Uyarılmış u-kuarkın FCC ve SppC Çarpıştırıcılarında Araştırılması

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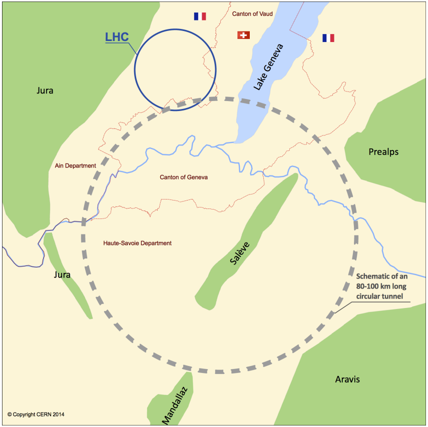
- In our analysis, we focused on 1^{st} family member spin-1/2 excited quark $u*$

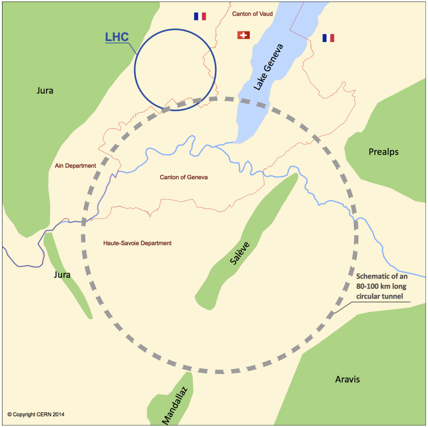
Mass Limits

- We investigated excited quarks that are decay into dijet. So, we checked ATLAS and CMS results on dijet for spin-1/2 excited quarks.
- In ATLAS dijets papers, ATLAS Collaboration put 6.0TeV mass limits on spin-1/2 excited quark mass (Center of Mass 13 TeV and $L_{int} = 37fb^{-1}$).
- In CMS dijets papers, CMS Collaboration put 5.4 TeV mass limits on spin-1/2 excited quark mass (Center of Mass 13 TeV and $L_{int} = 12.9fb^{-1}$).
- Therefore we have used $M_{u*} = 6000$ GeV starting mass point for spin-1/2 excited quark in our calculation.

1. Excited Quarks, Future Circular Collider (FCC) and Super proton proton Collider (SppC)
   - Quarks and Excited Quarks
   - Mass Limits for excited Quarks
   - Future Circular Collider (FCC) and Super proton proton Collider (SppC)
2. Excited Quark Interaction Lagrangian
   - Interaction Lagrangian
   - Simulation Software
3. Decay Widths and Cross Sections
   - Decay Widths and Cross Sections Plots
4. Signal and Background Analysis
   - Transverse Momentum (P_T), Rapidity(η), Invariant Mass (M_{jj})
   - P_T, η, Invariant Mass Cuts and Cone Radius of Jets Cuts
5. Results
6. Acknowledgments



- When the LHC life time is over, one of the new option for high energy physics is Future Circular Collider (FCC).



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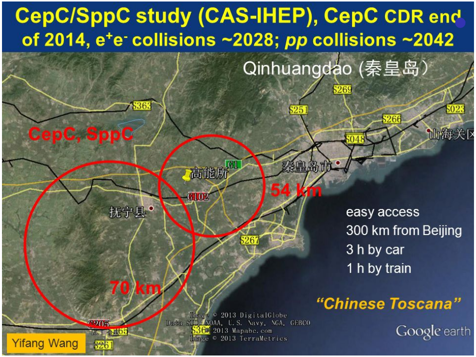
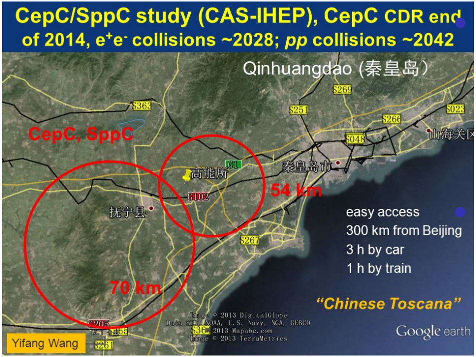
FCC	$L_{int}(fb^{-1})$	Operating Time
Phase I	250/year	2500 fb^{-1} within 10 Years
Phase II	1000/year	15000 fb^{-1} within 10 Years
Total	17500	25 Years

  - FCC is planned to be established at CERN in years 2030.



