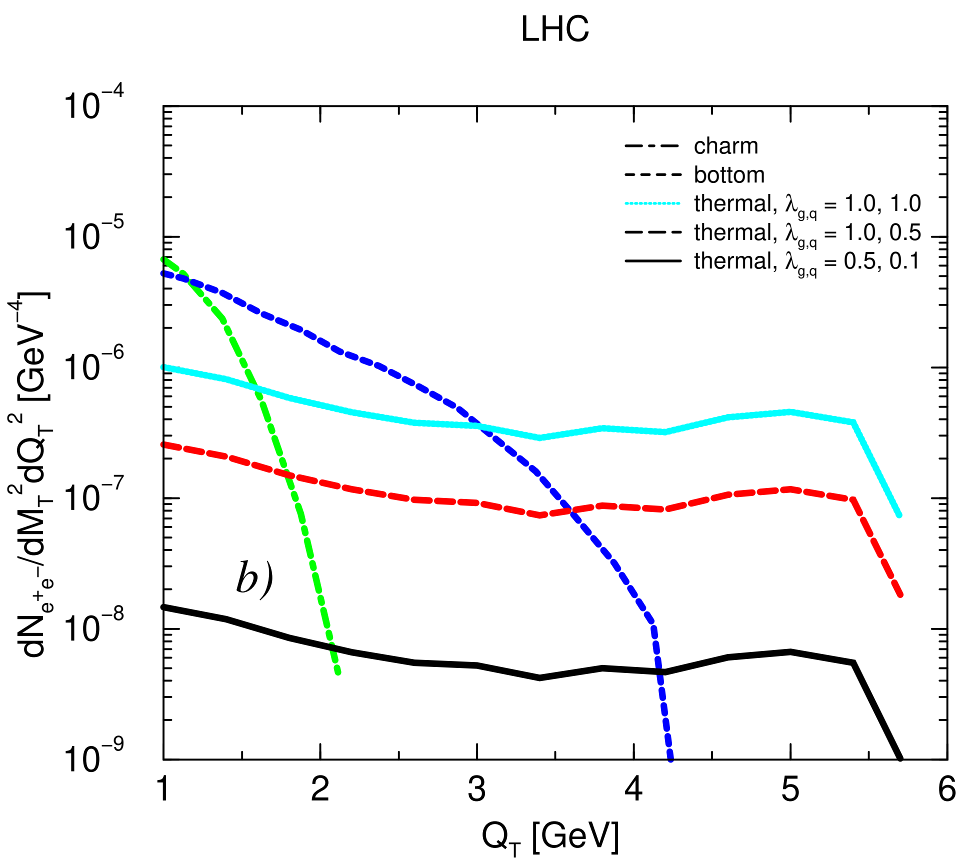


kinematical cuts: insufficient to suppress charm & bottom sources



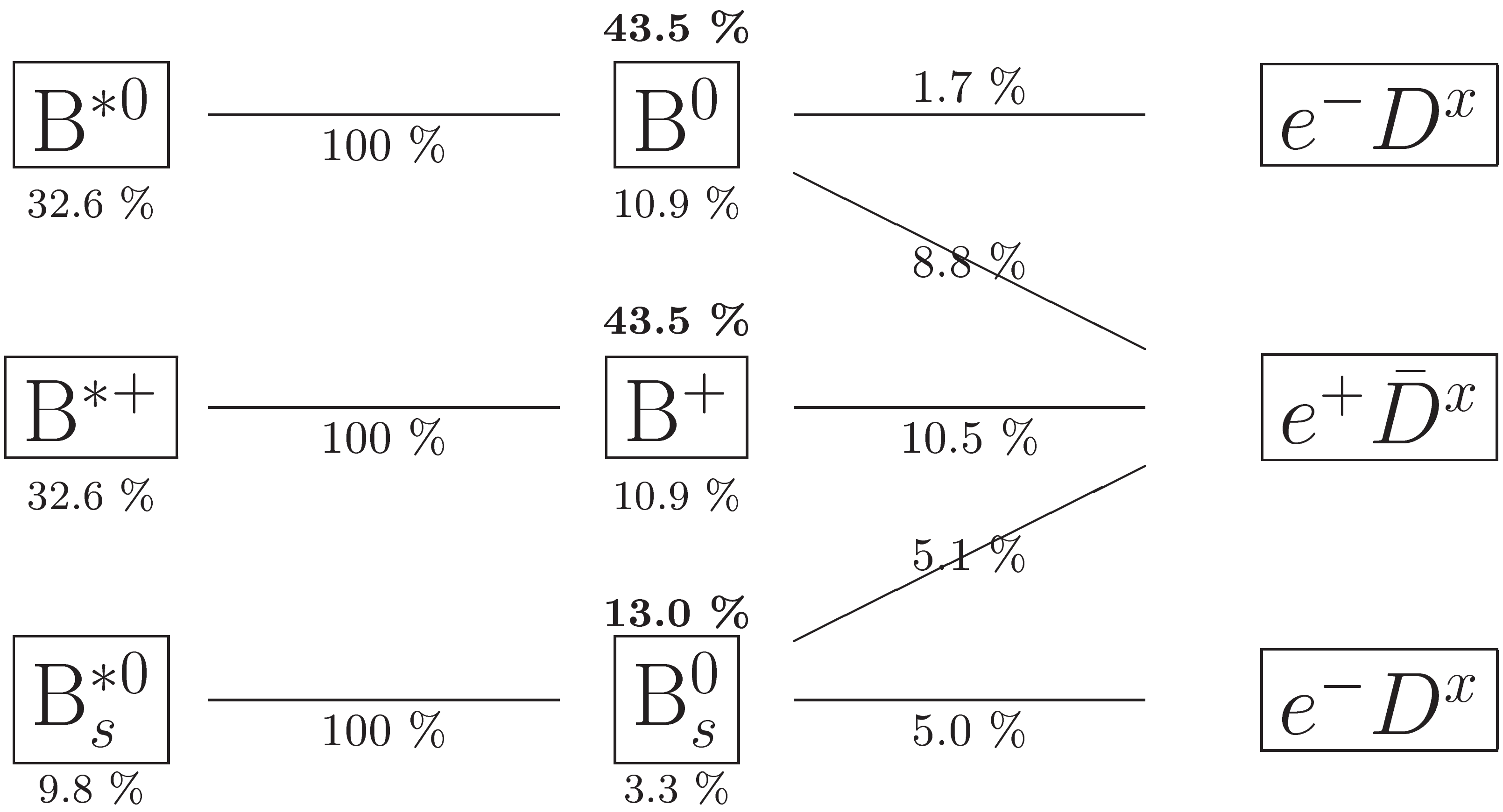


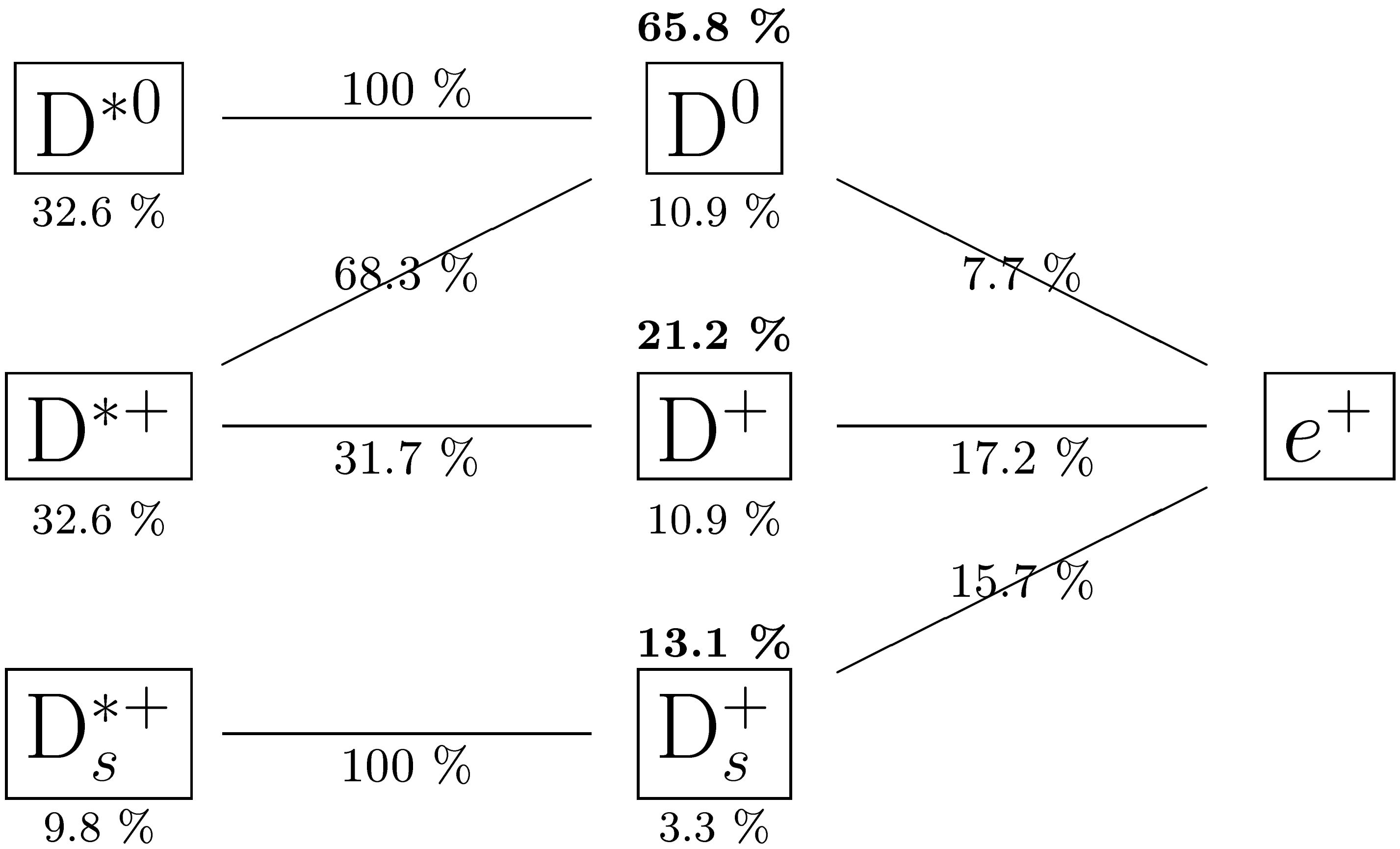
$p_\perp^{\min} = 2$ GeV, $\quad M_\perp \approx 5.5$ GeV



$\sqrt{\langle k_\perp^2 \rangle} = 0$, $\quad$ mostly only primary decays

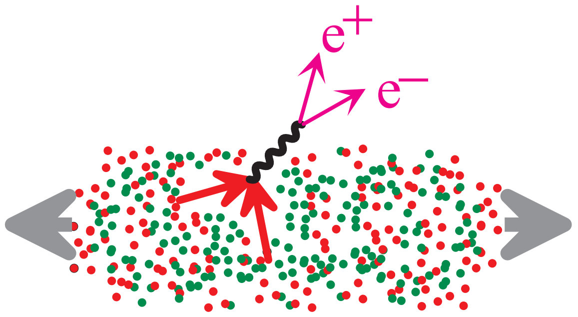
PYTHIA: decay chains





$\sum$: long decay chains $\Longrightarrow$ randomized $e^{\pm}$ $\Longrightarrow$ look