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PKU-SYEU Young Scientists Forum (June 1st 2022, Virtual)

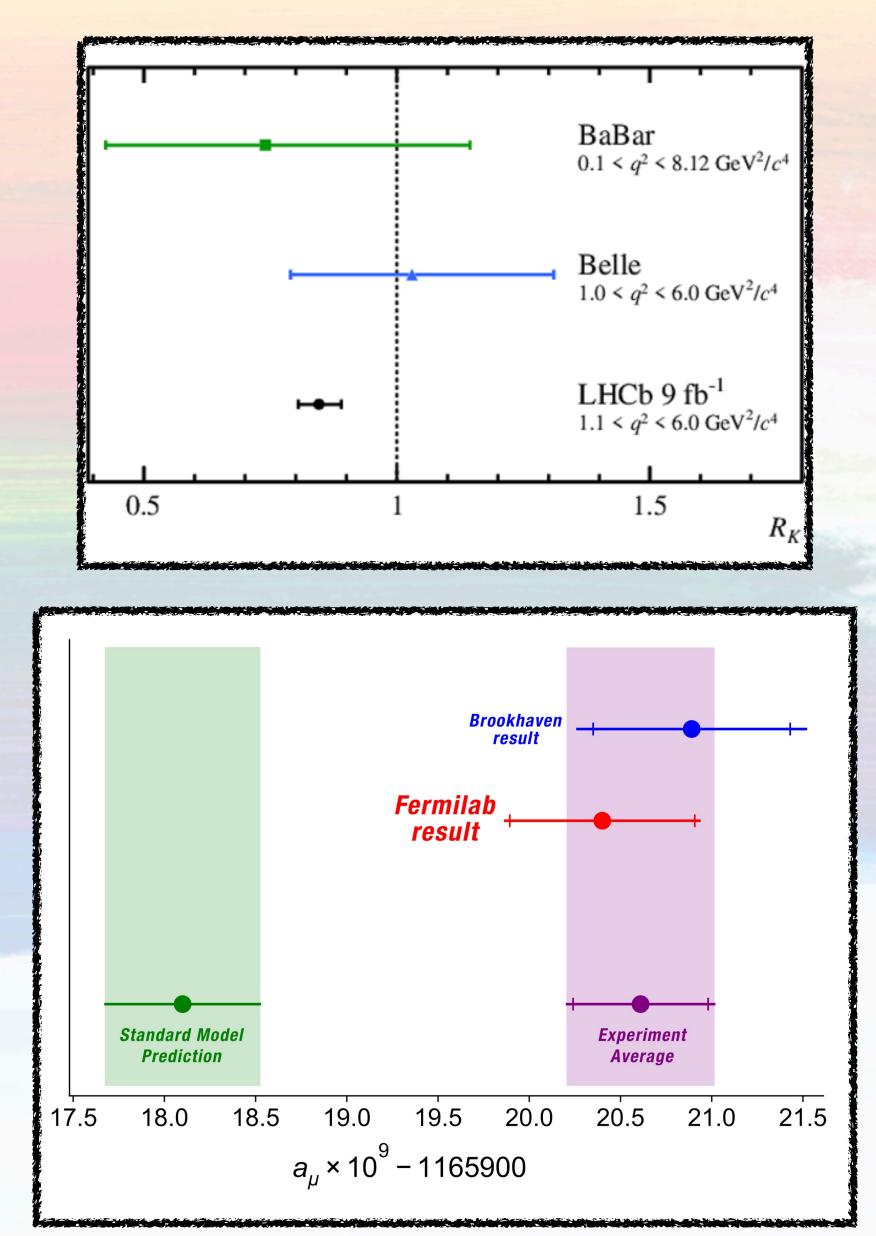
Non-natural Signatures in the Pursuit of Naturalness

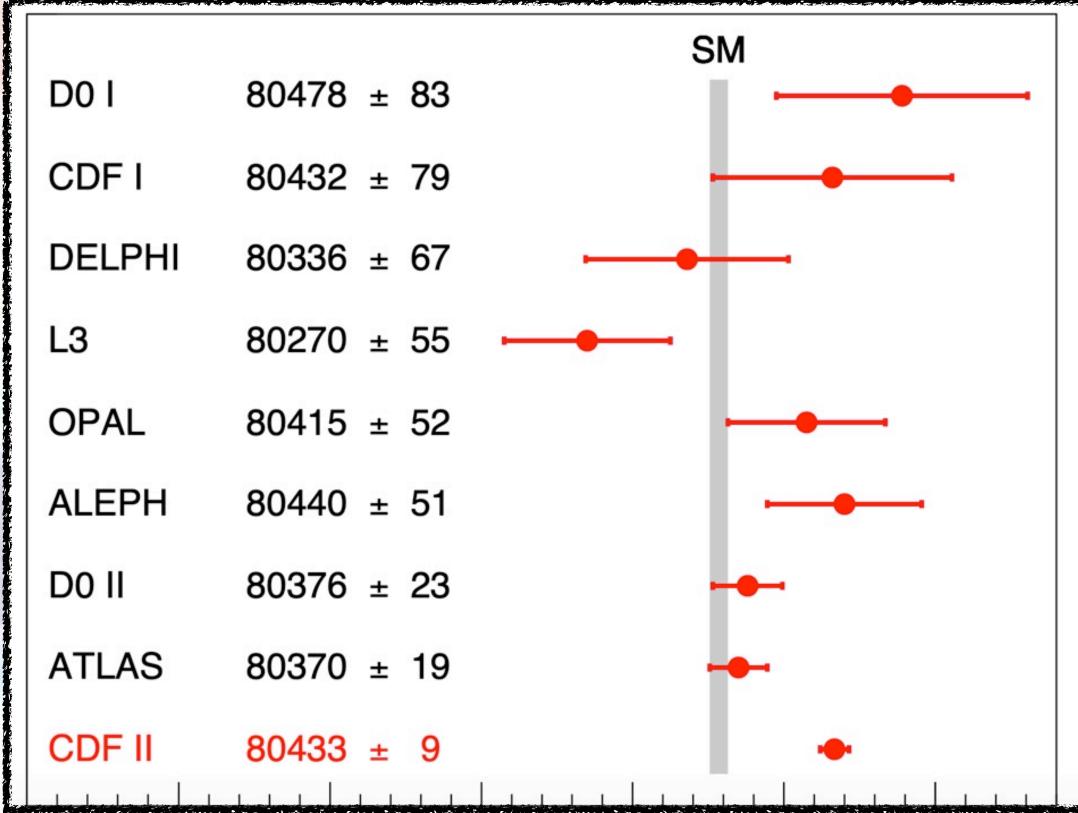
Bingxuan Liu Simon Fraser University

SFU



Exciting Time!





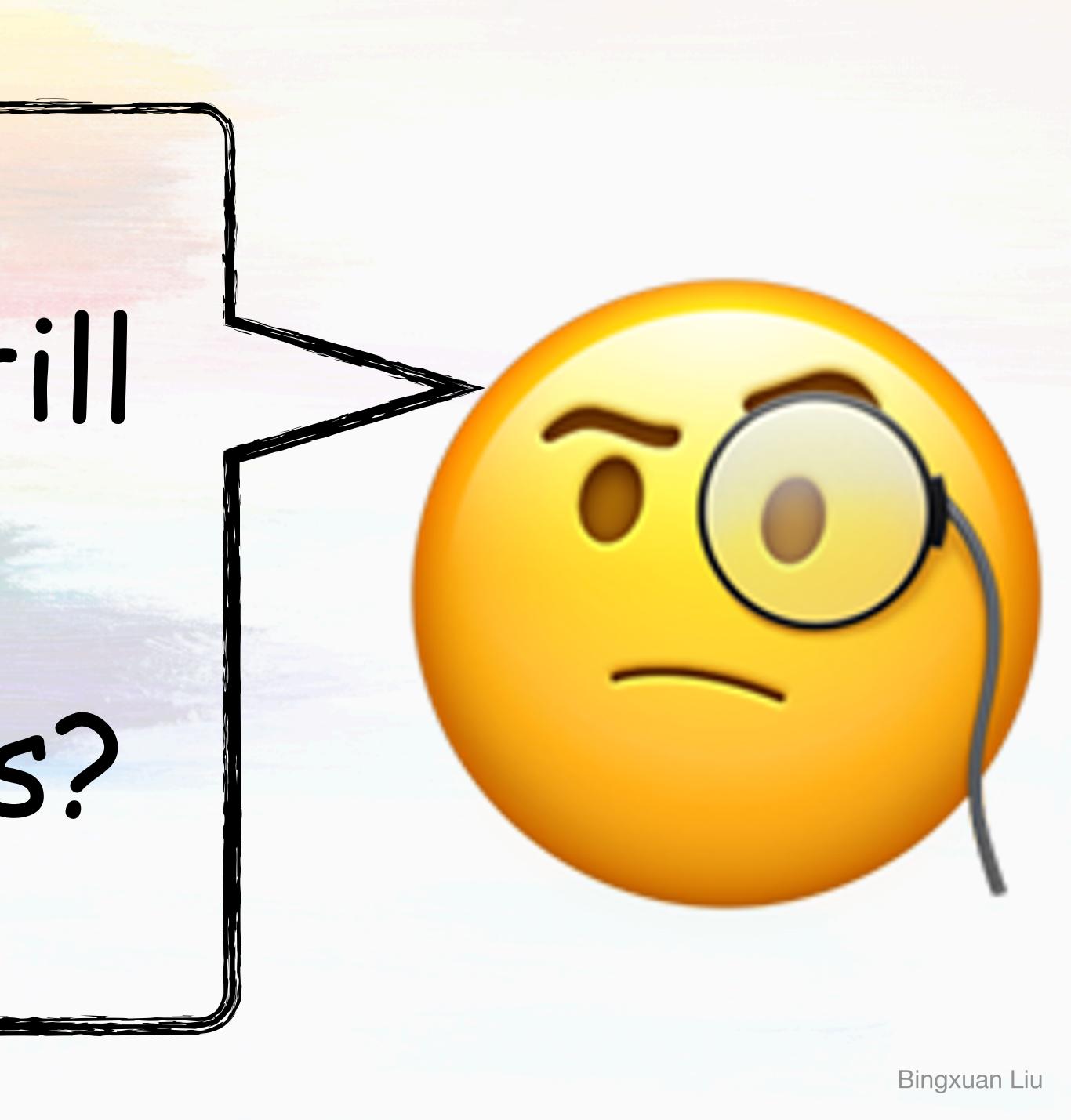


Hmmm..Ok what do these tell me. It looks like searches involving third generation is important, precision measurement is also vital and maybe something a bit more crazy???? So





Is there still room for naturalness?



Definition of Naturalness...A Different Point of View

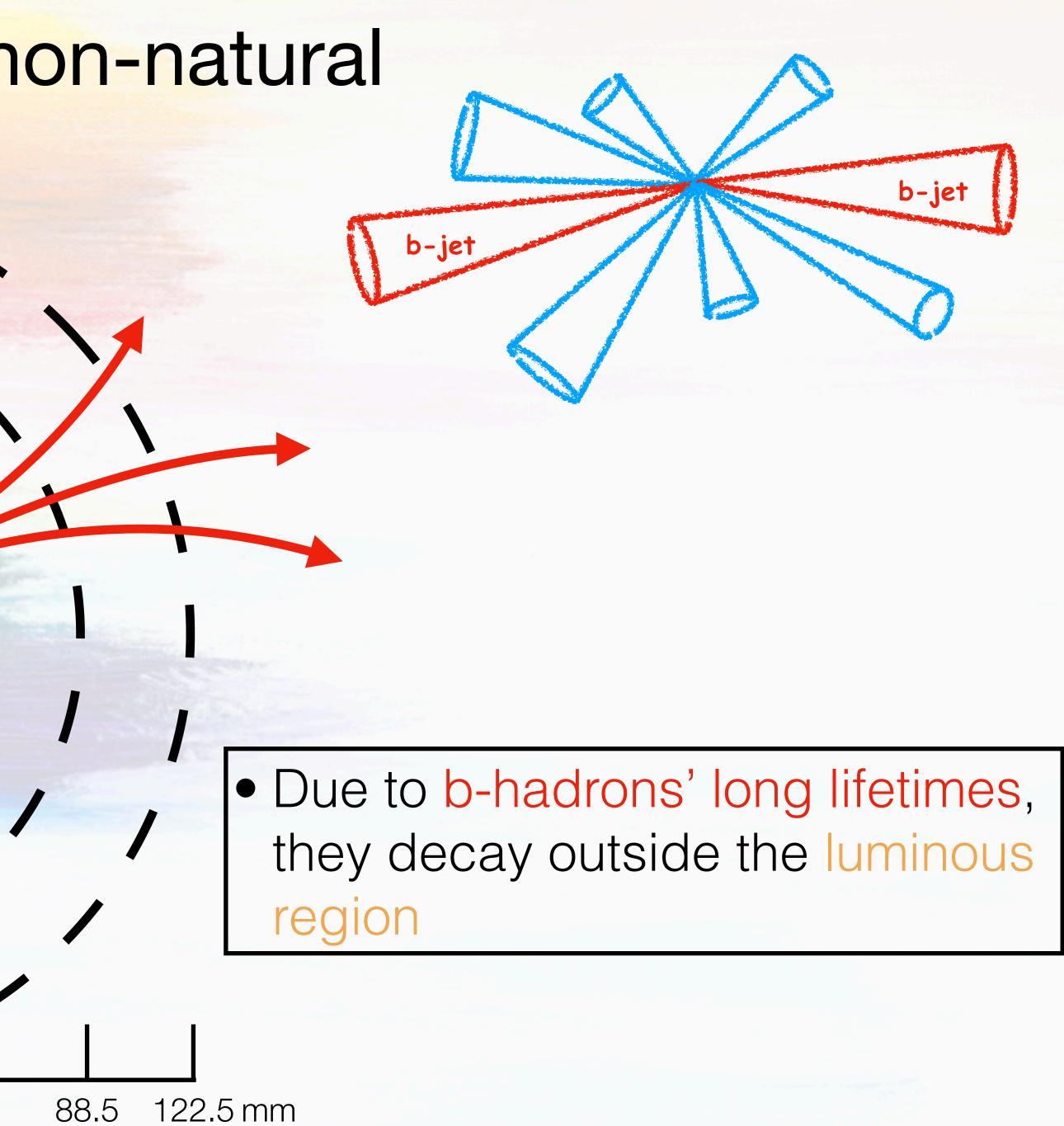
Inner Tracker Layers

- The detectors are cylindrically symmetric
 - A natural physics object is originated from the luminous region



