d-D quark mixing angle in the E_6 model

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in collaboration with

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Flavour at the LHC workshop

Recall the model

$$\begin{pmatrix} u_L \\ d_L \end{pmatrix}, u_R, d_R, D_L, D_R \quad \begin{pmatrix} c_L \\ s_L \end{pmatrix}, c_R, s_R, S_L, S_R \quad \begin{pmatrix} t_L \\ b_L \end{pmatrix}, t_R, b_R, B_L, B_R$$

D, S, B: New iso-singlet quarks (Q=−⅓)

$$\begin{aligned} \mathrm{L}_{\mathcal{D}} &= \frac{\sqrt{4\pi\alpha_{em}}}{2\sqrt{2}\sin\theta_W}\left[\bar{u}^\theta\gamma_\alpha\left(1-\gamma_5\right)d\cos\phi+\bar{u}^\theta\gamma_\alpha\left(1-\gamma_5\right)D\sin\phi\right]W^\alpha \\ &- \frac{\sqrt{4\pi\alpha_{em}}}{4\sin\theta_W}\left[\frac{\sin\phi\cos\phi}{\cos\theta_W}\bar{d}\gamma_\alpha\left(1-\gamma_5\right)D\right]Z^\alpha \\ &- \frac{\sqrt{4\pi\alpha_{em}}}{12\cos\theta_W\sin\theta_W}\left[\bar{D}\gamma_\alpha\left(4\sin^2\theta_W-3\sin^2\phi(1-\gamma_5)\right)D+\bar{d}\gamma_\alpha\left(4\sin^2\theta_W-3\cos^2\phi(1-\gamma_5)\right)d\right]Z^\alpha + h.c. \end{aligned} \tag{1}$$

The measured values of CKM elements & unitarity of the 3x4 CKM rows constrains ϕ : *sin ϕ < 0.07* .