like thermal signal break-through: TRD $\rightarrow$ identify D, B decay $e^{\pm}$

$\rightarrow$ access to DY + thermal signals



Thermal Signal

thermal yield from $q\bar{q} \rightarrow e^+e^-$:

$$dN \propto \int d\tau\tau\, K_0 \left(\frac{M_\perp}{T(\tau)}\right) \lambda_q^2(\tau)\, dp_{\perp+} dp_{\perp-} dy_+ dy_-$$

information in M spectrum: $\frac{dN}{dM\,dY} \propto (\tau_i\, \lambda_i^q\, T_i^3)^2\, f(\cdots)$ for $T_i \gg T_c$

$\Downarrow$

"initial" plasma state

problems:	gluon saturation: rate $gg \leftrightarrow ggg$	$\lambda_g(\tau)$
	quark saturation: rate $gg \leftrightarrow q\bar{q}$	$\lambda_q(\tau)$
expansion	hydrodynamics	$T(\tau)$

Conclusions

– collider: more hard processes $\leftarrow$ pQCD

if plasma: $T_i \gg T_c$, larger life time + size

– charm & bottom energy loss $\rightarrow$ TRD: modified $p_\perp^e$ spectrum (slope!)

– jet quenching stronger

– tagged high-$p_\perp$ jets possible

– pp & pA at same energy are required