B-hadron Decay: A bit non-natural

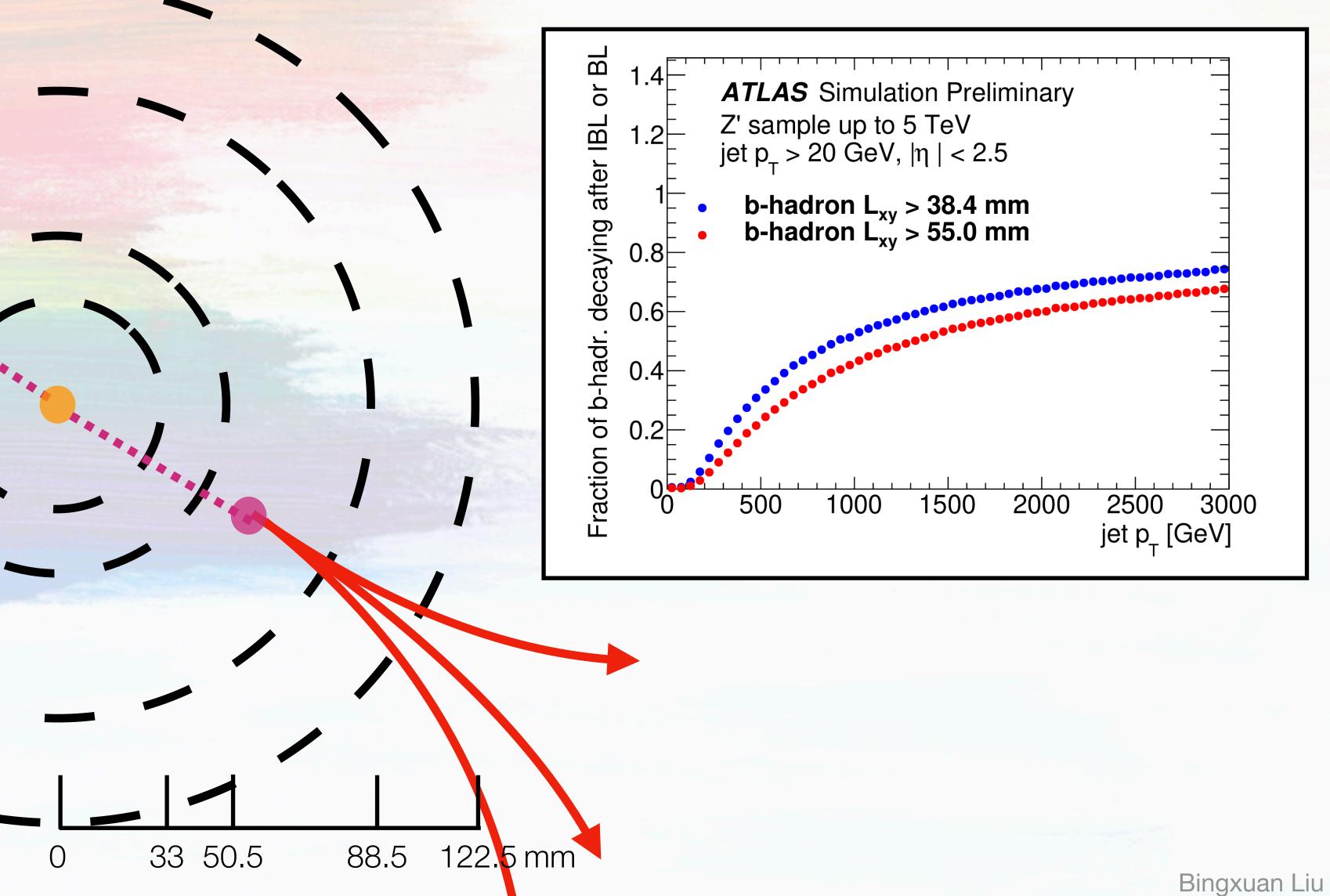
Inner Tracker Layers



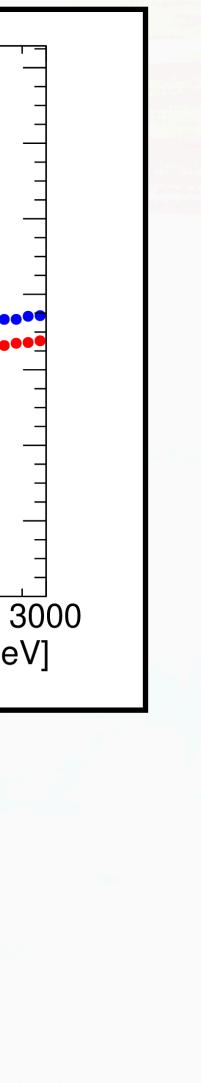


B-hadron Decay: A bit non-natural

Inner Tracker Layers



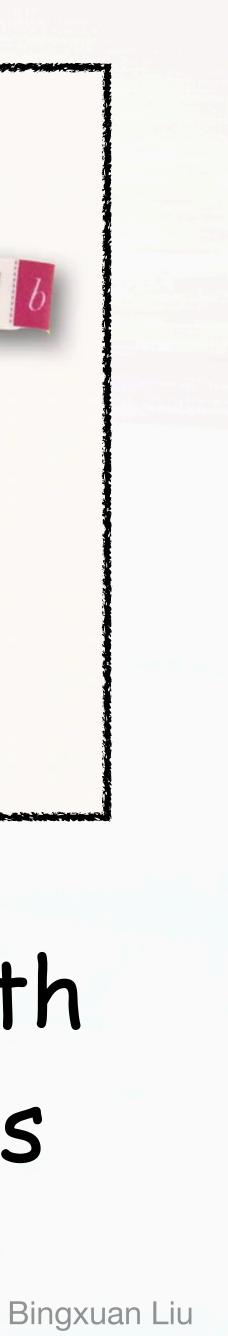




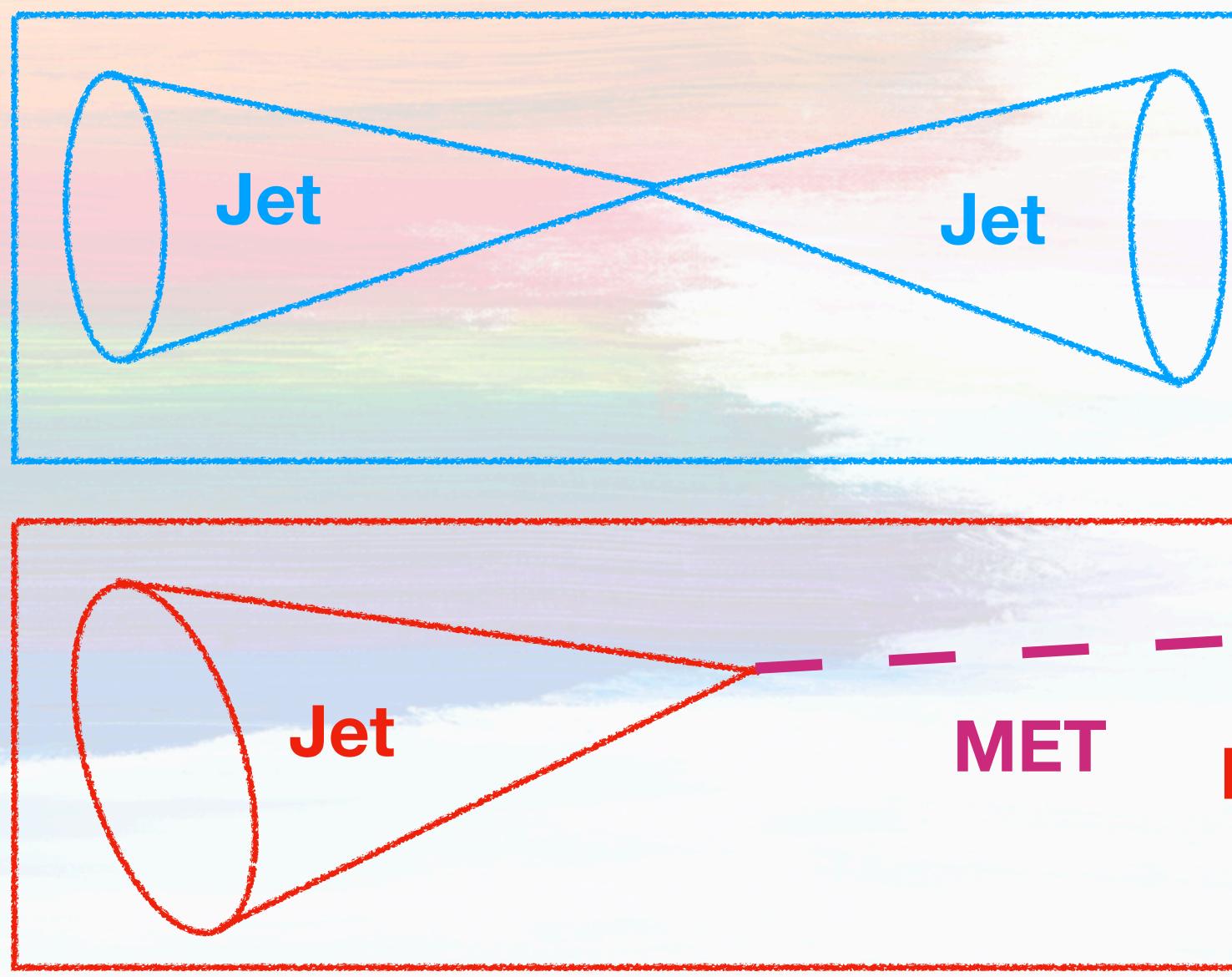




Inclusive search with heavy flavor quarks



Flagship Inclusive Searches



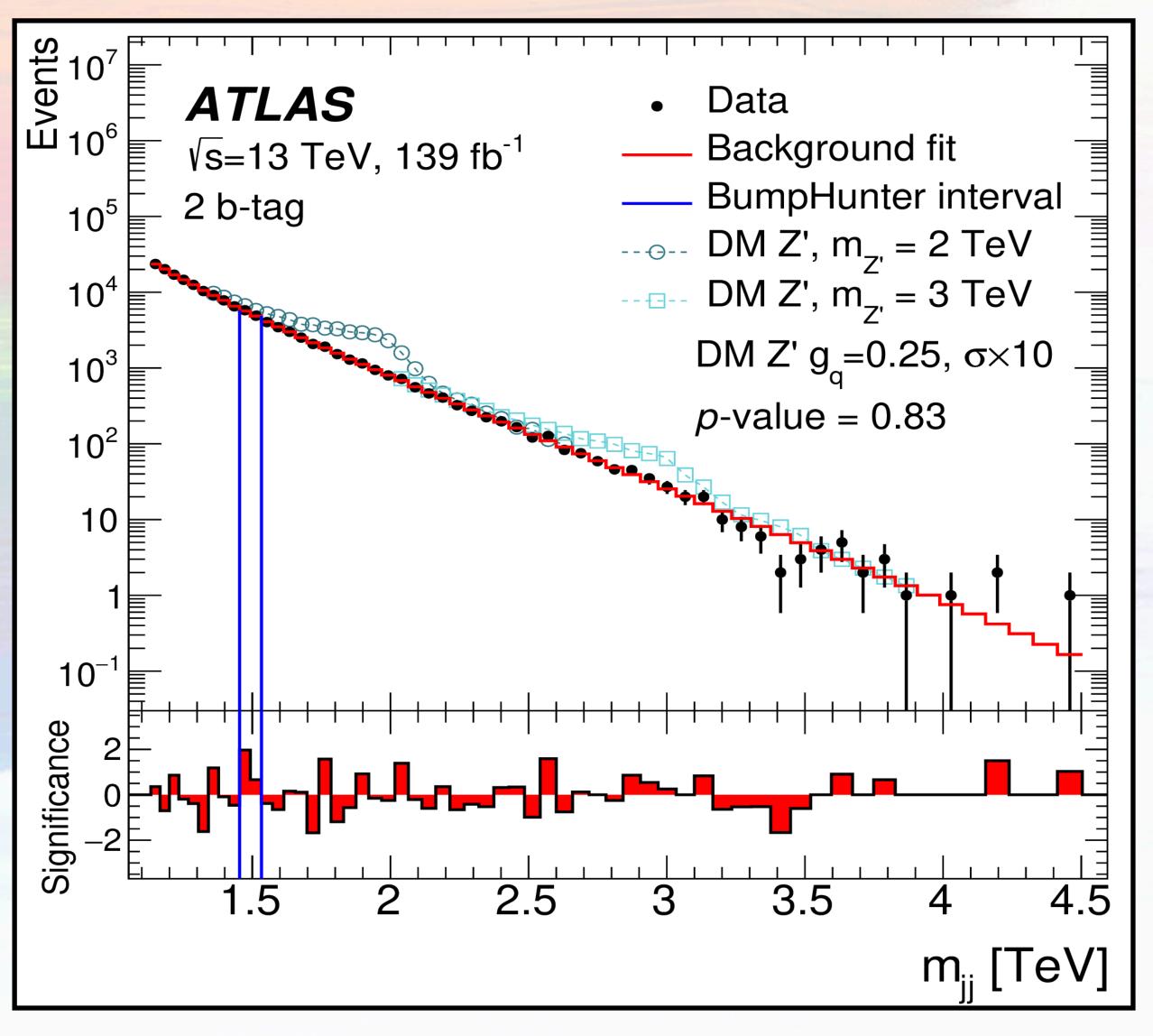
Dijet searches Heavy particle

Mono-jet searches Dark matter

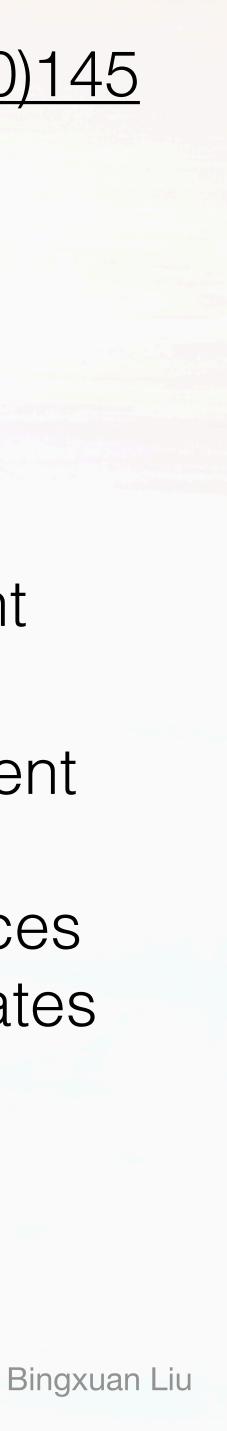


Inclusive Di-(b)-jet Search

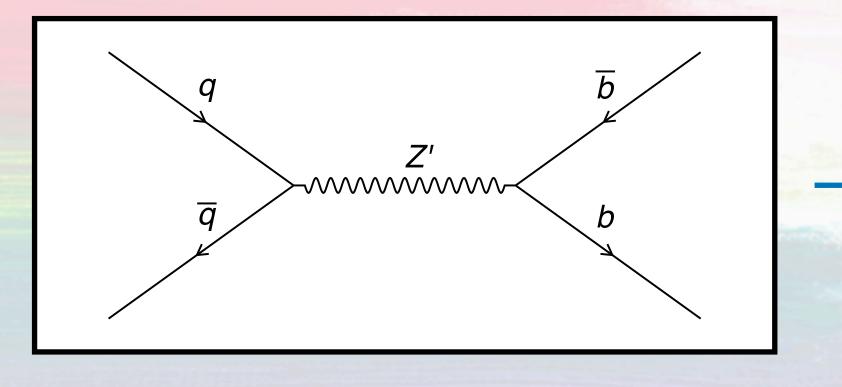
• ATLAS has published the full Run 2 inclusive di-(b)-jet search



- Very powerful/important search
- Setting the most stringent limits on models with narrow heavy resonances in the hadronic final states



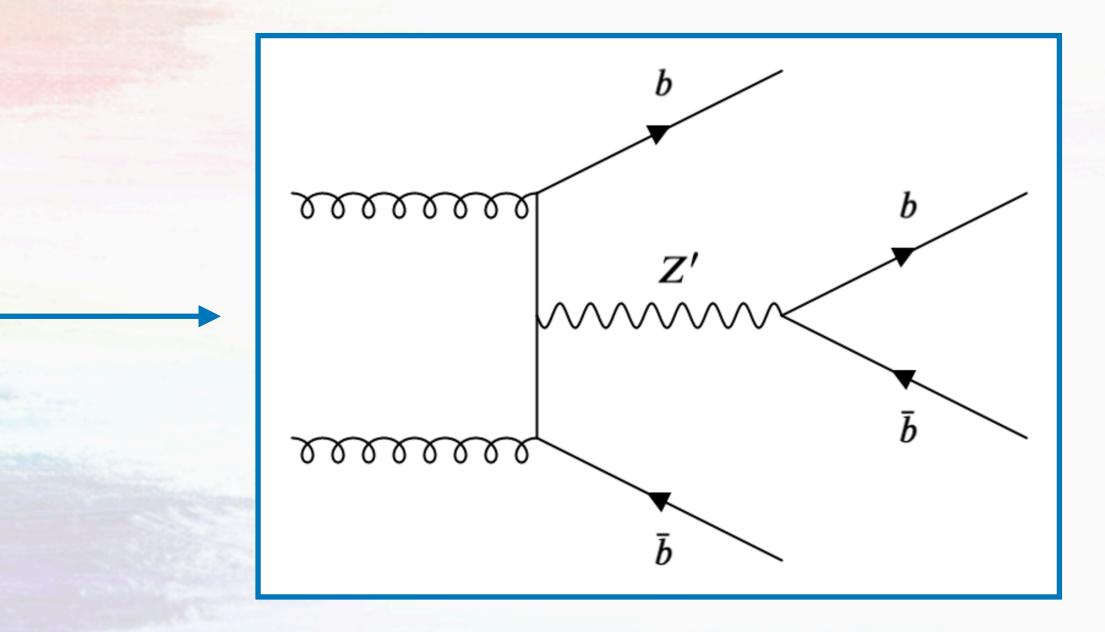
Heavy Particle Search with Associated b-quarks



• It has to be produced in association with additional b-quarks at the LHC • Multi-b-jet final state, two from the heavy particle decay and two from the

- spectator quarks
- - Lepton Universality Violating Z' [JHEP07(2015)142, Admir, et.al]

What if the new heavy particle is exclusively coupled to third generation

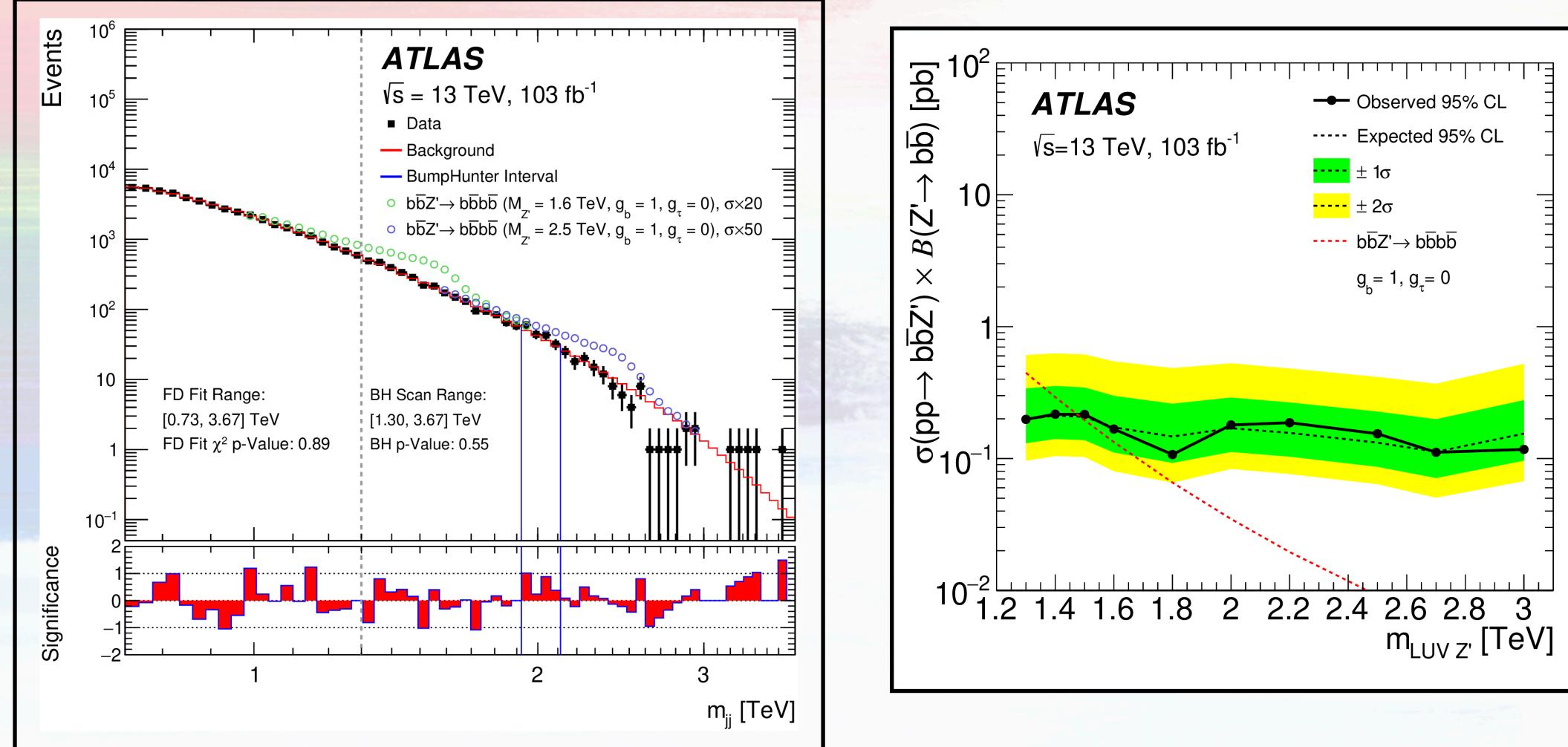


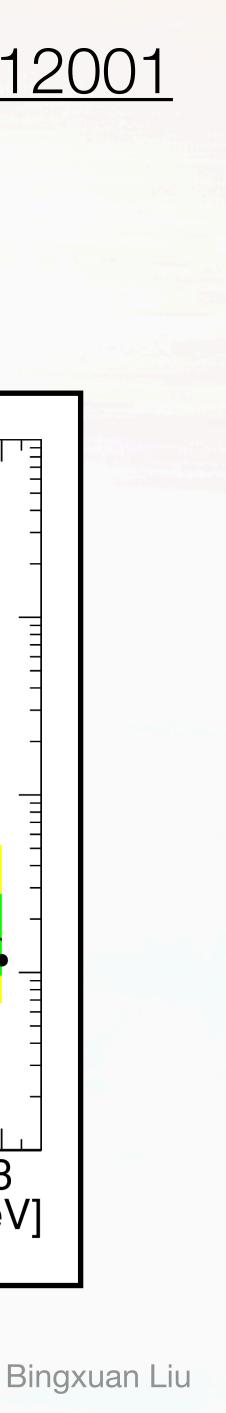
This type of Z' can incorporate the flavor physics anomalies observed in LHCb



Lepton Universality Violating (LUV) Z' PhysRevD.105.012001

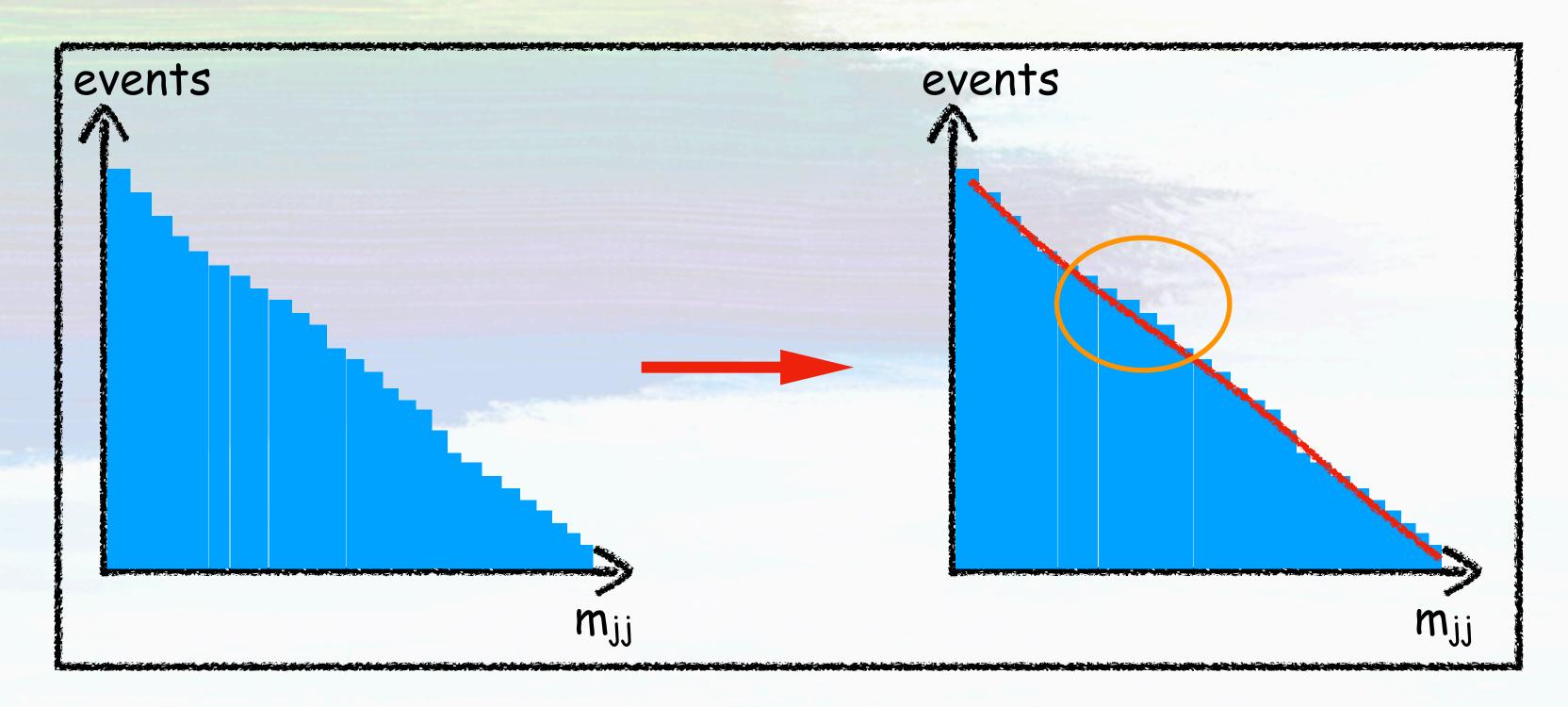
 No significant deviations are observed, limits are set on LUV Z' First coverage up to 3 TeV in this final state





Traditional Approach: Functional Fit

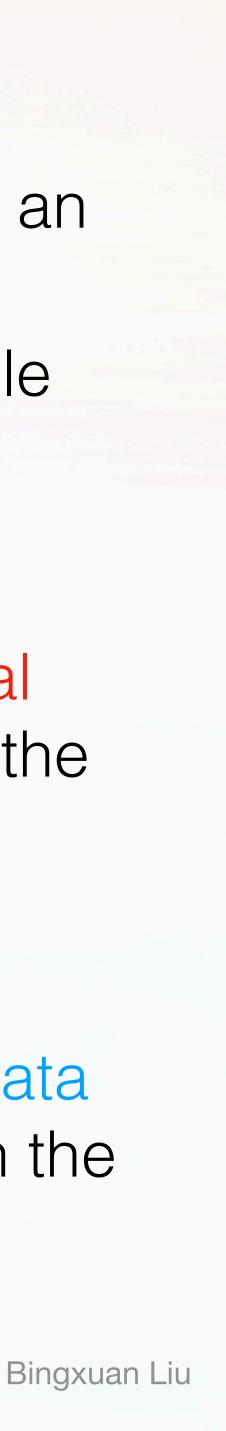
- enormous multi-jet background
 - Size
- Functional fit is widely applied



Heavy particle searches in hadronic final states usually have to deal with an

Multi-jet simulation has large theoretical uncertainties and limited sample

- Apply empirical functions to fit the data spectrum
- And look for significant deviations in data compared with the background fit



Traditional Approach: Functional Fit

- enormous multi-jet background
 - size

But empirical functions may Is there a more universal approach?