θ : CKM mixing angle
ϕ : d - D mixing angle

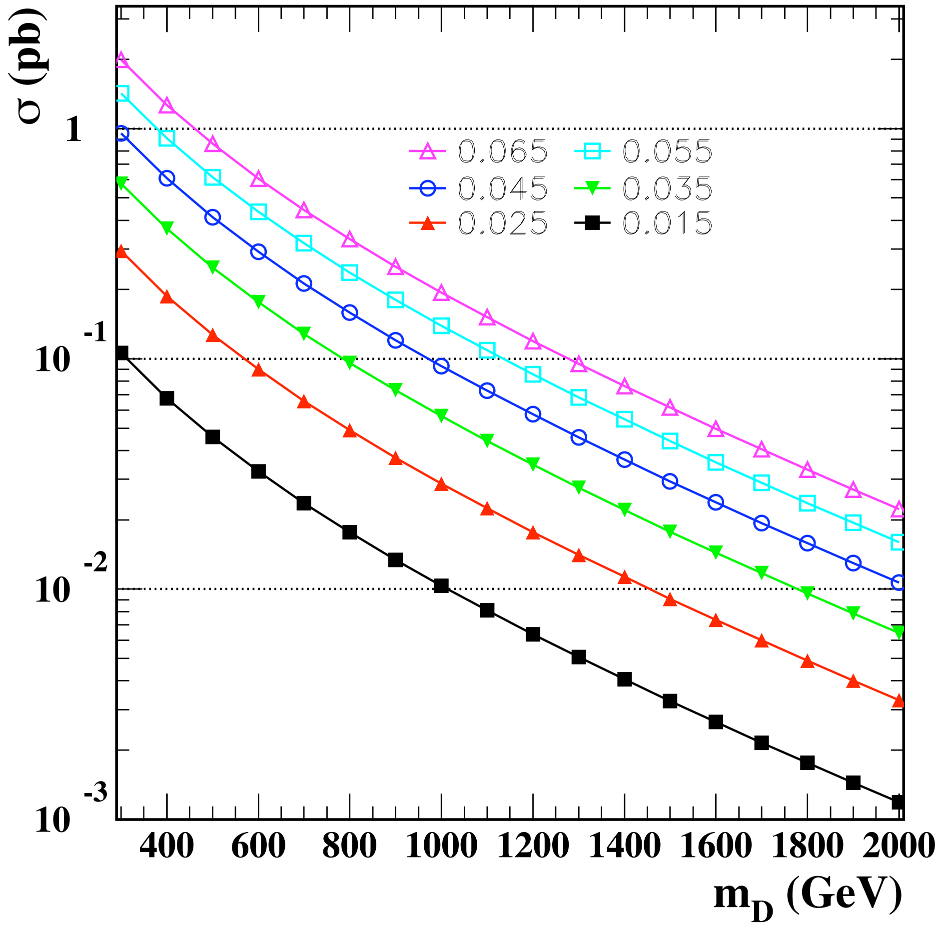
***Assumptions*:**

1. In-family mixing bigger than between family mixing
2. D quark is the lightest, like SM: most accessible in LHC
3. E_6 gauge bosons heavy & don't interact w/ SM bosons

Mixing angle with SM quark

•d-D mixing angle can only be extracted from the single production of D quark since the cross section depends linearly on ($\sin\Phi$)^2

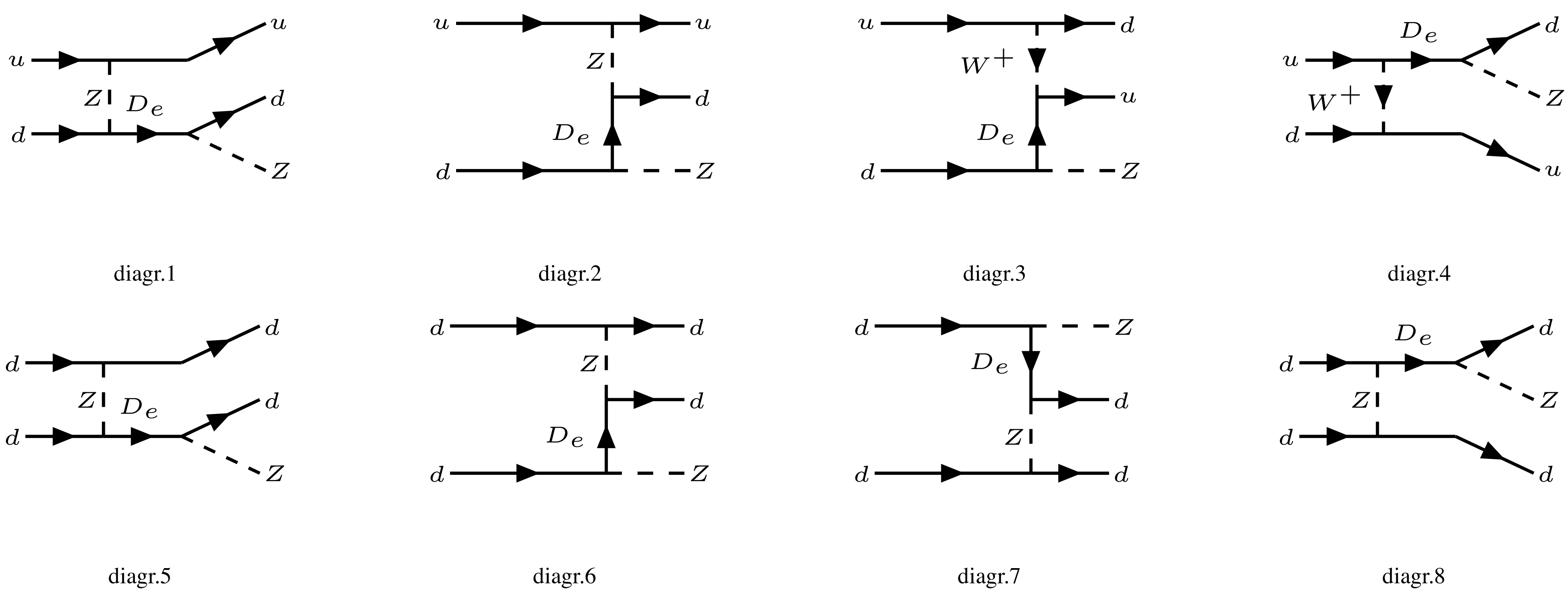
•Cross section for pp→D+jet as a function of m_D and for various values of the mixing angle (0.015 ... 0.065)



➡D quark + jet production and decay @ LHC should be studied

Single D quark production

- Decays involving Z would be easiest to reconstruct:



➡m_D = 400 ... 2000 GeV cases are considered using generator level MC (CompHEP) with 2j+Z as the signal (sinΦ=0.045)