When the LHC life time is over, the other new option for high energy physics is Super proton proton Collider (SppC).



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SppC	$L_{int}(fb^{-1})$	Operating Time
run	1500/years	22500 fb^{-1} within 15 Years

- SppC is planned to be established at China in years 2042.

Spin-1/2 Excited Quarks Effective Lagrangian

$$L_{eff} = \frac{1}{2\Lambda}\bar{q}^{*}\sigma^{\mu\nu}[g_s f_s \frac{\lambda^a}{2} F^a_{\mu\nu} + gf\frac{\vec{\tau}}{2}\vec{W}_{\mu\nu} + g' f' \frac{Y}{2} B_{\mu\nu}] q_L + h.c.$$

- Λ : Compositeness Scale
- q^* : Excited Quark
- q_L : Lefthanded ground state Quark
- $F^a_{\mu\nu}$, $\vec{W}_{\mu\nu}$, $B_{\mu\nu}$: Field strength tensors for gluon, SU(2) and U(1).
- λ^a: Gell-Mann matrices.
- $\vec{\tau}$: Pauli Spin Matrices
- $Y = 1/3$: Weak hypercharge
- g_s, g, g': Gauge coupling constants
- f_s, f, f' are free parameters
- We took $f_s = f = f' = 1$ in our calculations.

HEP Calculation Software CalcHEP.

- One of the popularly used softwares to calculate particle cross-section, decay width , etc. is CalcHEP.
- For the numerical calculation we implemented spin-1/2 excited quark effective Lagrangian via LanHEP to CalcHEP.

Feynman Diagrams

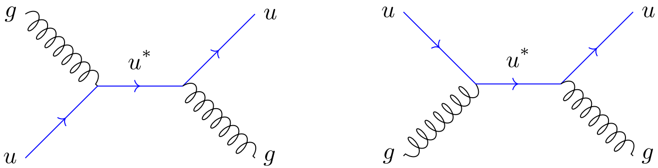
Signal and background processes as:

$$p + p \rightarrow u^* + X \rightarrow g + u + X$$

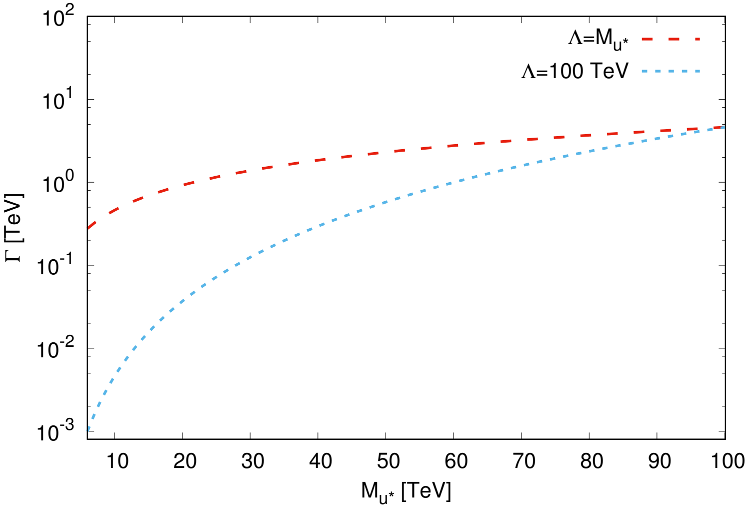
$$p + p \rightarrow j + j + X$$

where $j : u, \bar{u}, d, \bar{d}, c, \bar{c}, s, \bar{s}, b, \bar{b}, g$

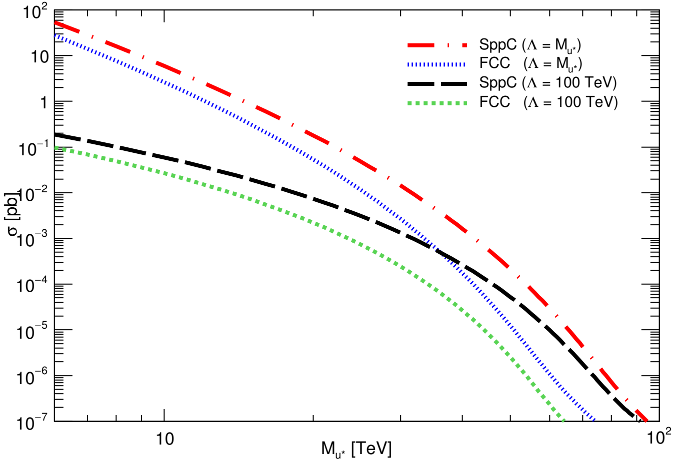
Signal diagrams that include excited quark as:



Decay Widths Plot

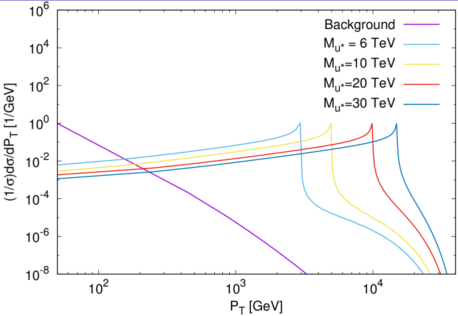


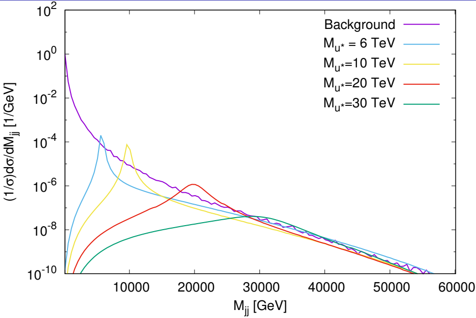
These decay width values are plotted for 2 compositeness scale options.

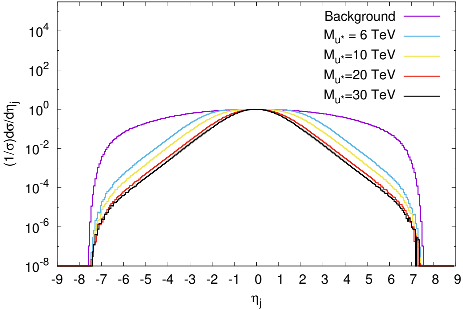


Cross Sections values of u^* are also plotted with respect to 2 different compositeness scales at the FCC ($\sqrt{s} = 100$ TeV) and SppC ($\sqrt{s} = 136$ TeV)

FCC 100 TeV Center of Mass

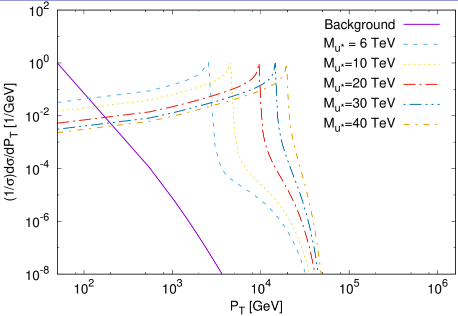


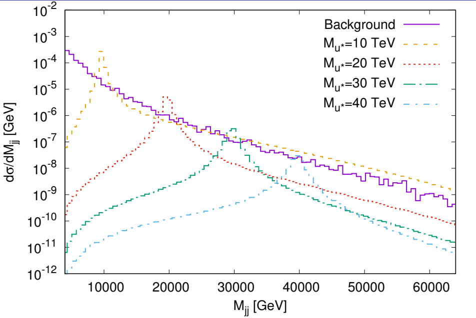


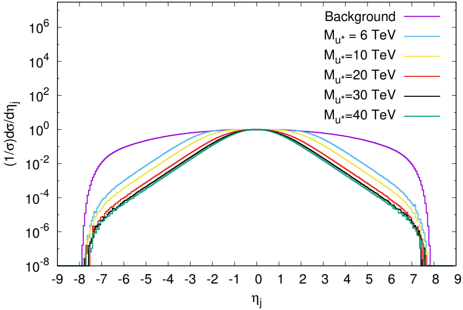


- We do simulations for 4 different mass values and draw P_T, η, invariant mass distribution plots.
- We determine P_T cuts 2000GeV from the P_T distributions and η cut was selected between -2.5 and 2.5 by using ATLAS and CMS detector parameters.