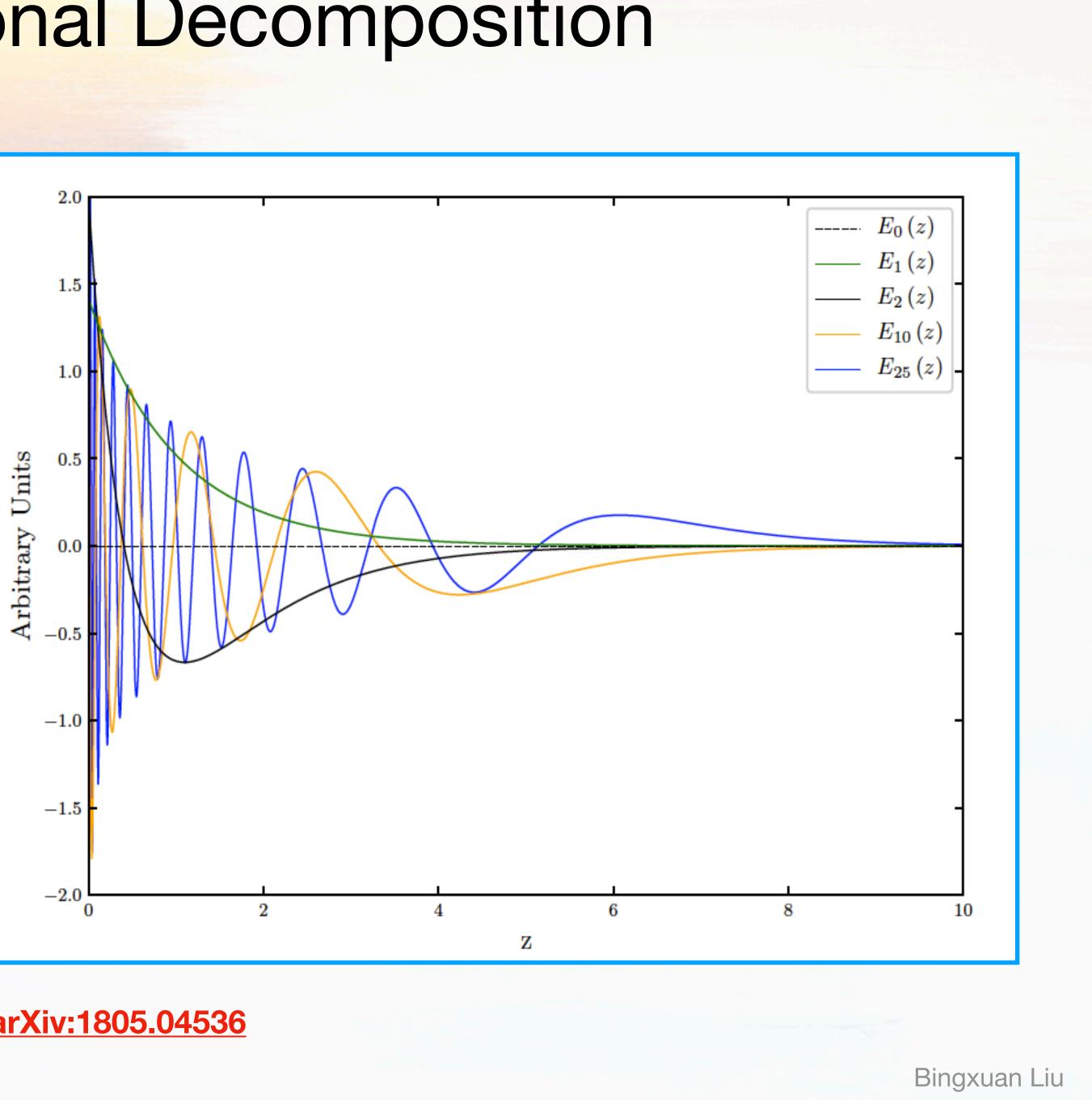
Heavy particle searches in hadronic final states usually have to deal with an

Multi-jet simulation has large theoretical uncertainties and limited sample



New Approach: Functional Decomposition

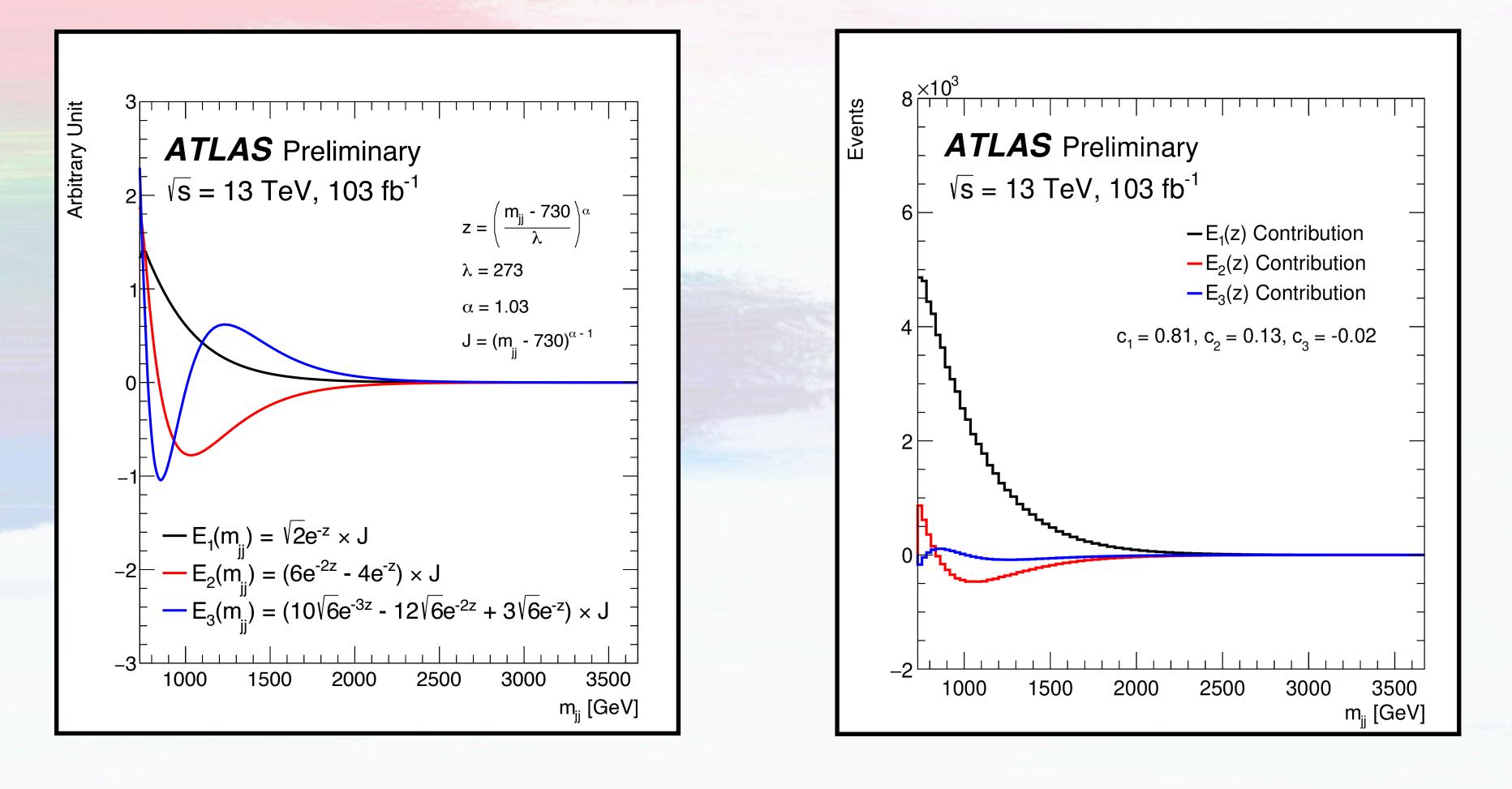
- Functional Decomposition
 - Using orthonormal basis
 - Analogous to Fourier Analysis
- An infinite series can describe any given spectrum
- Truncate the series so that it is sufficient to describe the background not incorporating new physics



arXiv:1805.04536

Decomposed Background

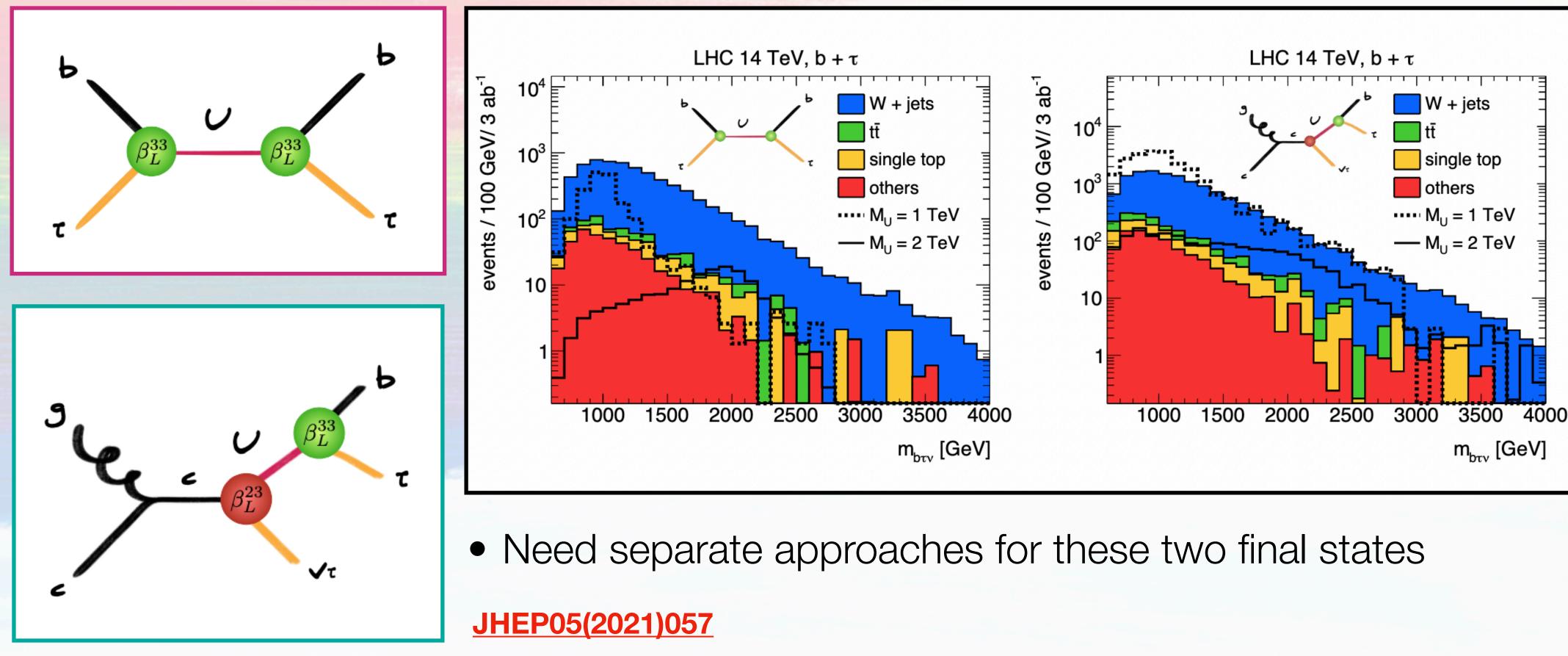
 Using three moments is sufficient to describe the background The background components are not physical as they come from mathematical forms



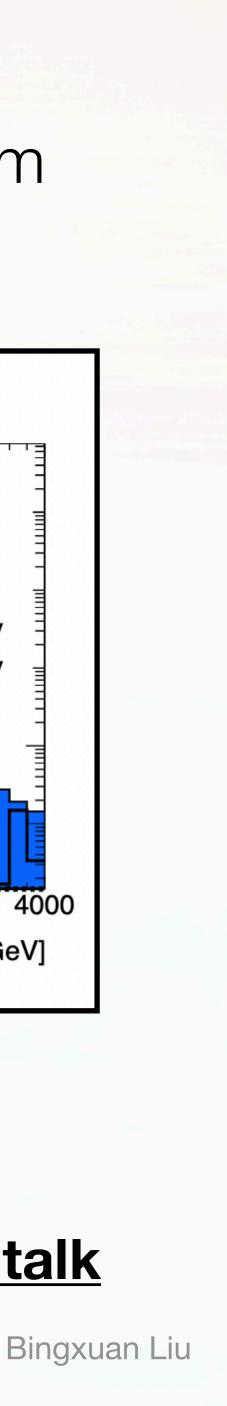
PhysRevD.105.012001



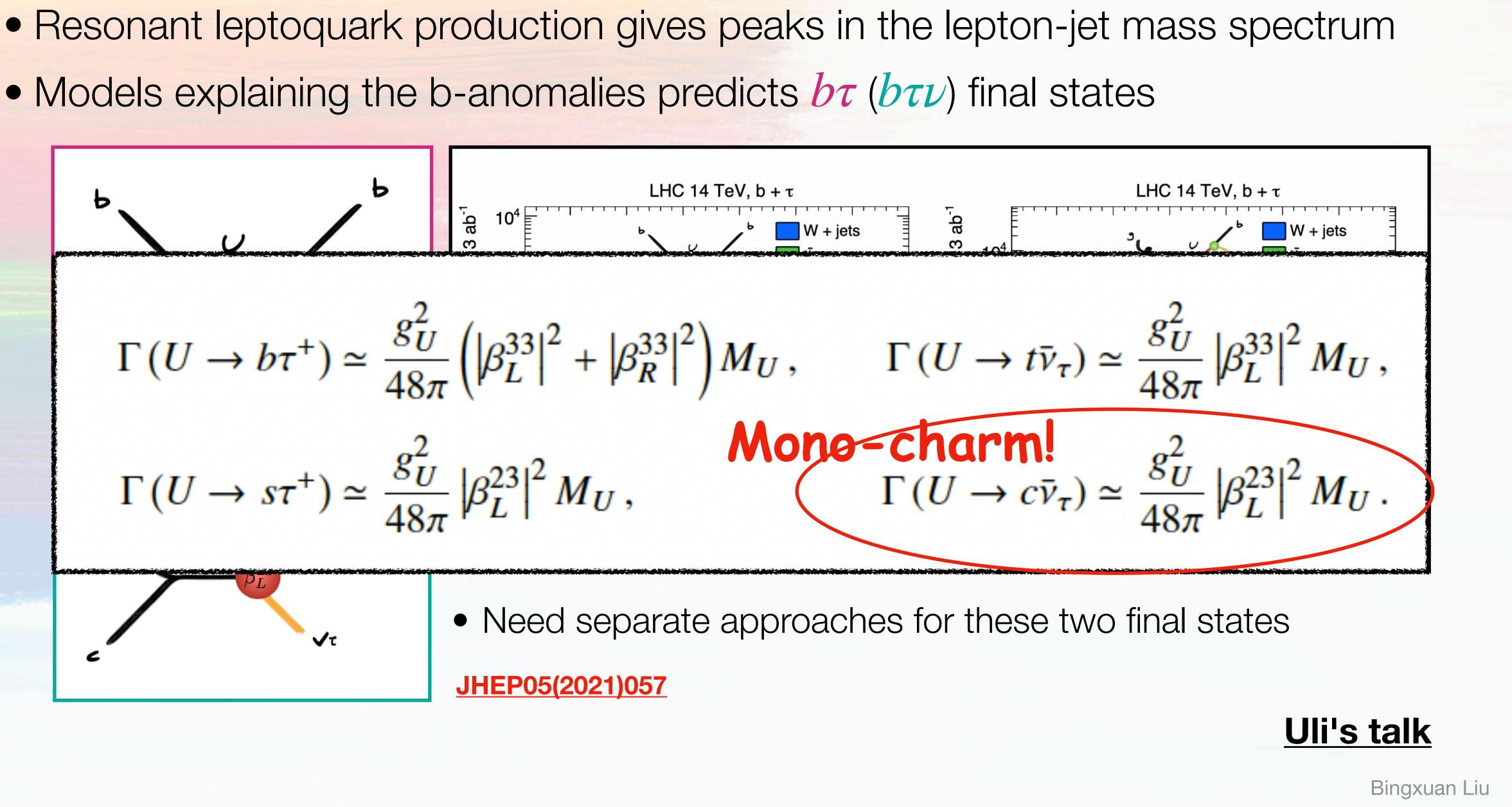
Lepton Universality Violating Leptoquark Resonant leptoquark production gives peaks in the lepton-jet mass spectrum • Models explaining the *b*-anomalies predicts $b\tau$ ($b\tau\nu$) final states



Uli's talk

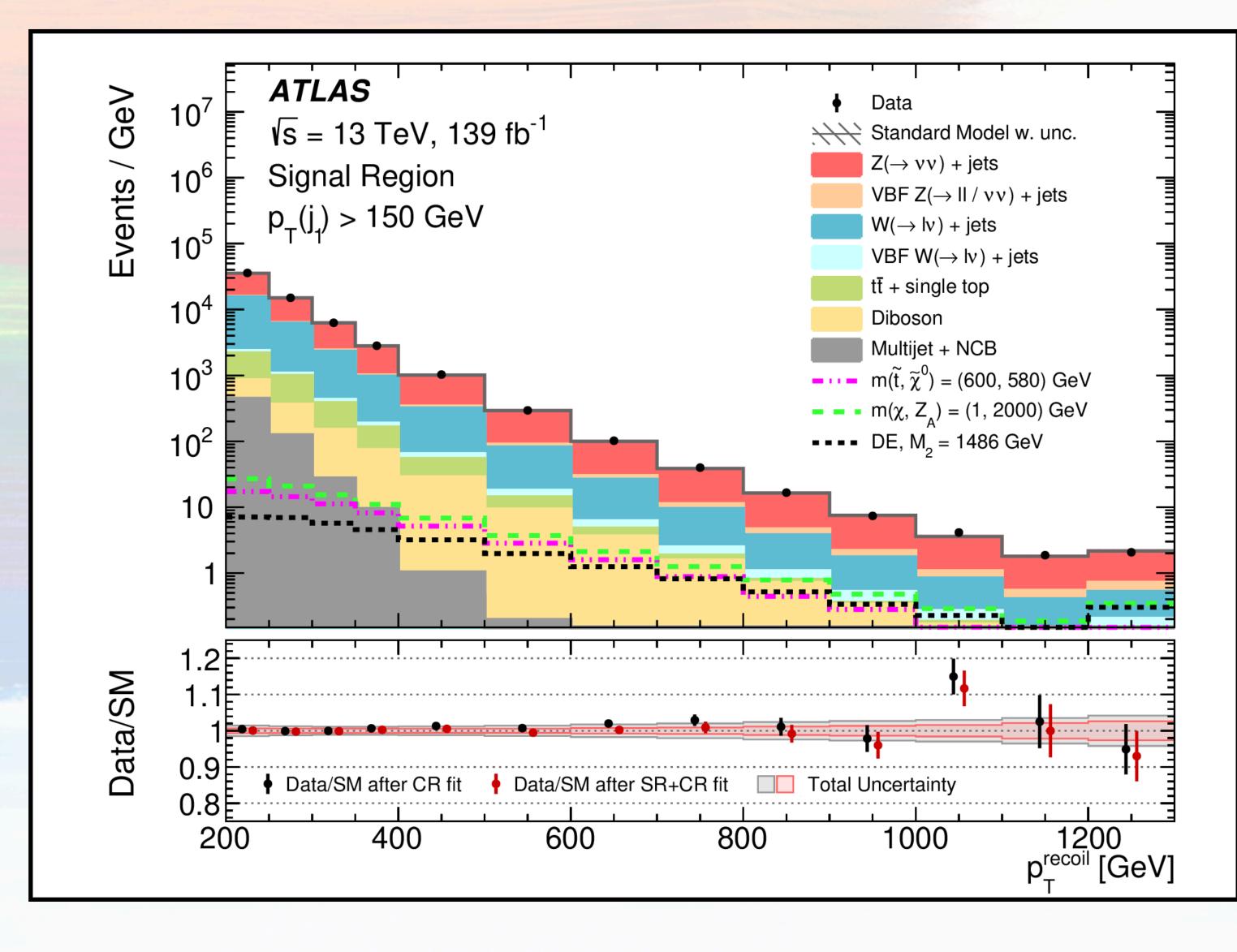


How About Mono-jet?