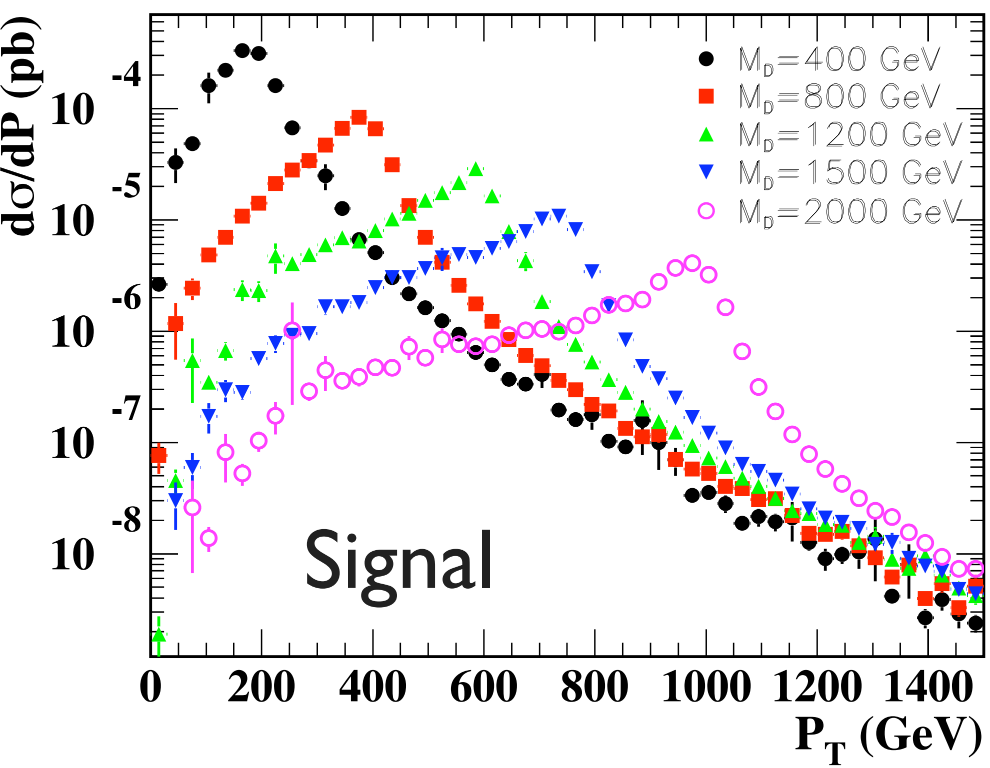
- All SM processes yielding 2j+Z are also considered as background events where j can be any light jet.