SppC 136 TeV Center of Mass







- We do simulations for 4 different mass values and draw P_T, η, invariant mass distrubution plots.
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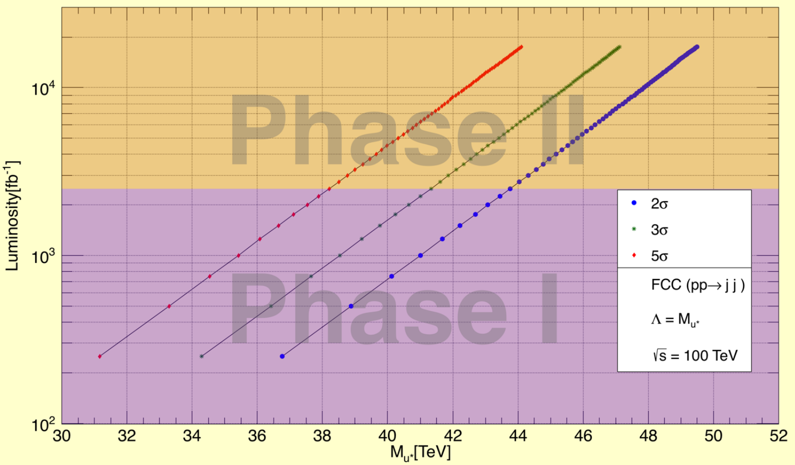
Outline

P_T, η, Invariant Mass and Cone Radius of Jets Cuts

- Applying P_T and η cuts which mentioned before.
- We apply Invariant mass cuts by using decay rates that correspond to each mass values scanned.
- Invariant Mass Cut: $M_{u^*} \pm 2 * \Gamma_{u*}$
- Finally we apply cone of radius of jets: $\Delta R = 0.5$.
- Then, we scanned all mass values for signal and background to calculate significances.
- Significance Calculation:

$$\sigma_S = \frac{S}{\sqrt{S+B}} * \sqrt{L}$$

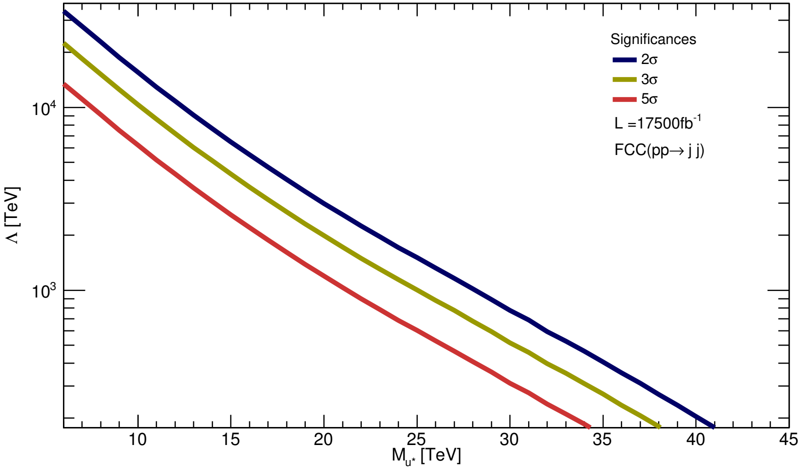
S: Signal Cross Section
B: Background Cross Section
L: Integrated Luminosity



We scanned all luminosity ranges with respect to u^* mass which are planned to be achieved at FCC with $\Lambda = M_{u^*}$ for Phase I (250-2500 fb^{-1}) in 10 years and Phase II (2500-17500 fb^{-1}) in 15 years.