Inclusive Mono-jet

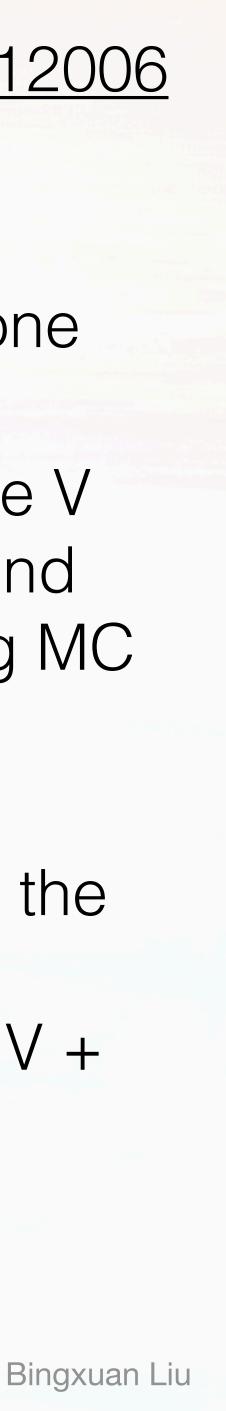
ATLAS has published the full Run 2 inclusive mono-jet search



19

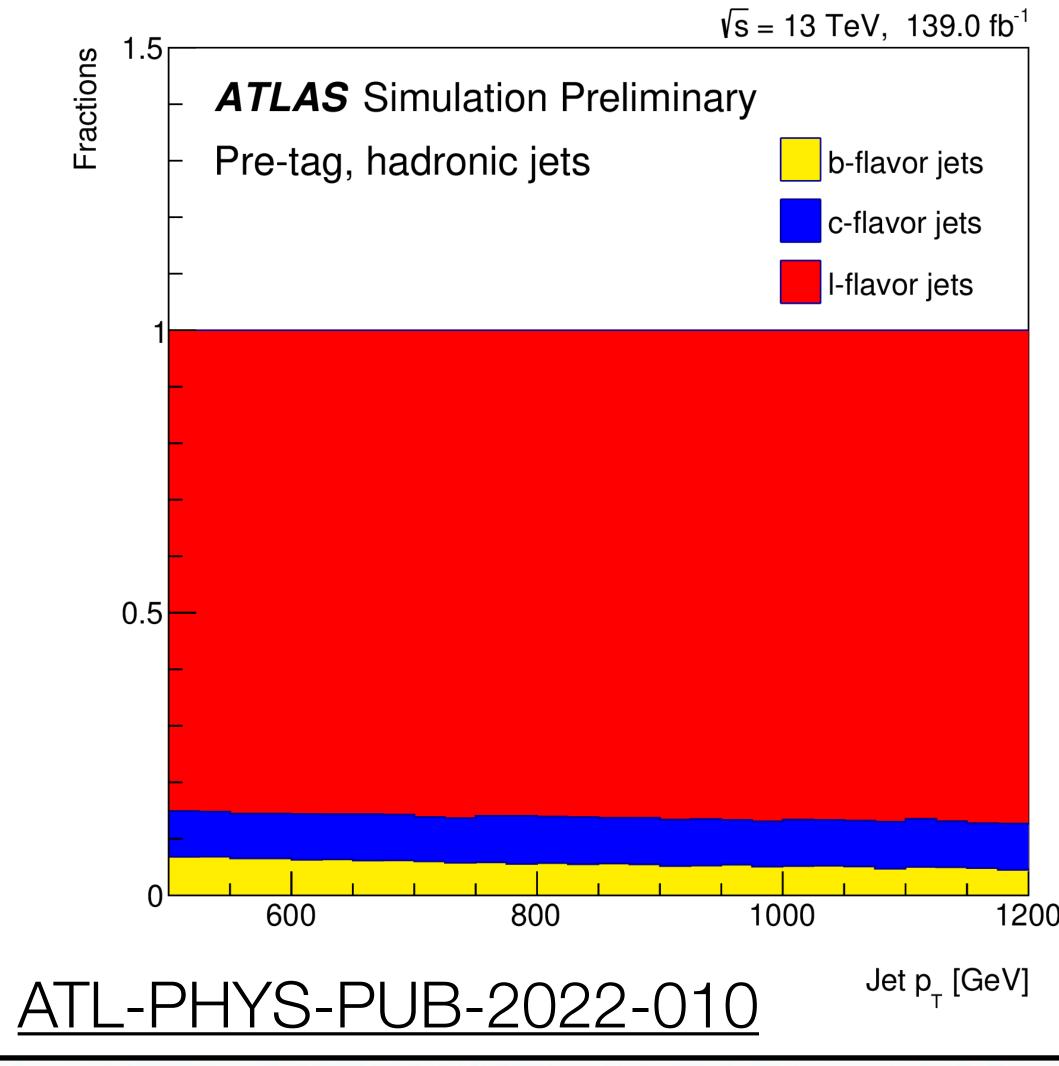
PhysRevD.103.112006

- Excellent work done by the theorists
 - Amazing precise V + jets background estimation using MC
- Mono-HF (b or c) could have been hiding here given the large light jet contribution from V + jets

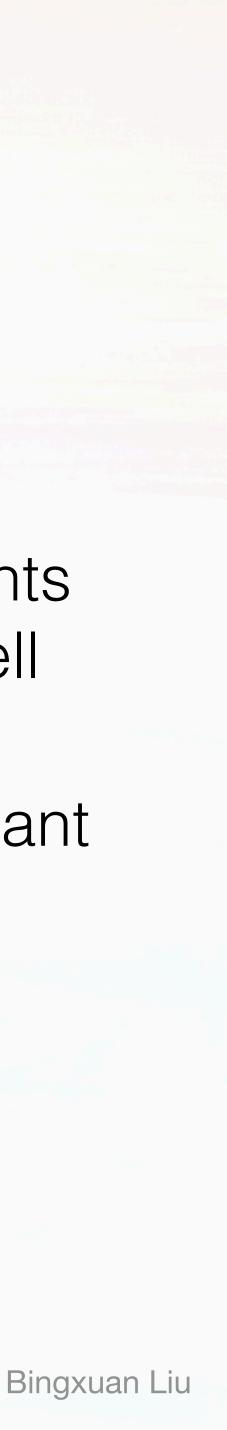


Inclusive Mono-jet

Multi-jet and V + jets are dominated by light flavor jets

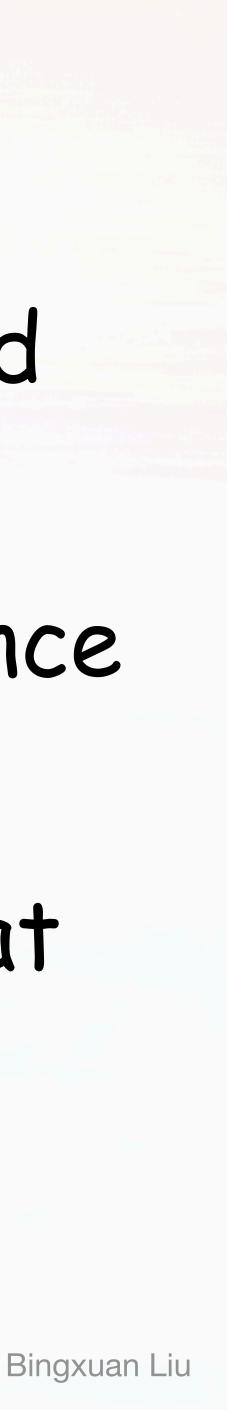


- Better sensitivities can be achieved via bottom/charmtagging
- However V + HF measurements and simulations are not as well studied as the inclusive case
- Theory inputs are very important and good opportunity to collaborate again

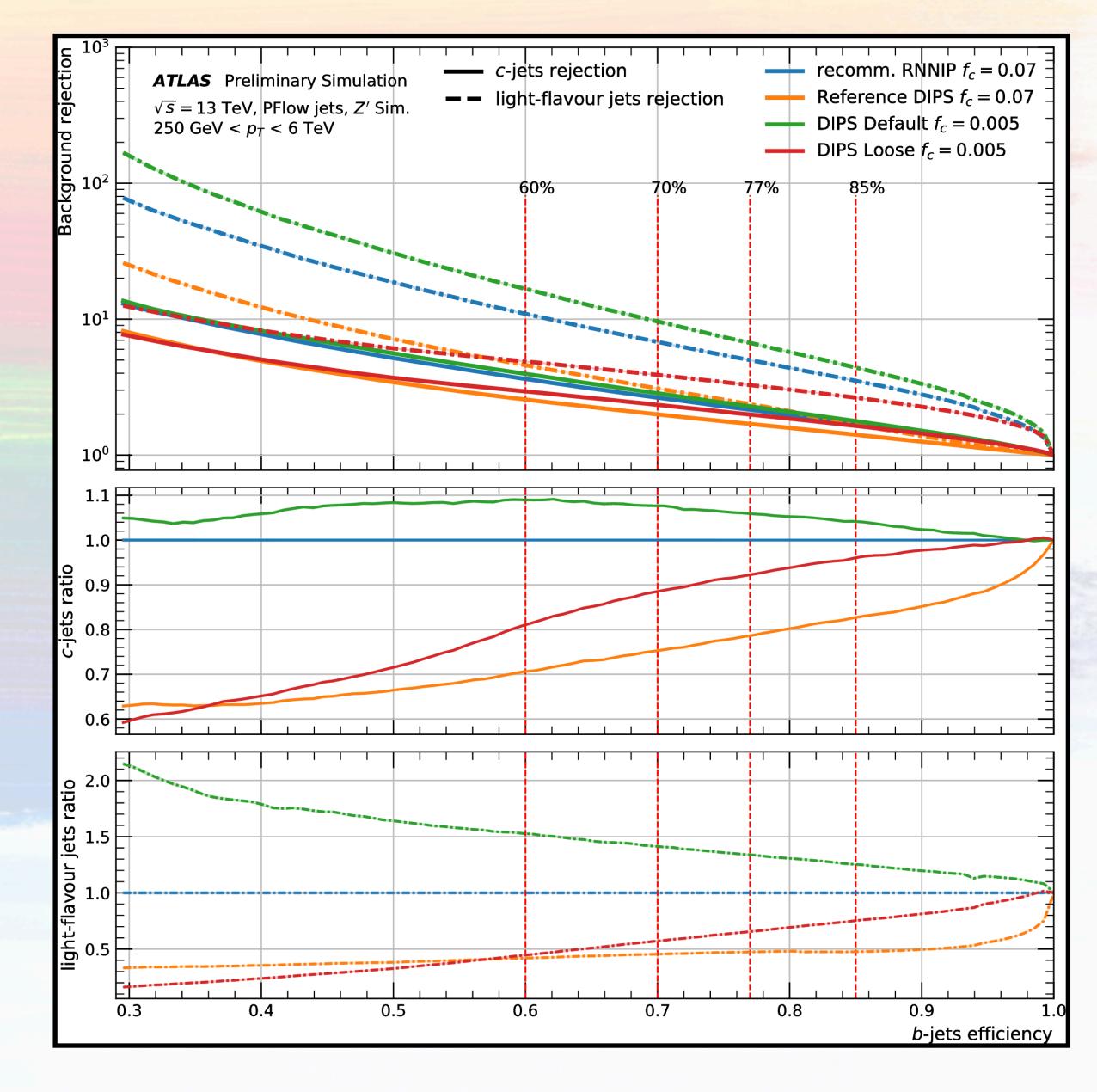




Heavy flavor associated production mode Flavor tagging performance at high energy scale Heavy flavor modeling at high energy scale



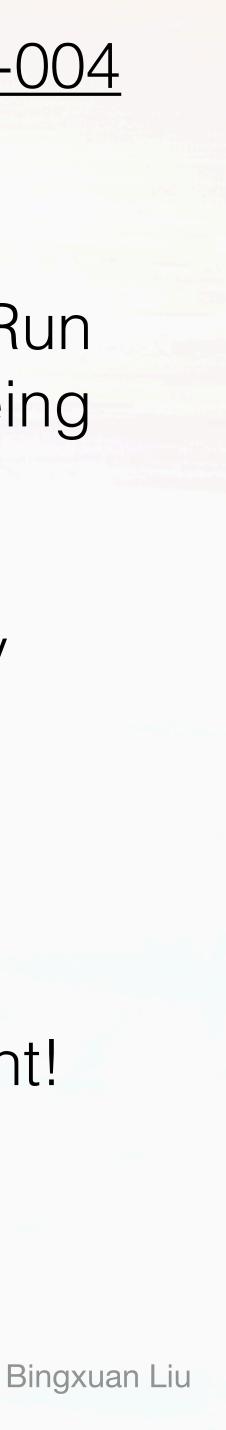
New b-Tagger For Run 3



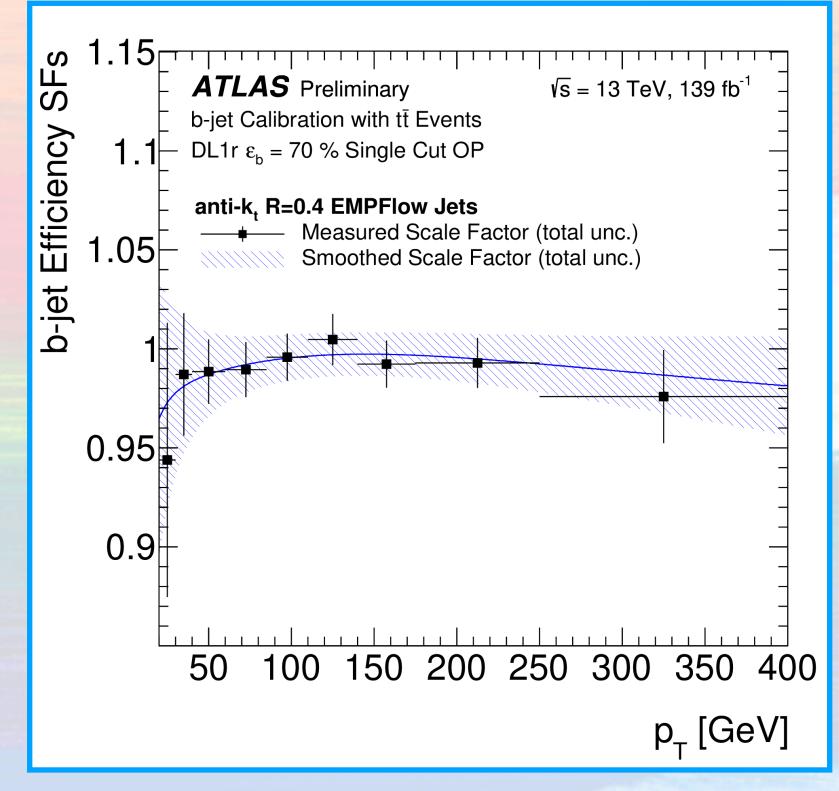
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FTAG-2021-004

- New b-taggers for ATLAS Run 3 physics programs are being developed
- Already seen great improvement in preliminary results for high pT jets
- The reason why projected sensitivities are often pessimistic
 - Performance improvement!

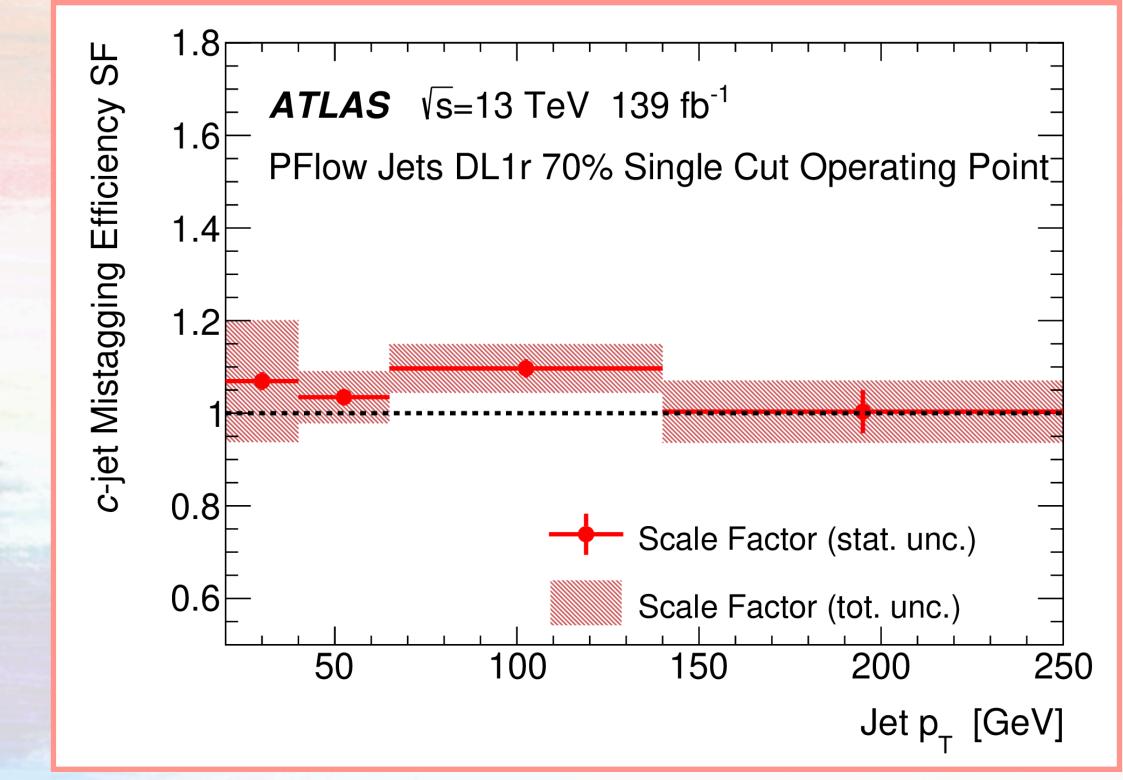


Uncovered Phase Space FTAG-2021-001

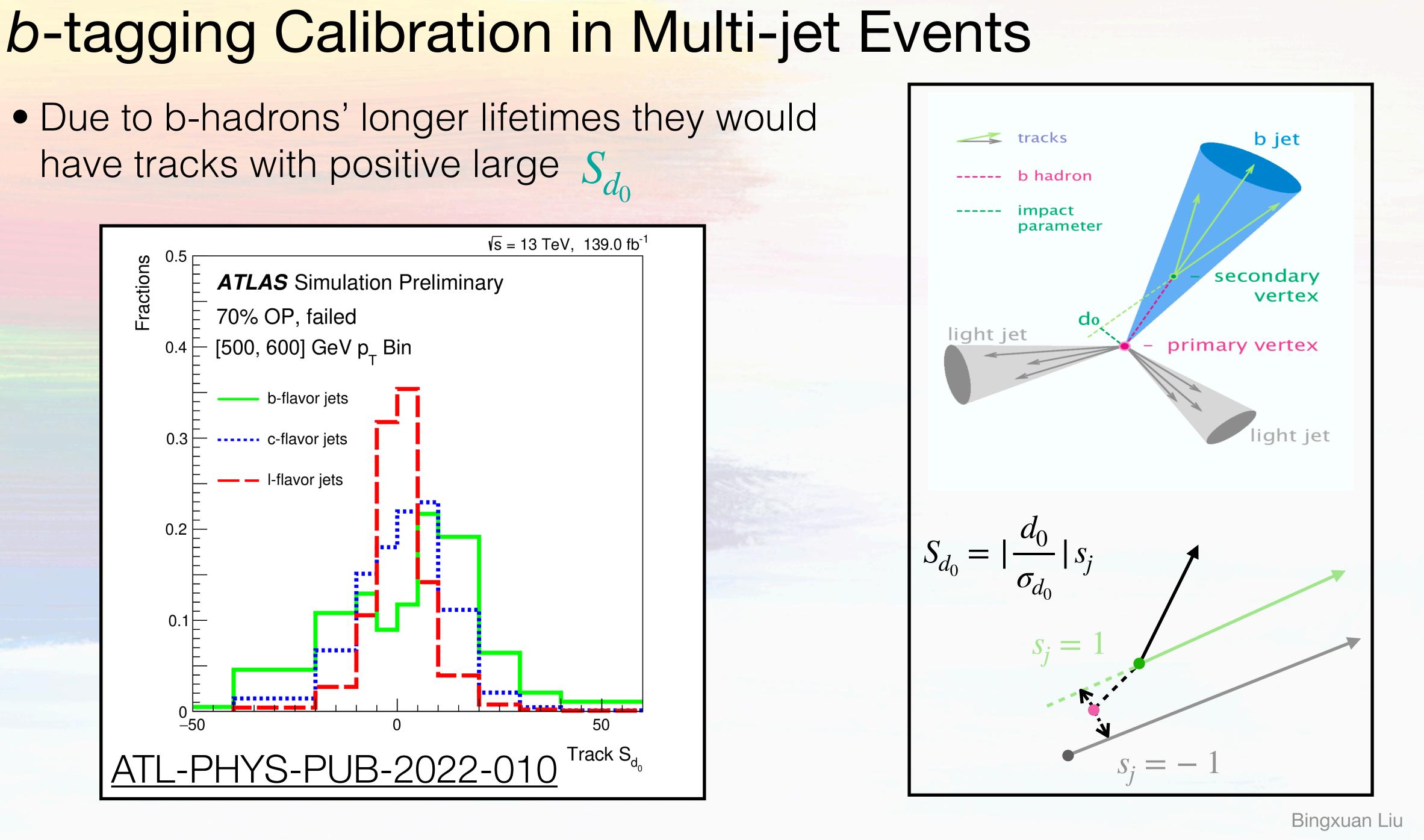


 TeV scale jets are considered in these searches but the tagging performance is only studied up to a few hundreds GeV in data