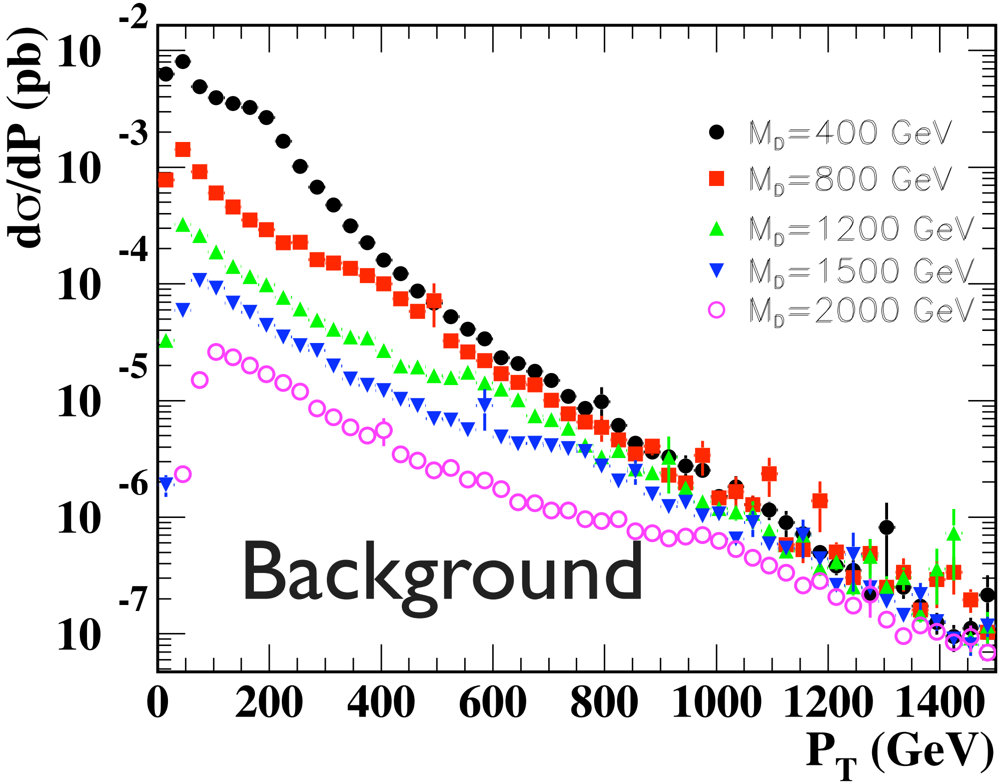
Event selection

- Trigger and detector driven common cuts for all mD values:

$$
\begin{aligned}
P_{Tp} &> 15\,\mathrm{GeV} \\
|\eta_p| &< 3.2 \\
|\eta_Z| &< 3.2 \\
R_p &> 0.4 \\
M_{Zp} &= M_D \pm 20\,\mathrm{GeV}
\end{aligned}
$$

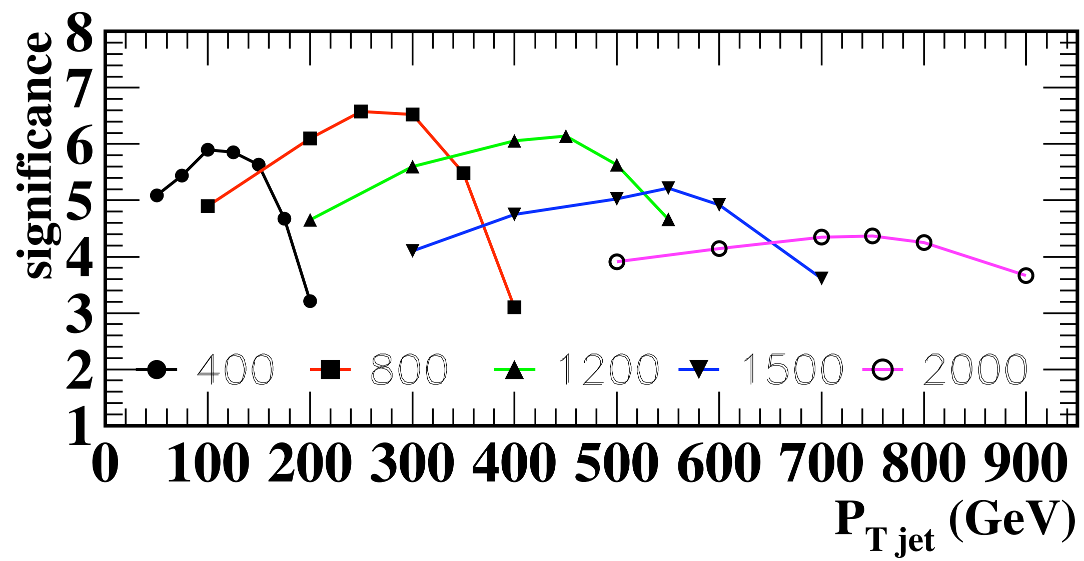
✓Signal & Bg can be separated using the PT of the most energetic jet:





Further details

- Cut values were optimized by maximizing the signal significance, $\sigma = S/\sqrt{B}$