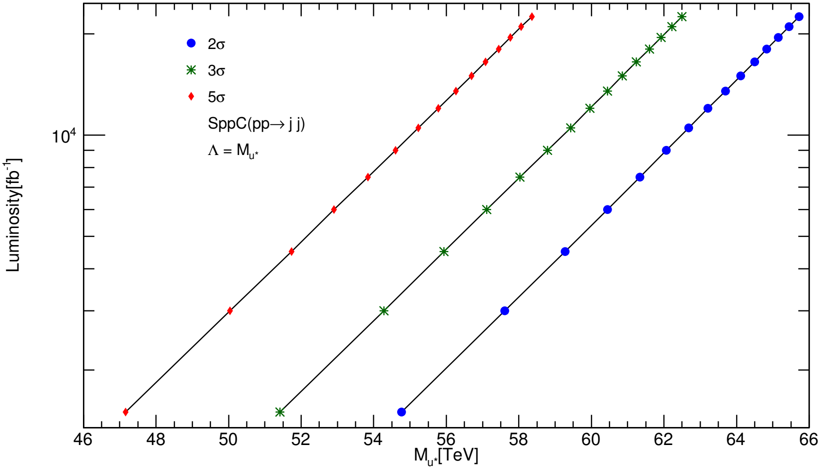
Future Circular Collider ($\sqrt{s}$ = 100 TeV)				
Λ (TeV)	L_{int} (fb^{-1})	M_{u^*} (TeV)		
		2σ	3σ	5σ
100	250	29.6	26.4	22.5
	2500	38.3	35.2	31.4
	17500	45.2	42.4	38.7
M_{u^*}	250	36.8	34.3	31.2
	2500	43.8	41.3	38.2
	17500	49.5	47.1	44.1

FCC Results



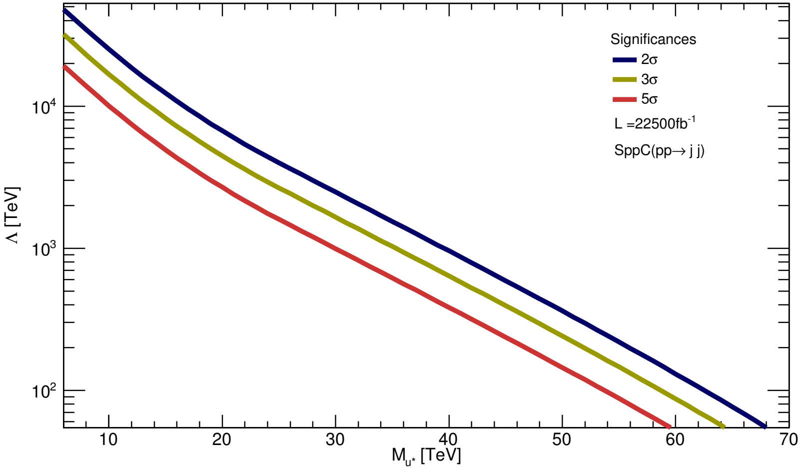
We scanned compositeness versus M_{u^*} for 25 years.

	Λ (TeV)		
M_{u^*}(TeV)	5σ	3σ	2σ
6	13455.7	22426.2	33639.3
10	6209.63	10349.4	15524.1
20	1195.12	1991.86	2987.79
30	310.559	517.598	776.397



We scanned all luminosity ranges with respect to u^* mass which are planned to be achieved at SppC with $\Lambda = M_{u^*}$ for 1500-22500 fb^{-1} in 15 years.

Super proton proton Colliders ($\sqrt{s} = 136$ TeV)				
Λ (TeV)	L_{int} (fb^{-1})	M_{u^*} (TeV)		
		2σ	3σ	5σ
100	22500	62.2	58.3	53.8
M_{u^*}	22500	65.7	62.5	58.3



We scanned compositeness versus M_{u^*} for 15 years.

	Λ (TeV)		
M_{u^*}(TeV)	5σ	3σ	2σ
6	19206.1	32010.1	48015.2
10	10058.4	16763.9	25145.9
20	2682.99	4471.66	6707.49
30	992.979	1654.97	2482.45

ACKNOWLEDGMENTS

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Spin-1/2 particle propagator:

$$S_F(p) = \frac{\gamma^\mu p_\mu + m}{p^2 - m^2 + i\varepsilon}$$

Spin-3/2 particle propagator:

$$S_F(p^{\mu\nu}) = \frac{1}{p^2 - M^2}[-(\not{p}+M)(\eta^{\mu\nu} - \frac{p^\mu p^\nu}{M^2}) - \frac{1}{3}(\gamma^\mu + \frac{p^\mu}{M})(\not{p} - M)(\gamma^\nu + \frac{p^\nu}{M})]$$