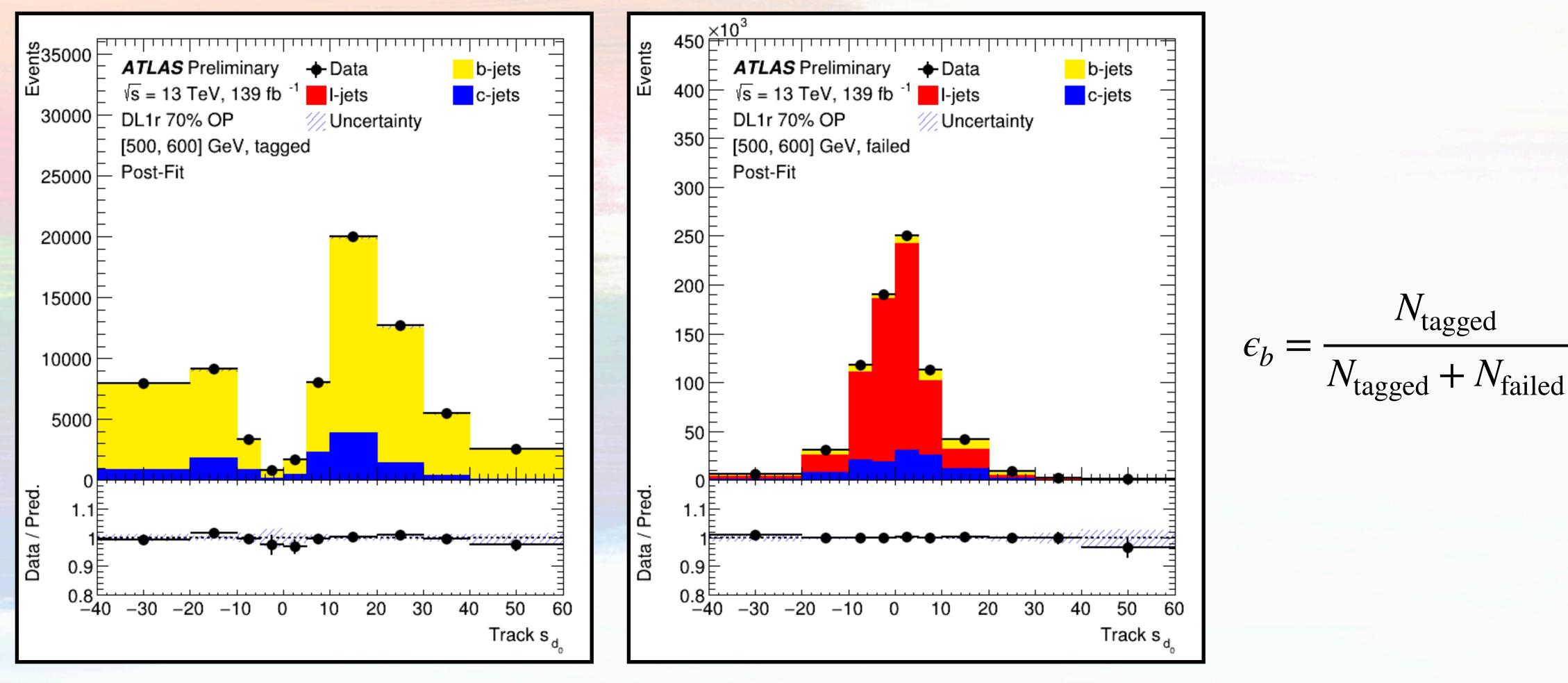
Eur. Phys. J. C (2022) 82:95



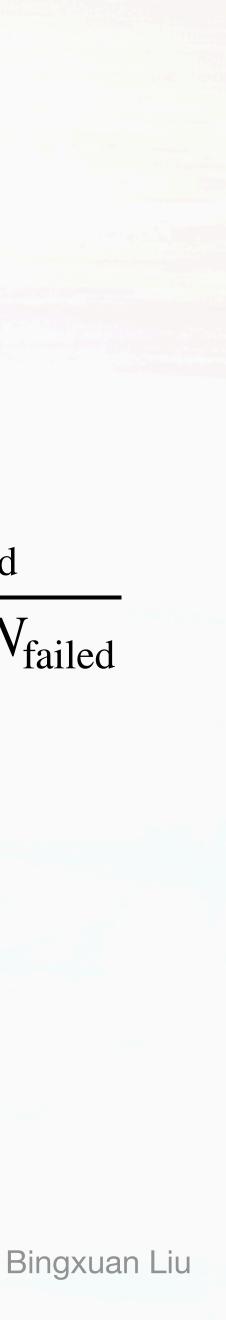




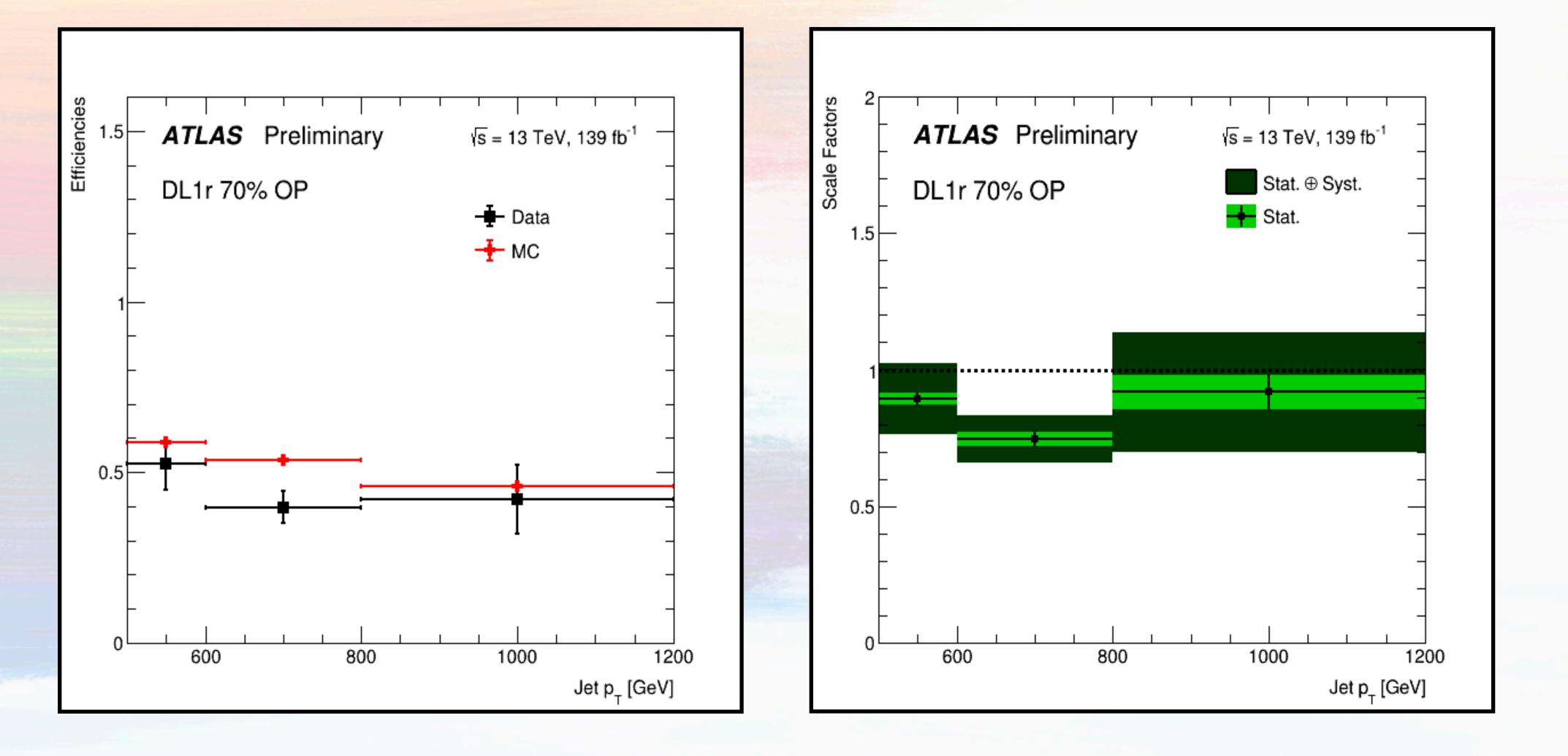
b-tagging Calibration in Multi-jet Events



ATL-PHYS-PUB-2022-010



b-tagging Calibration in Multi-jet Events

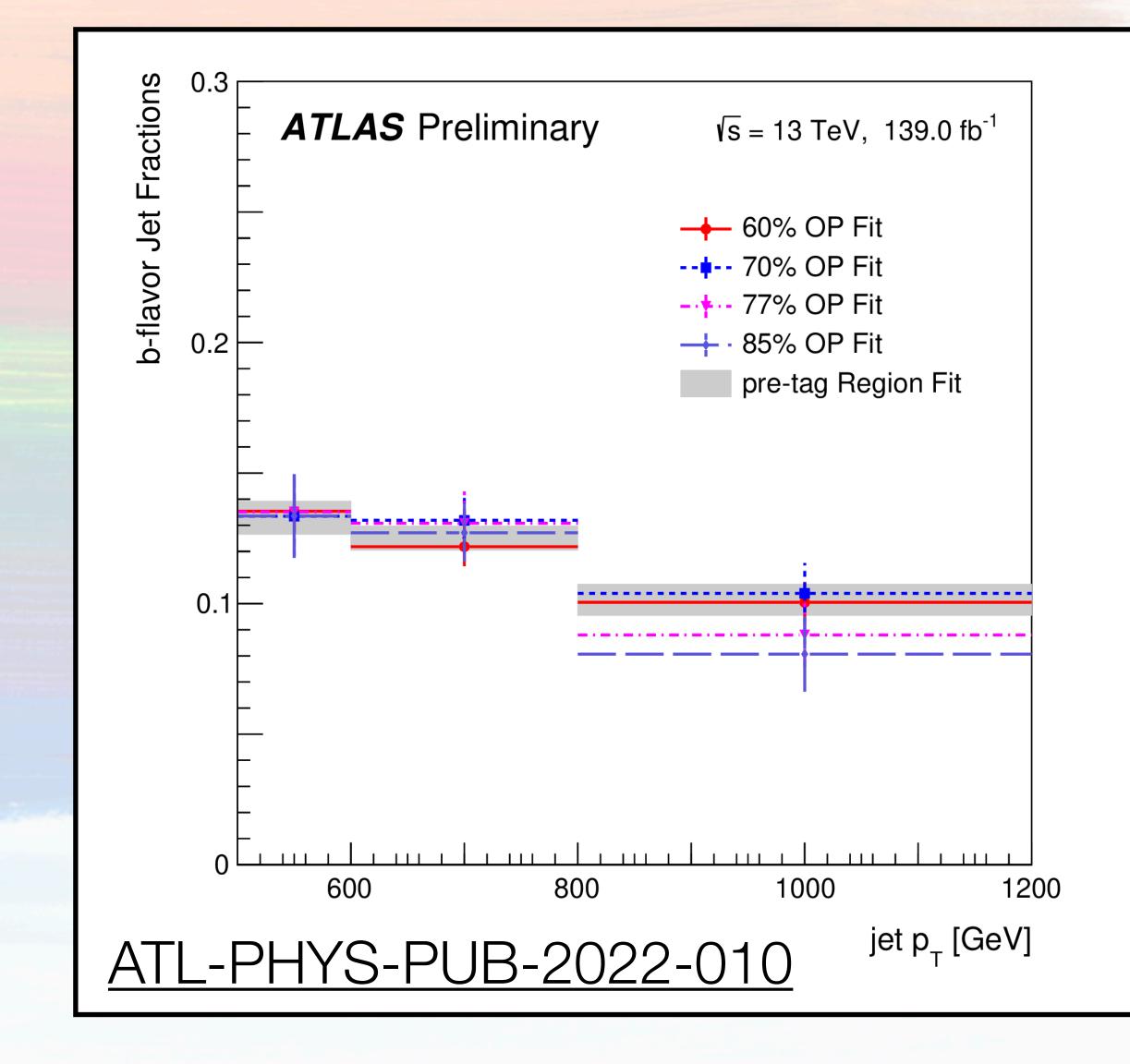


ATL-PHYS-PUB-2022-010

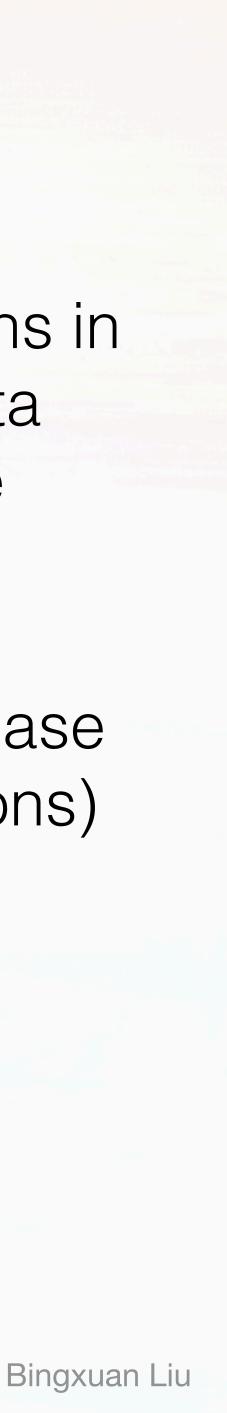
• The performance at TeV scale is not optimal. Need to improve



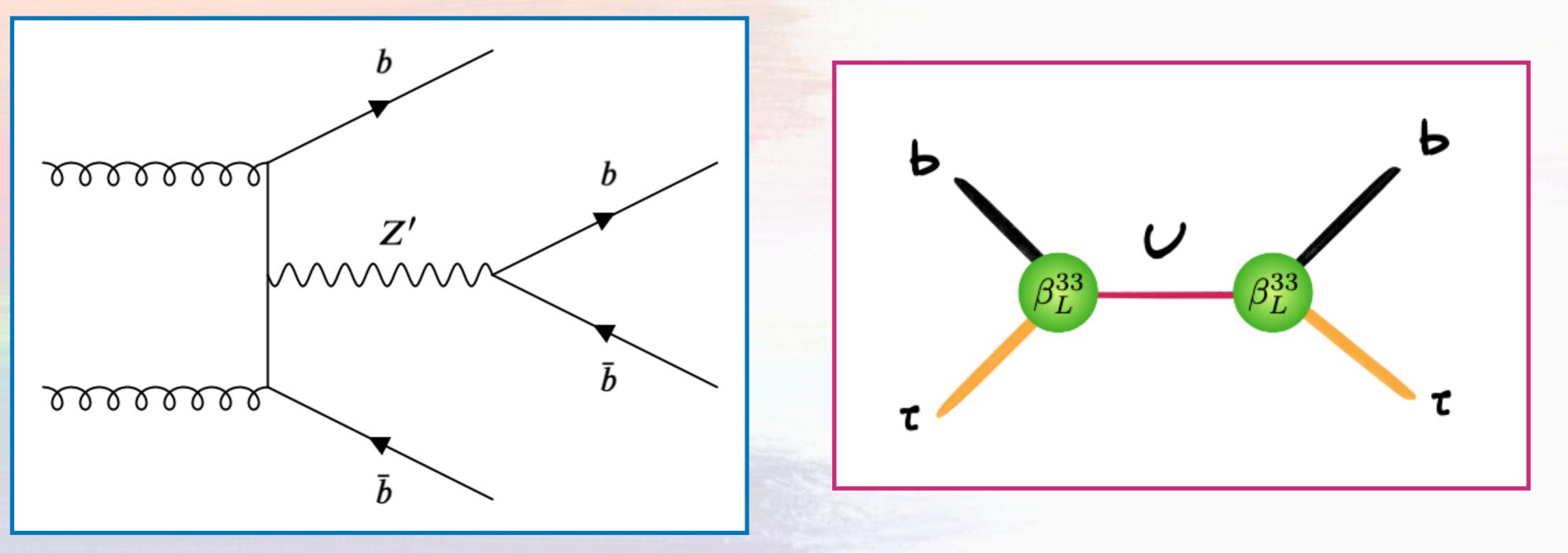
HF Measurement at High Energy Scale



- Tuning the jet flavor fractions in simulation to match the data will significantly reduce the background estimate uncertainties
- Had a look at a specific phase space (jets containing muons) in this calibration work
- A thorough measurement would be ideal

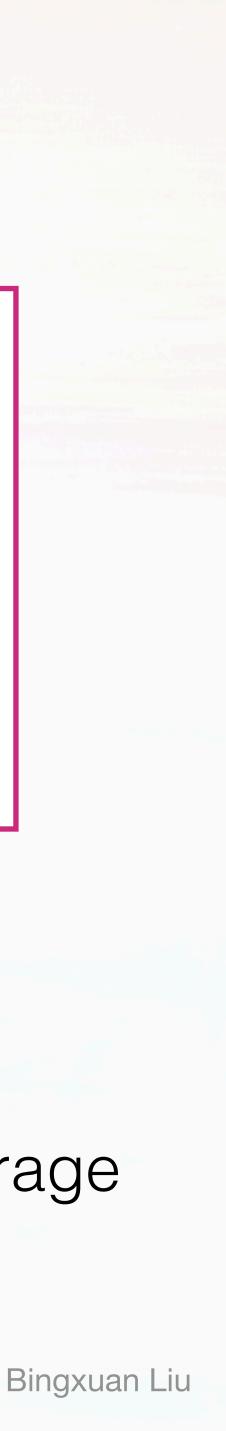


HF Flavor Associated Production

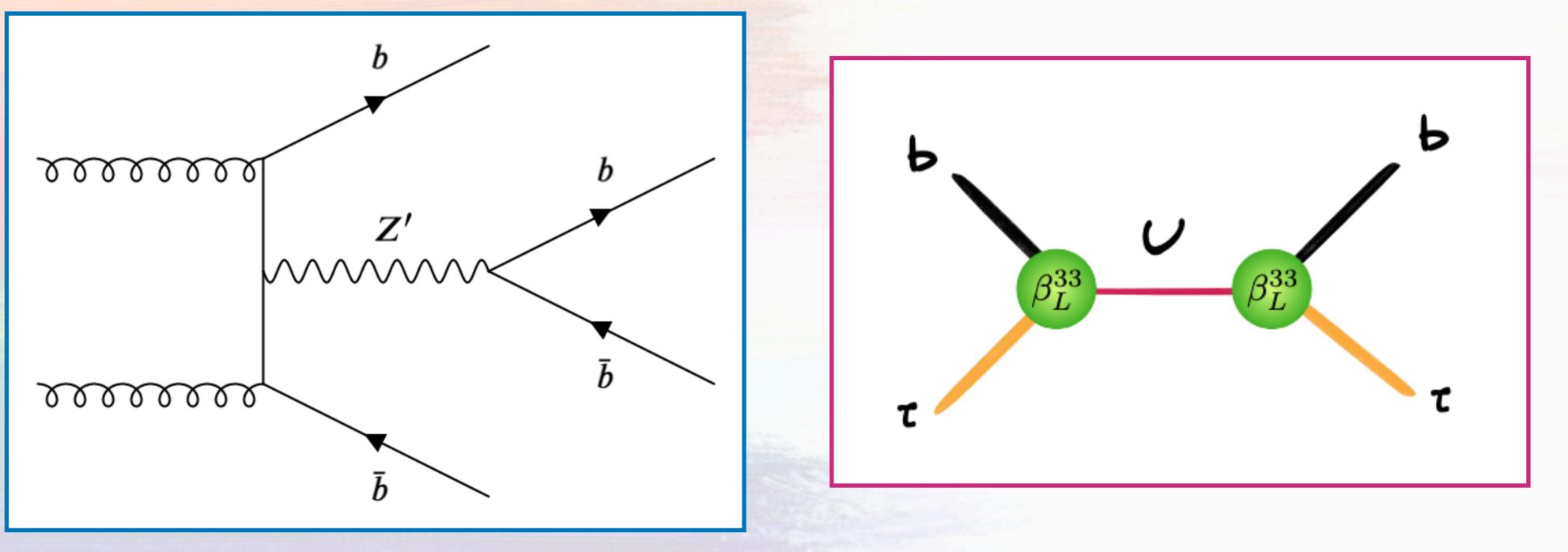


- Due to LHC PDF, soft additional heavy flavor quarks are produced
 - Extra objects to trigger on
 - - Tracker Upgrade (ITK) and forward flavor tagging

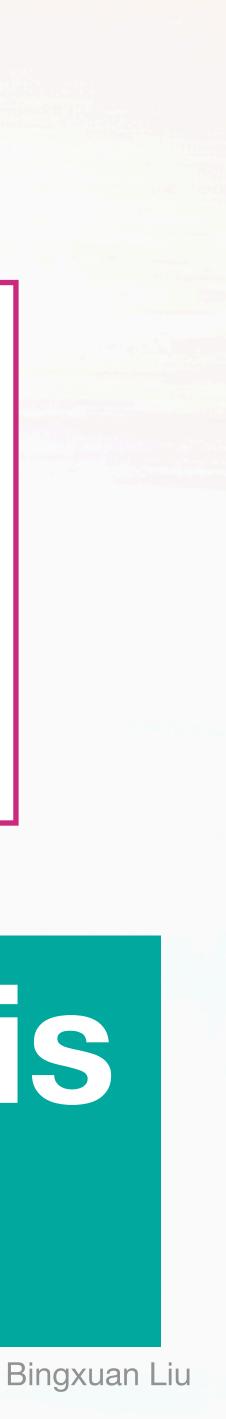
Additional heavy flavor quarks can go beyond the current tracker coverage



HF Flavor Associated Production



Plenty room to optimize this scenaro



BSM Long-lived Particles (LLPs) Decay

Inner Tracker Layers



- New physics can have particles with significantly longer life-time compared with the b-hadrons
 - They decay further away from the luminous region

122.5 mm 88.5



Long-lived Particle Search

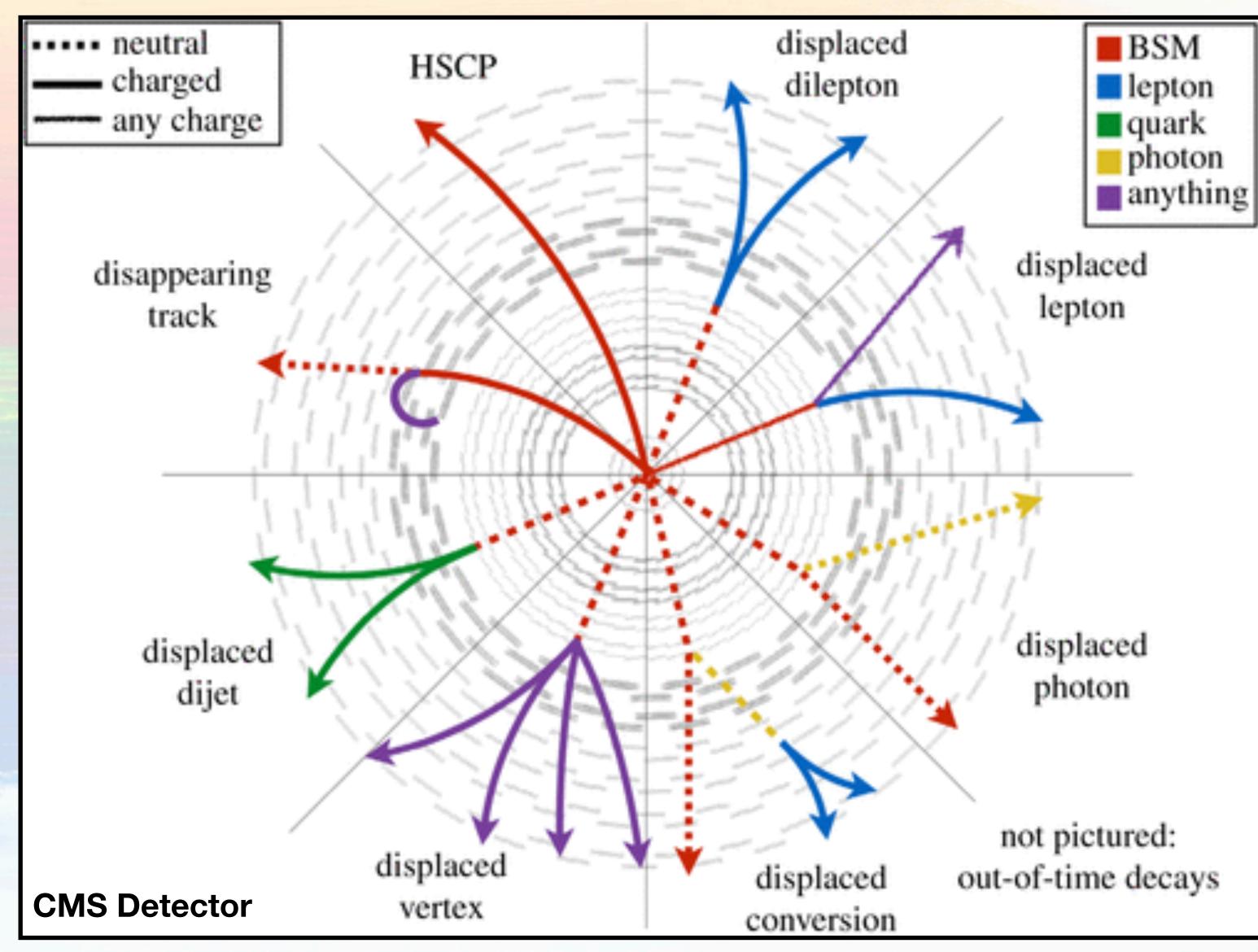
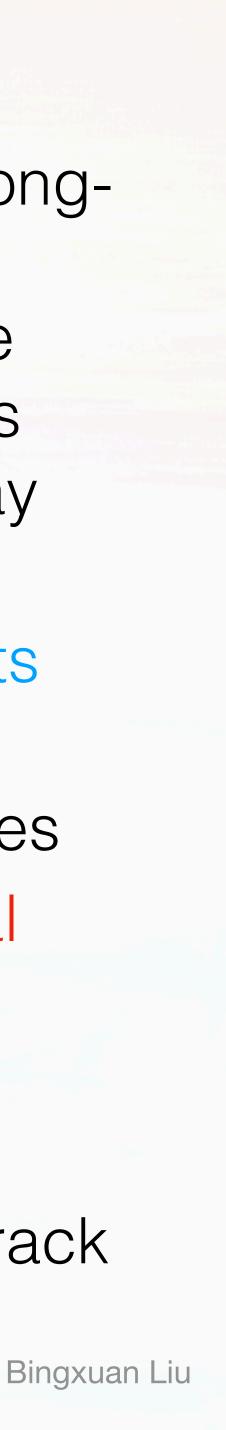