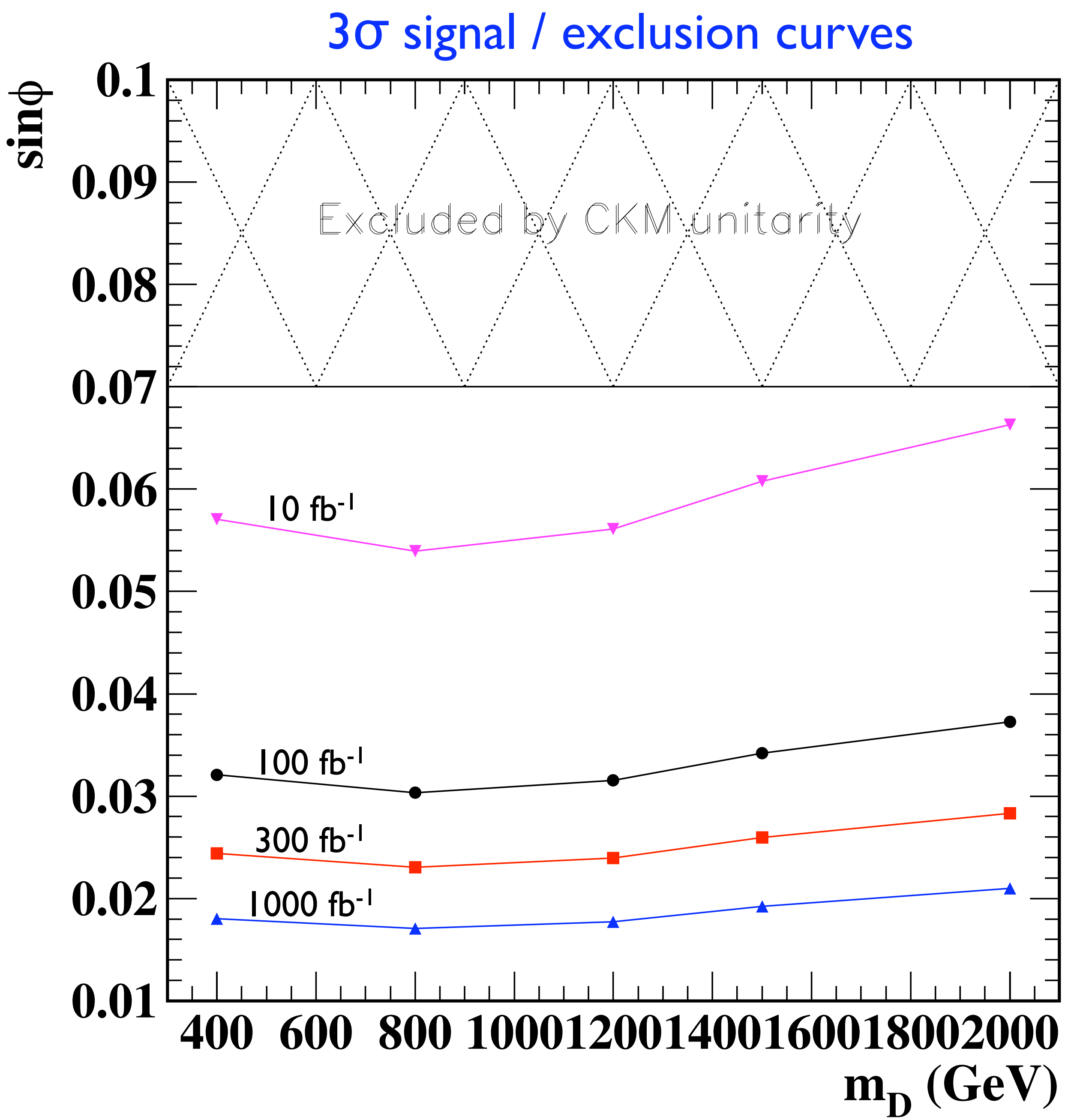
- effective signal and bg cross sections for 2j+Z:

M_D(GeV)	400	800	1200	1500	2000
Γ(GeV)	0.064	0.51	1.73	3.40	8.03
Signal (fb)	100.3	29.86	10.08	5.09	1.92
Background (fb)	2020	144	18.88	6.68	1.36
optimal P_T cut	100	250	450	550	750

- number events from Z leptonic decays after 100fb^{-1} ∫luminosity:

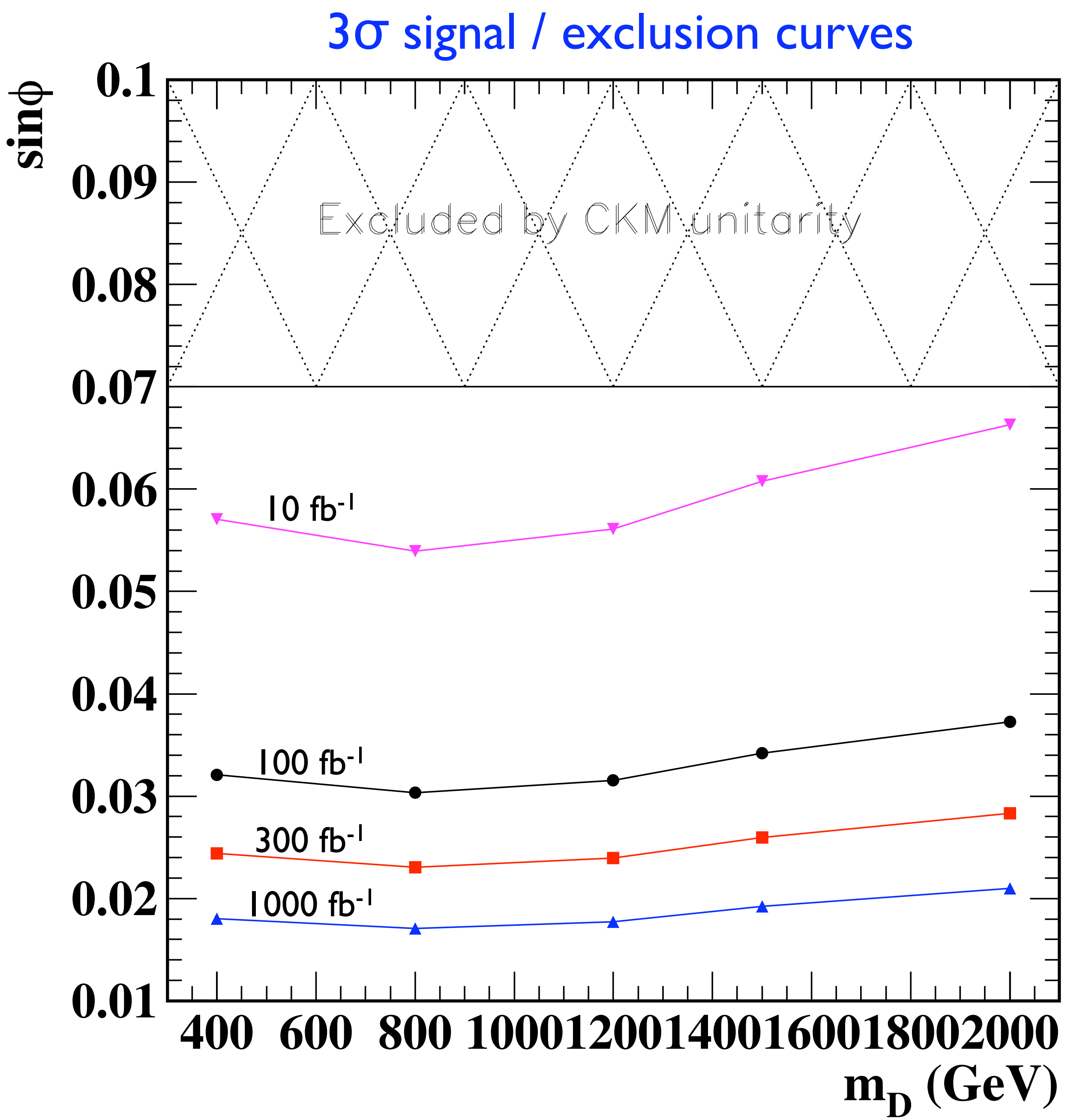
M_D(GeV)	400	800	1200	1500	2000
Signal Events	702	209	71	36	13.5
Background Events	14000	1008	132	47	9.5
Signal significance	5.9	6.6	6.1	5.2	4.37

Mixing angle reach



- cross section at a given m_D depends linearly on $(\sin\Phi)^2$
- the signal significances obtained at the example $\sin\Phi=0.045$ can be converted to 3σ exclusion plots for angular reach at fixed mass values

Mixing angle reach



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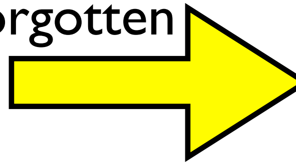
BUT: gluon jets were forgotten



σ_{BG} should be ~ *3.4

Outlook

- Fix the BG problem, re-optimize, recalculate
- We can use the jet associated production of the D quark to make a measurement on its mixing angle to the SM quarks.
- If there is no signal observation a limit curve on the $\sin \Phi$ vs m_D plane can be imposed.
- If the mixing angle is not so small, the single production might become more efficient than the double production for the discovery as well.