Figure credit: J. Antonelli

- Often categorize longlived particle searches by where the particle decays and what the decay products are
 - Displaced objects
 - Jets, leptons, photons, vertices
 - Non conventional objects
 - Highly ionizing track, disappearing track



Long-lived Particle Search

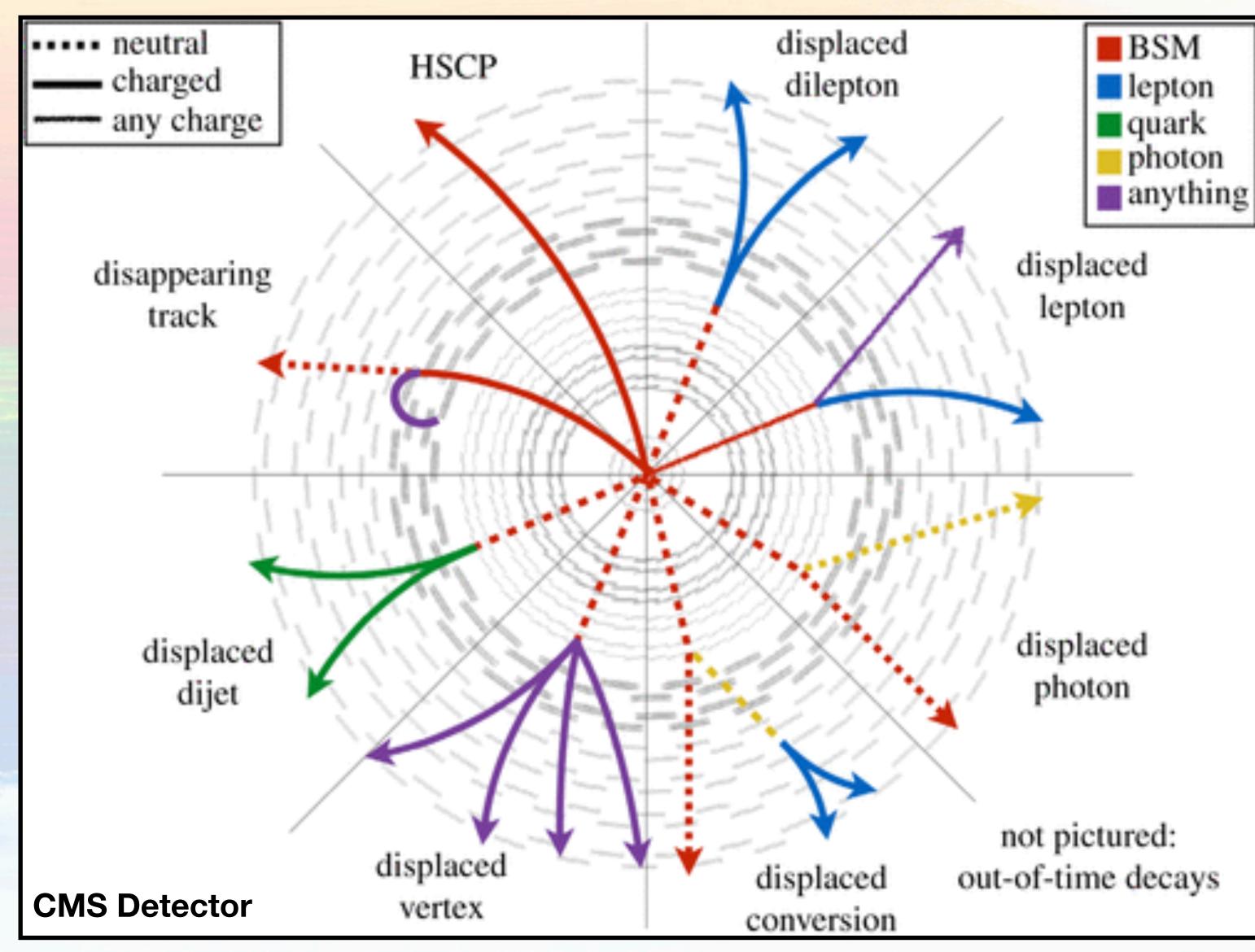


Figure credit: J. Antonelli

Signature Drivent Look for special signatures in the detector that have not been searched before

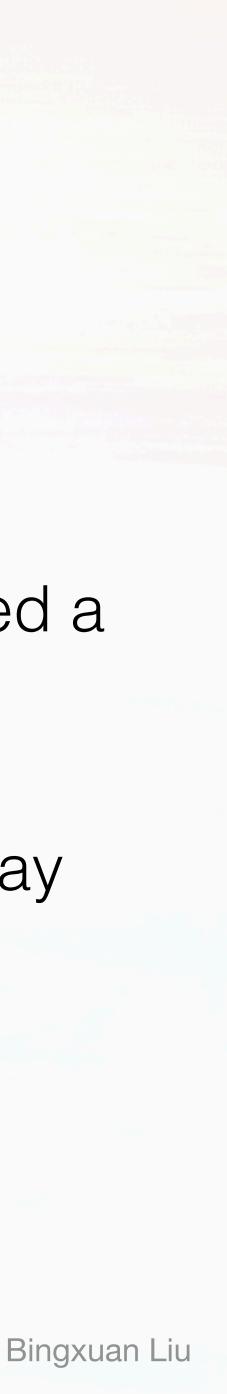


Long-lived Particle Search

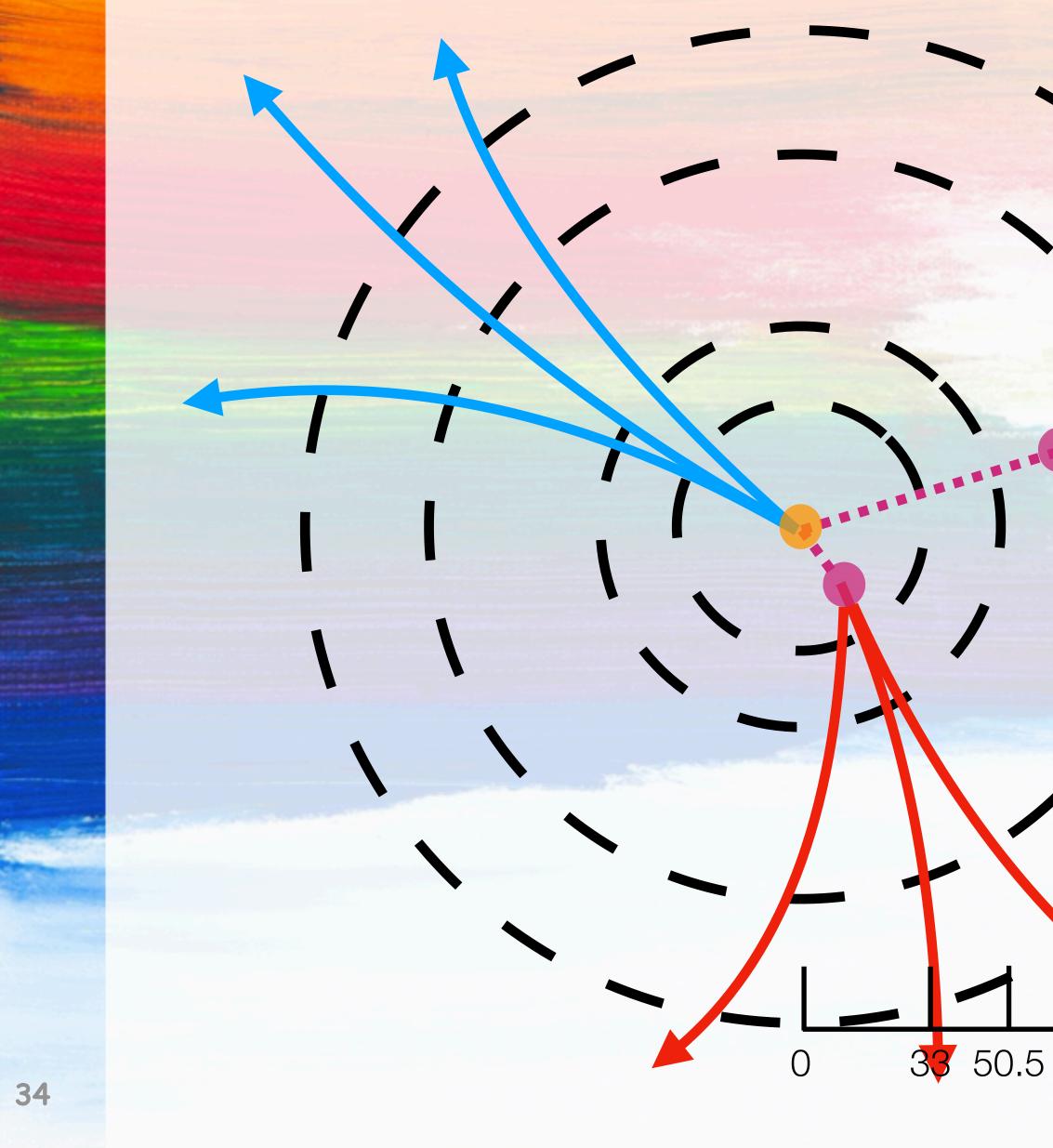
- They are also well motivated theoretically Predicted in many scenarios
- R-parity violated Supersymmetry
 - whose mean lifetimes are free parameters
 - large parameter space
- Hidden valley scenarios
 - chain can have long lifetimes
 - Higgs is very sensitive to this scenario
- Many other models as well
 - Anomaly Mediated SUSY Breaking (AMSB), etc.

 The lightest supersymmetric particles (LSP) can decay to SM particles Becoming more important as traditional SUSY searches have excluded a

A hidden sector is connected with SM and the new particles in the decay

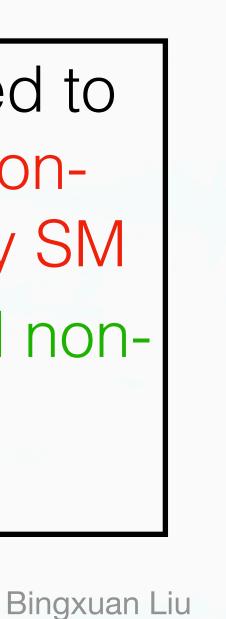


Challenging!



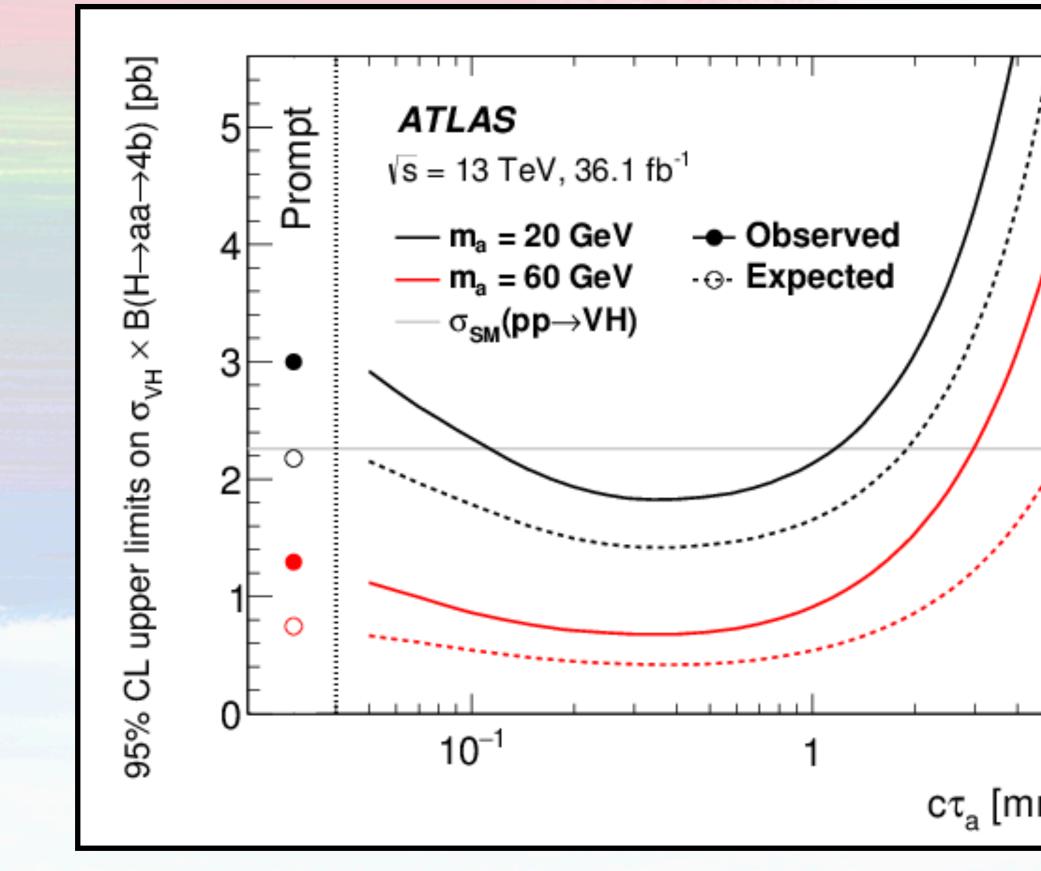
- The detectors were designed to look for prompt decays or nonprompt decays expected by SM
- Performance on exotic BSM nonprompt decays were not optimized

122.5 mm 88.5



b-tagging Long-lived Particles

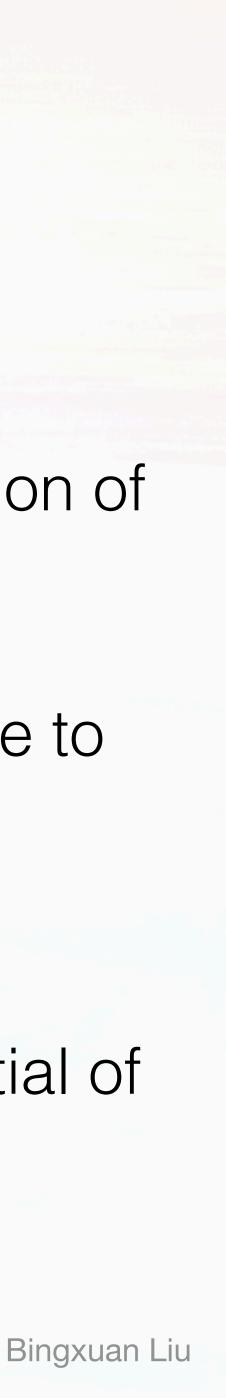
- Long-lived particles can have lifetimes similar as b-hadrons
 - Can be b-tagged

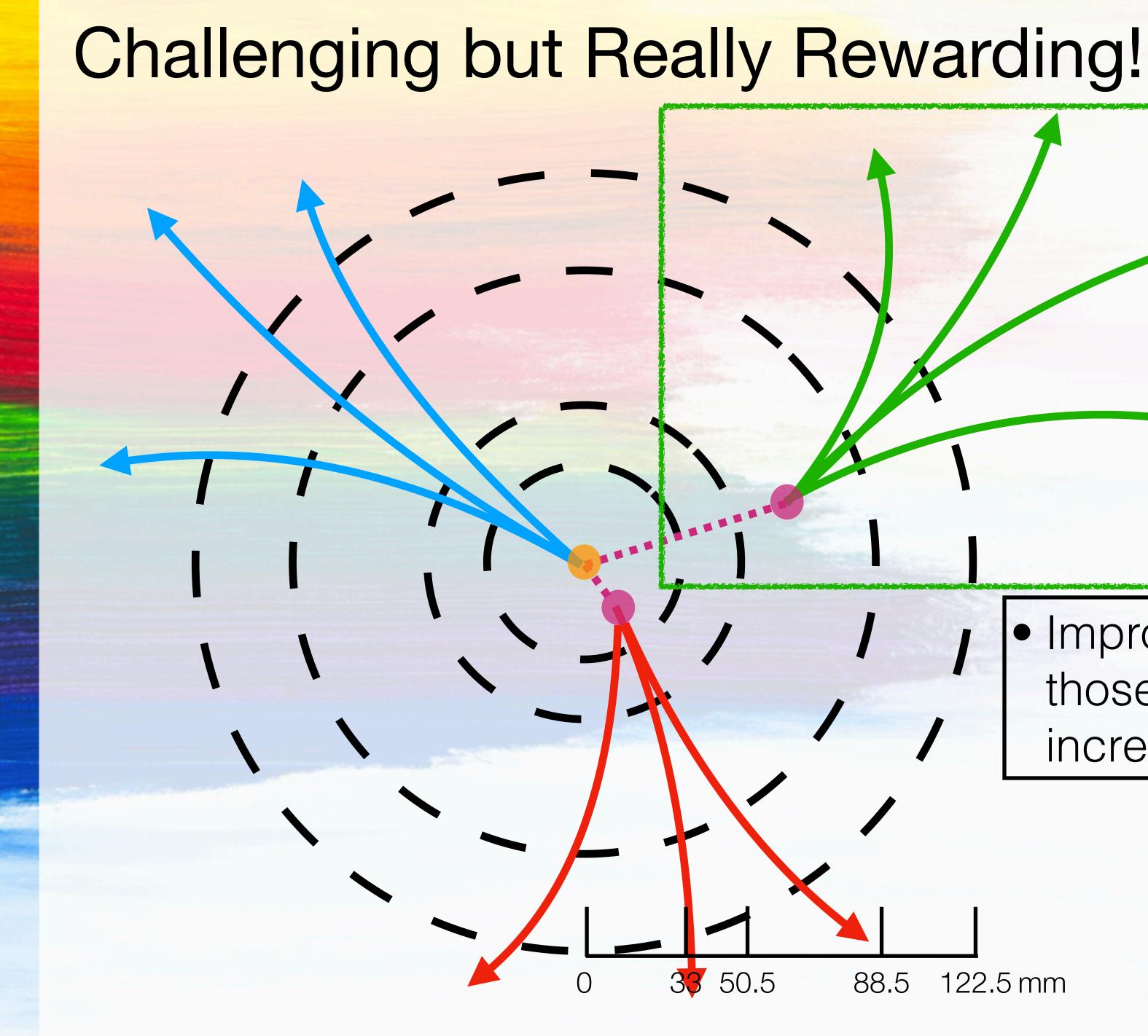


JHEP (2018) 31

Standard searches with b-tagging have sensitivities to such LLPs

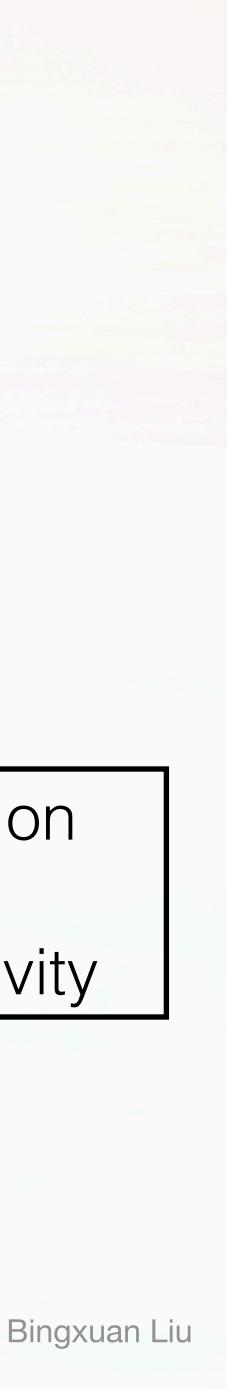
	• We performed a re-interpretation the $VH(H \rightarrow aa \rightarrow b\overline{b}b\overline{b})$ search
	• Without changing analysis strategy, the search is sensitive to $c\tau_a$ up to 1mm
	• Usually consider $c\tau$ as a parameter of the signal
m]	 Very exciting to see the potential dedicated taggers targeting intermediate lifetimes





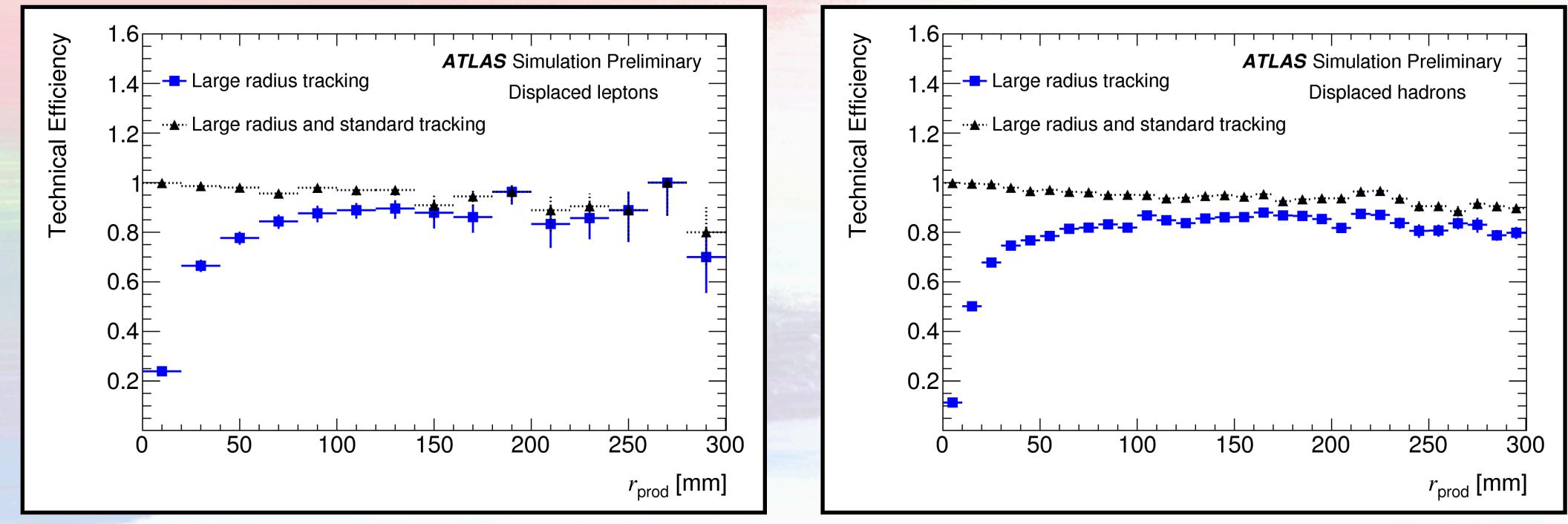
 Improving the performance on those displaced signature increases the search sensitivity

88.5 122.5 mm



Large Radius Tracking in ATLAS

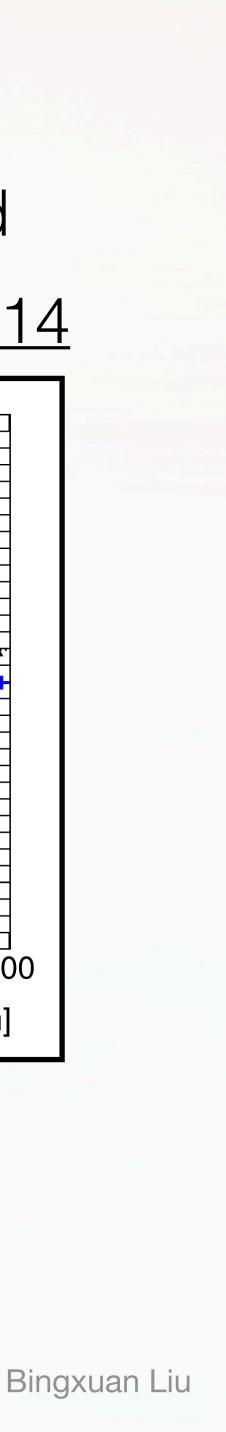
particle (LLP) searches



 It has been applied in many Run2 LLP searches Good efficiency up to production radius ~ 300 mm!

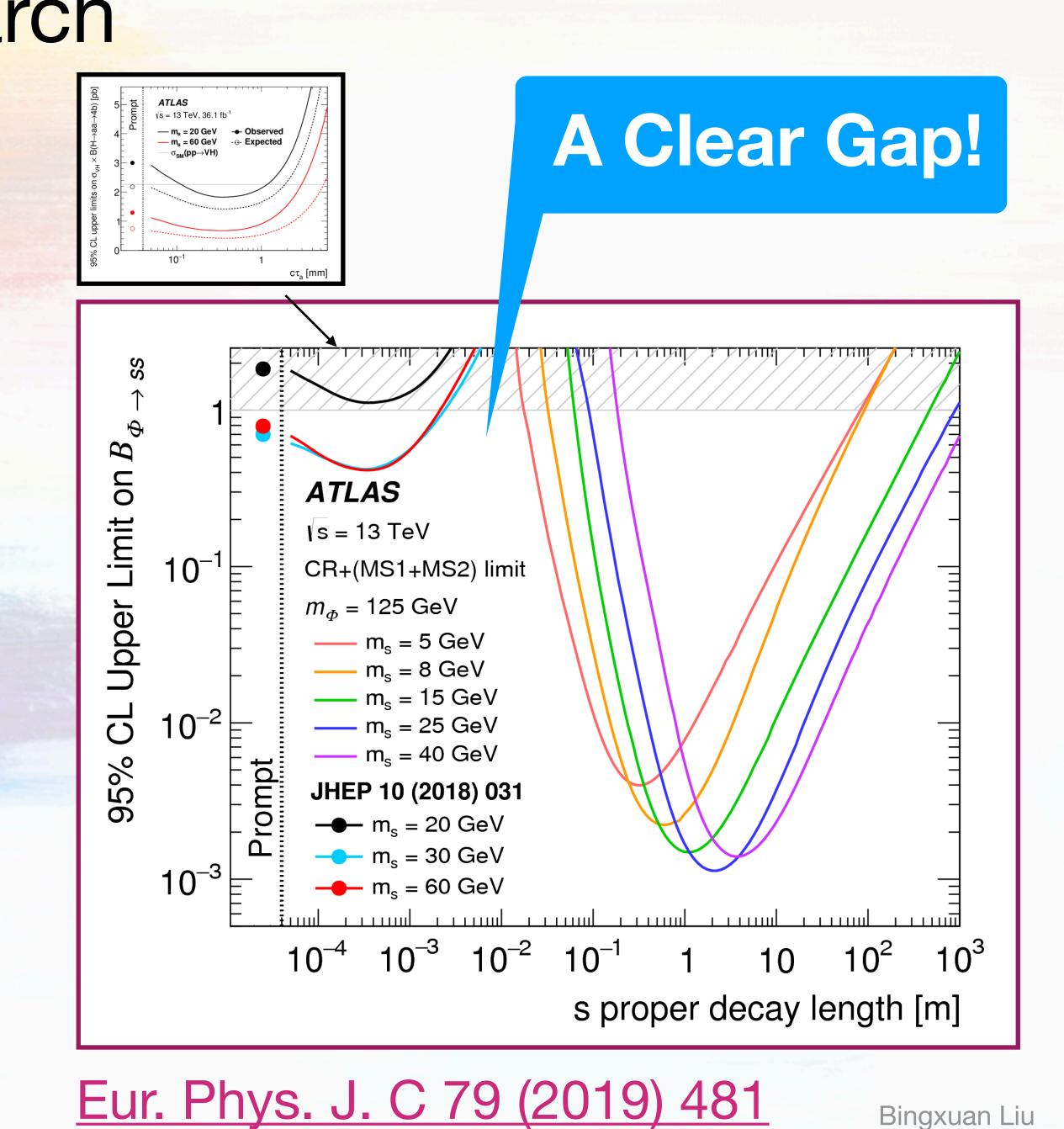
Large Radius Tracking (LRT) is a special tracking algorithm for long-lived

ATL-PHYS-PUB-2017-014



VH4b Dedicated LLP Search

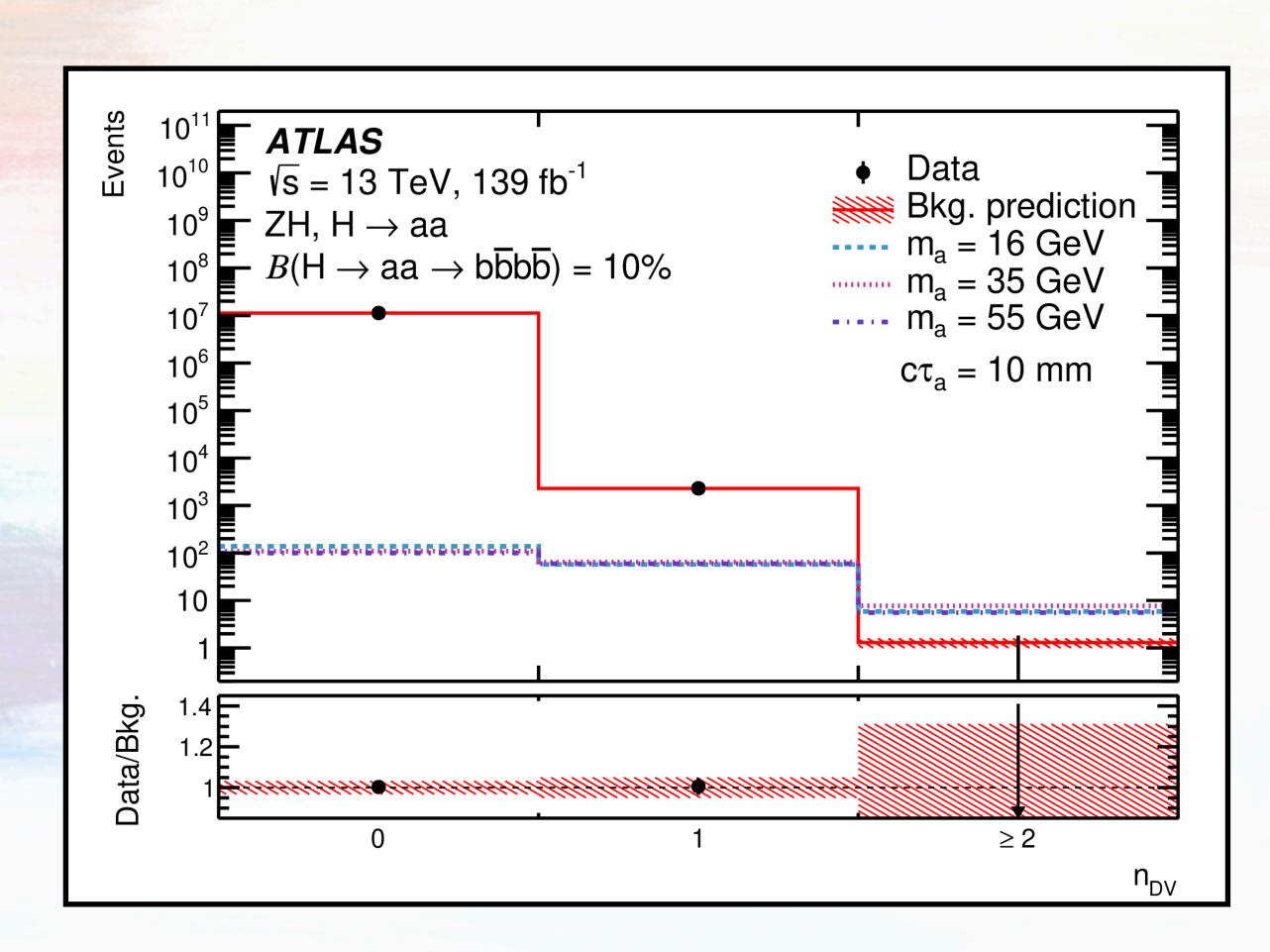
- Intermediate lifetime region has not been covered well
 - Displaced decays within the tracker volume
- We did a dedicated search using LRT to cover this gap
 - Searching for V+Higgs -> aa (long-lived) -> 4 b-quarks via displaced vertices (DV) reconstructed using LRT



Bingxuan Liu

VH4b Dedicated LLP Search

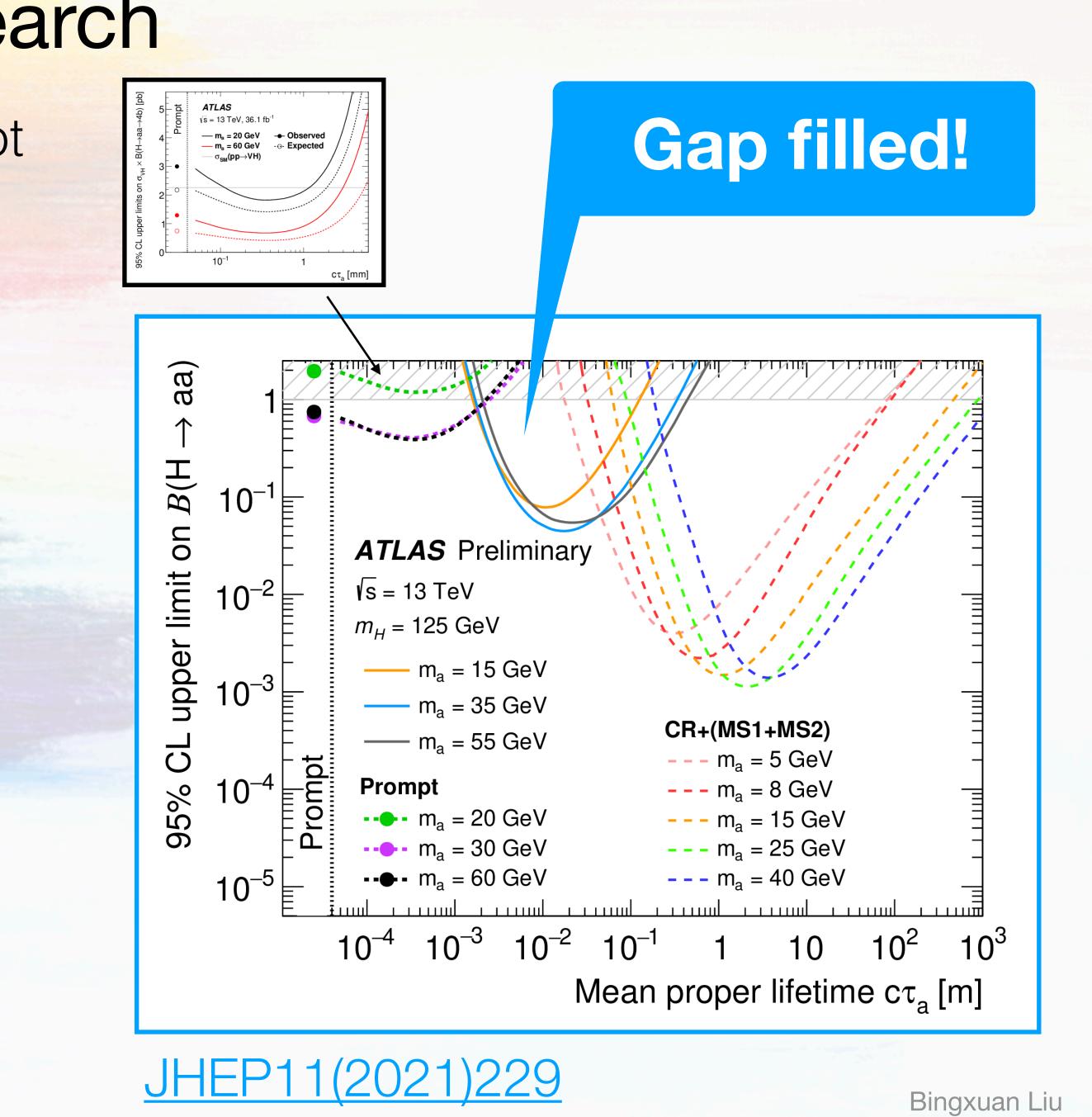
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 - Signal region requires at least two DVs



JHEP11(2021)229

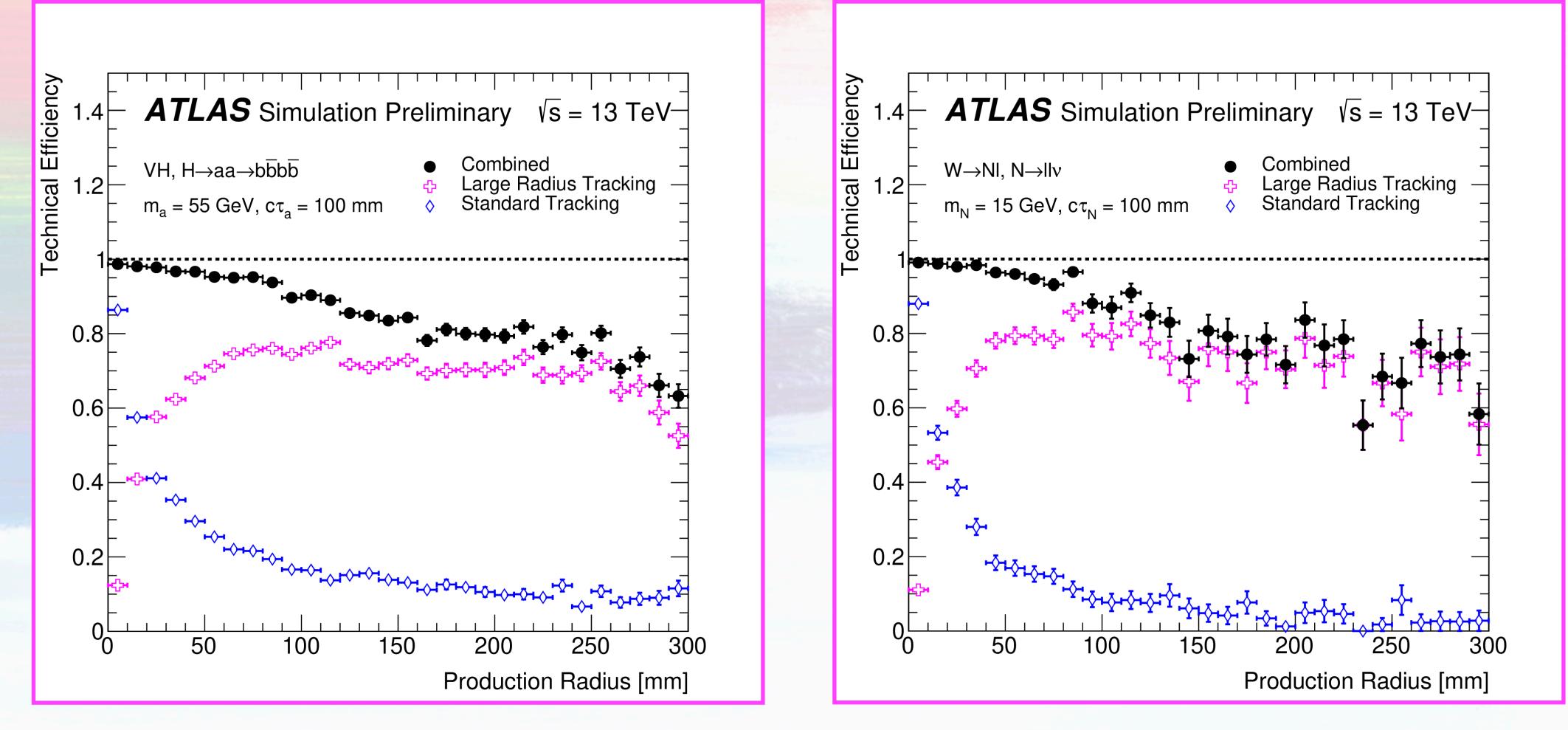
VH4b Dedicated LLP Search

- Intermediate lifetime region has not been covered well
 - Displaced decays within the tracker volume
- We did a dedicated search using LRT to cover this gap
 - Searching for V+Higgs -> aa (long-lived) -> 4 b-quarks via displaced vertices (DV) reconstructed using LRT
- Aiming at filling this gap
- And it did fill this gap



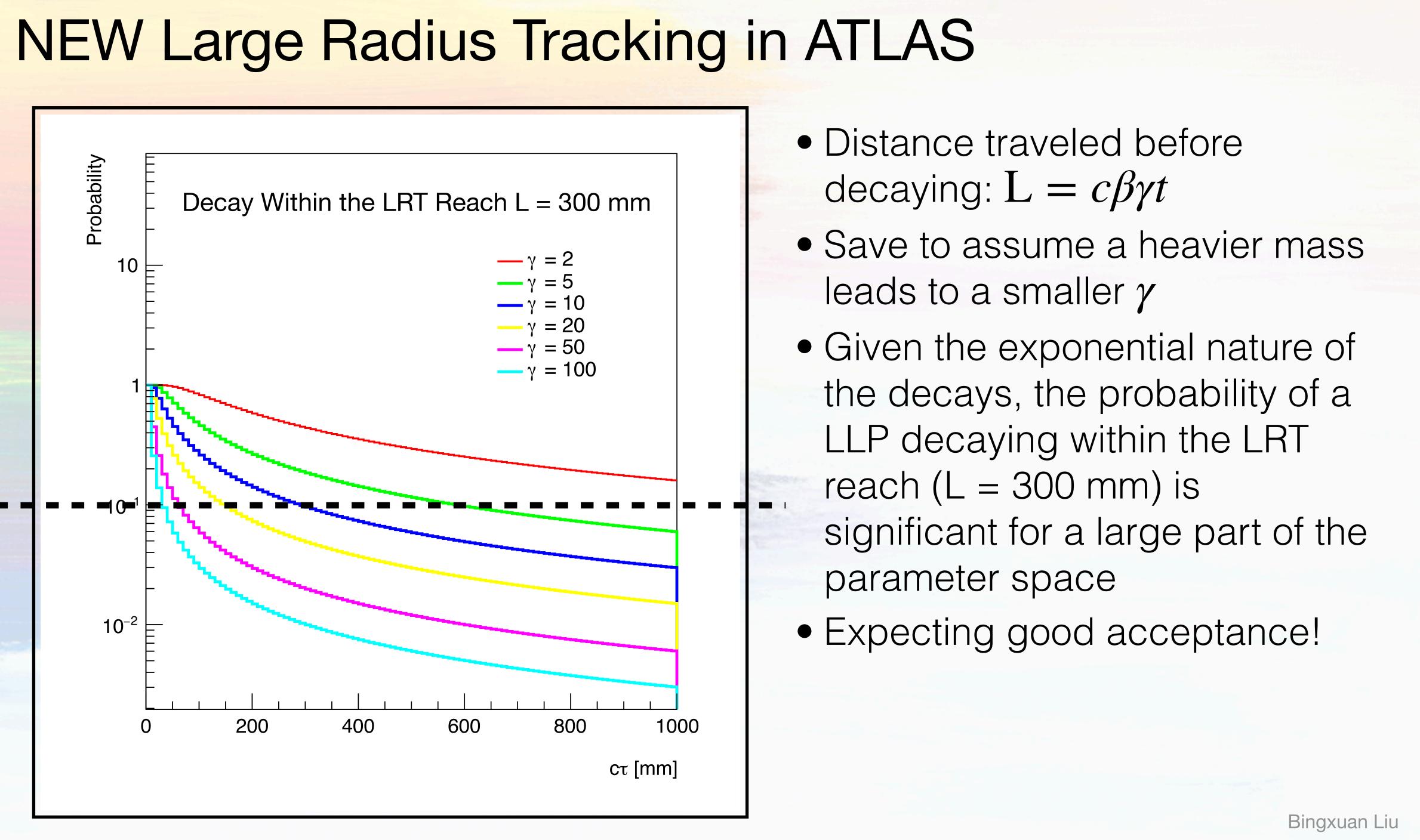
NEW Large Radius Tracking in ATLAS

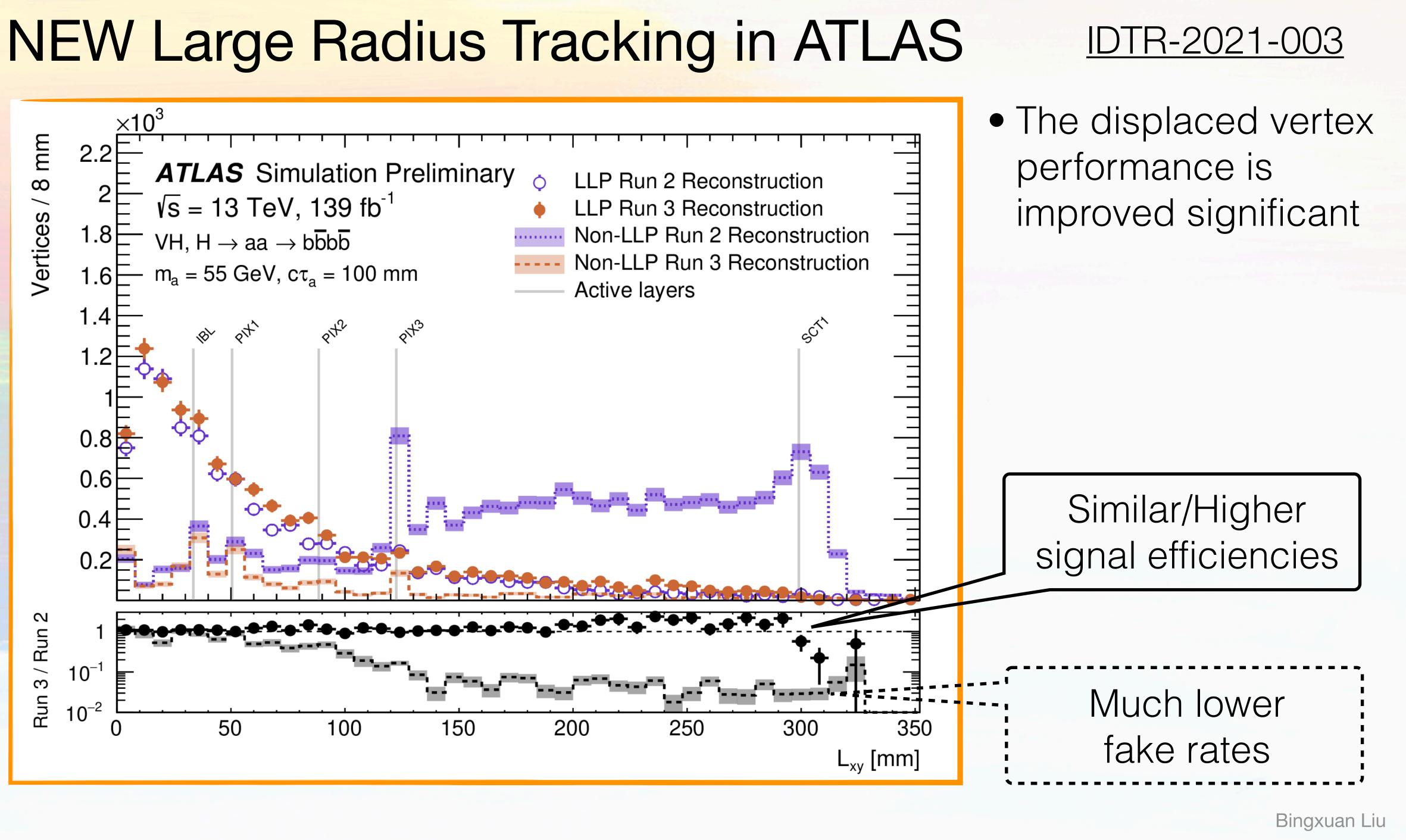
 LRT has been significant updated/improved for Run3! Run2 LLP program can also benefit it from reprocessing



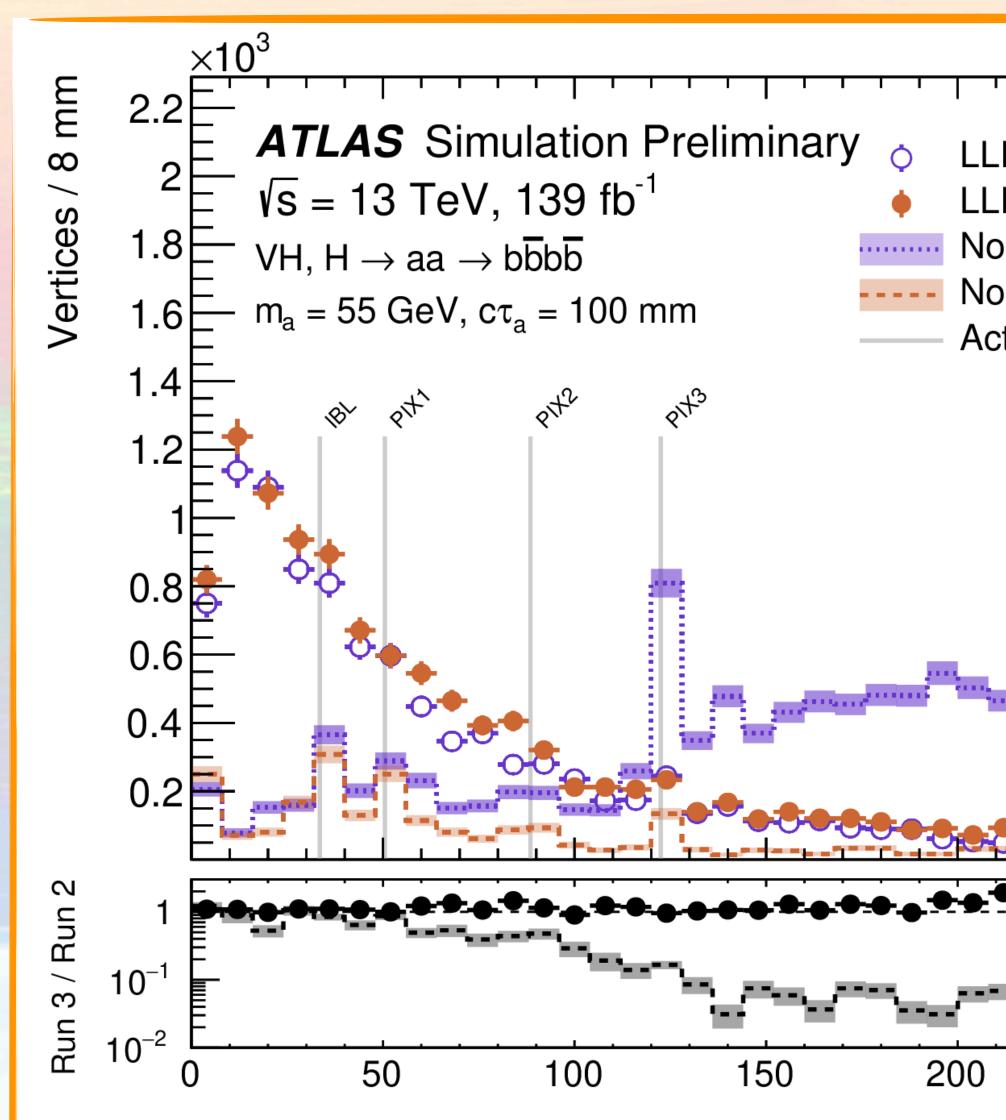
IDTR-2021-003







NEW Large Radius Tracking in ATLAS



44

LLP Run 2 Reconstruction LLP Run 3 Reconstruction Non-LLP Run 2 Reconstruction Non-LLP Run 3 Reconstruction Active layers

250

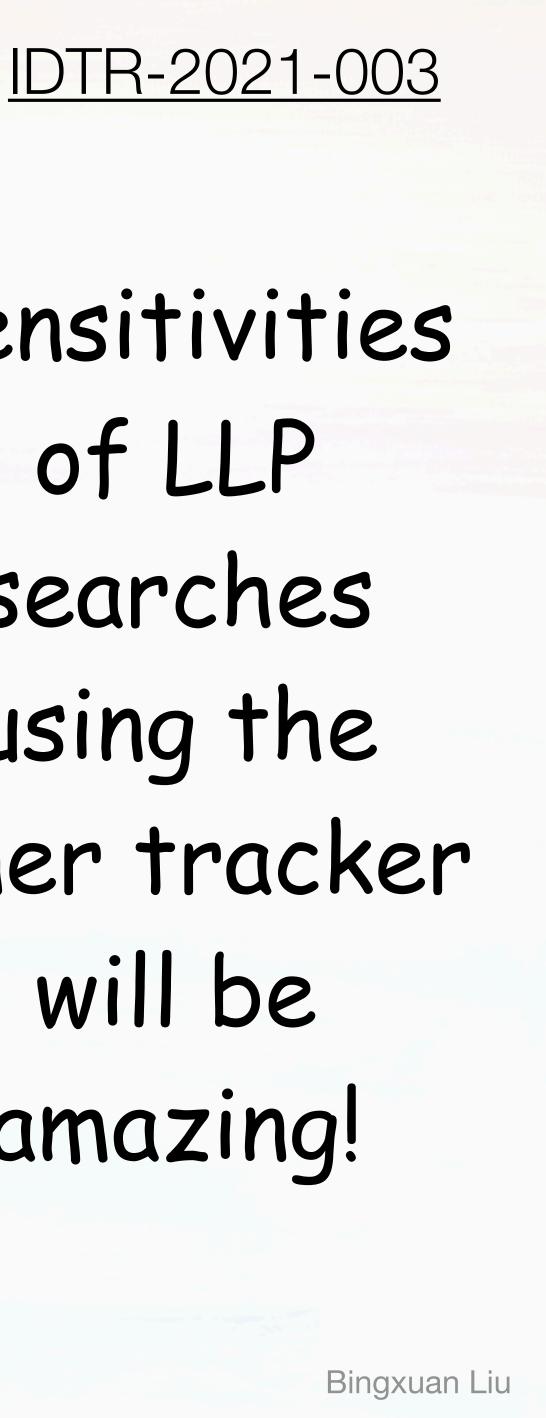
300

350

L_{xy} [mm]

Sensitivities of LLP searches using the

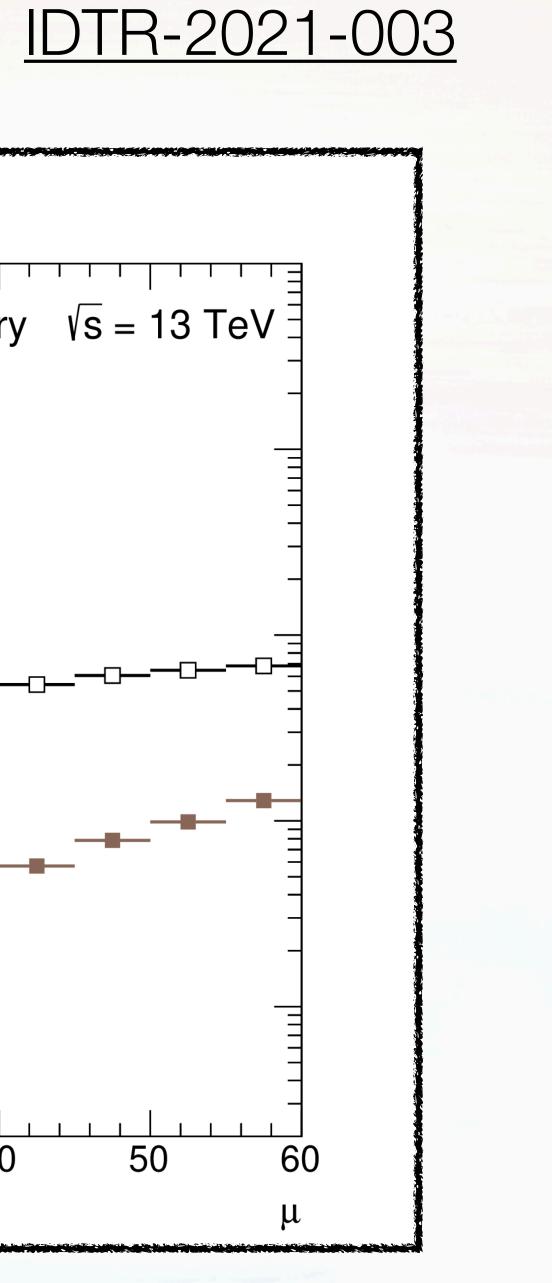
inner tracker will be amazing!

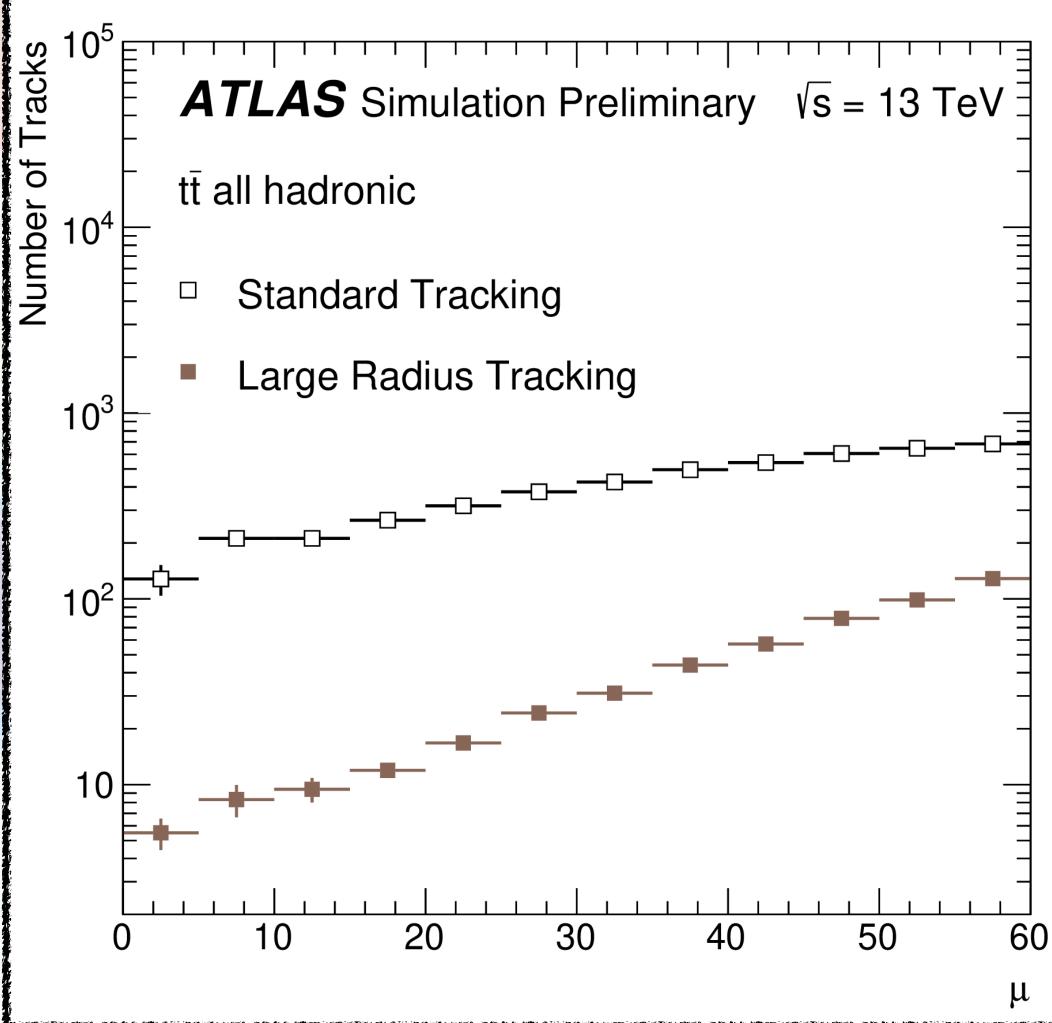


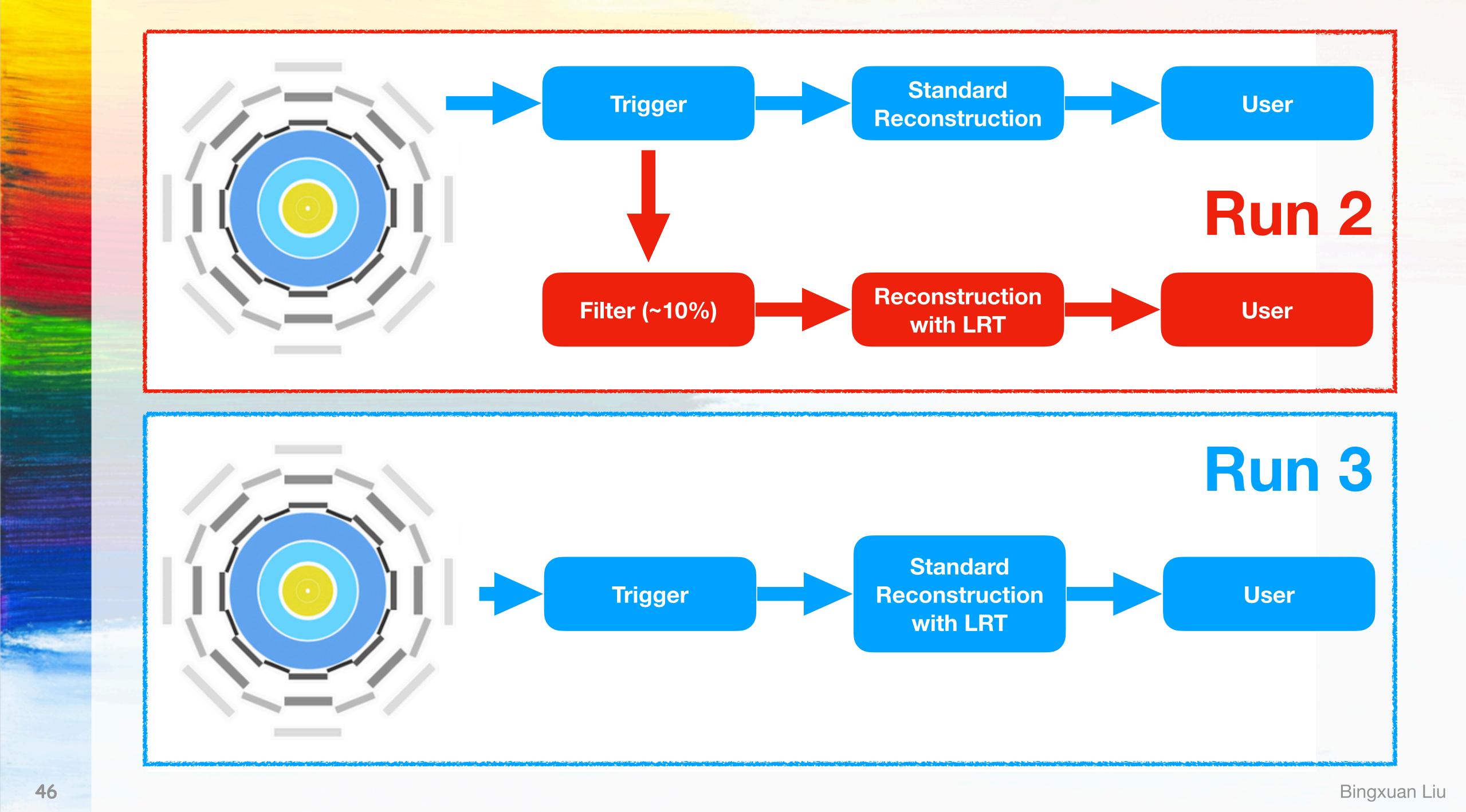
NEW Large Radius Tracking in ATLAS

- The new algorithm only adds ~10% more tracks on average in each event
- It is enabled for every single event collected by ATLAS
 - No additional filtering or processing is needed
 - Save computational resource and person power

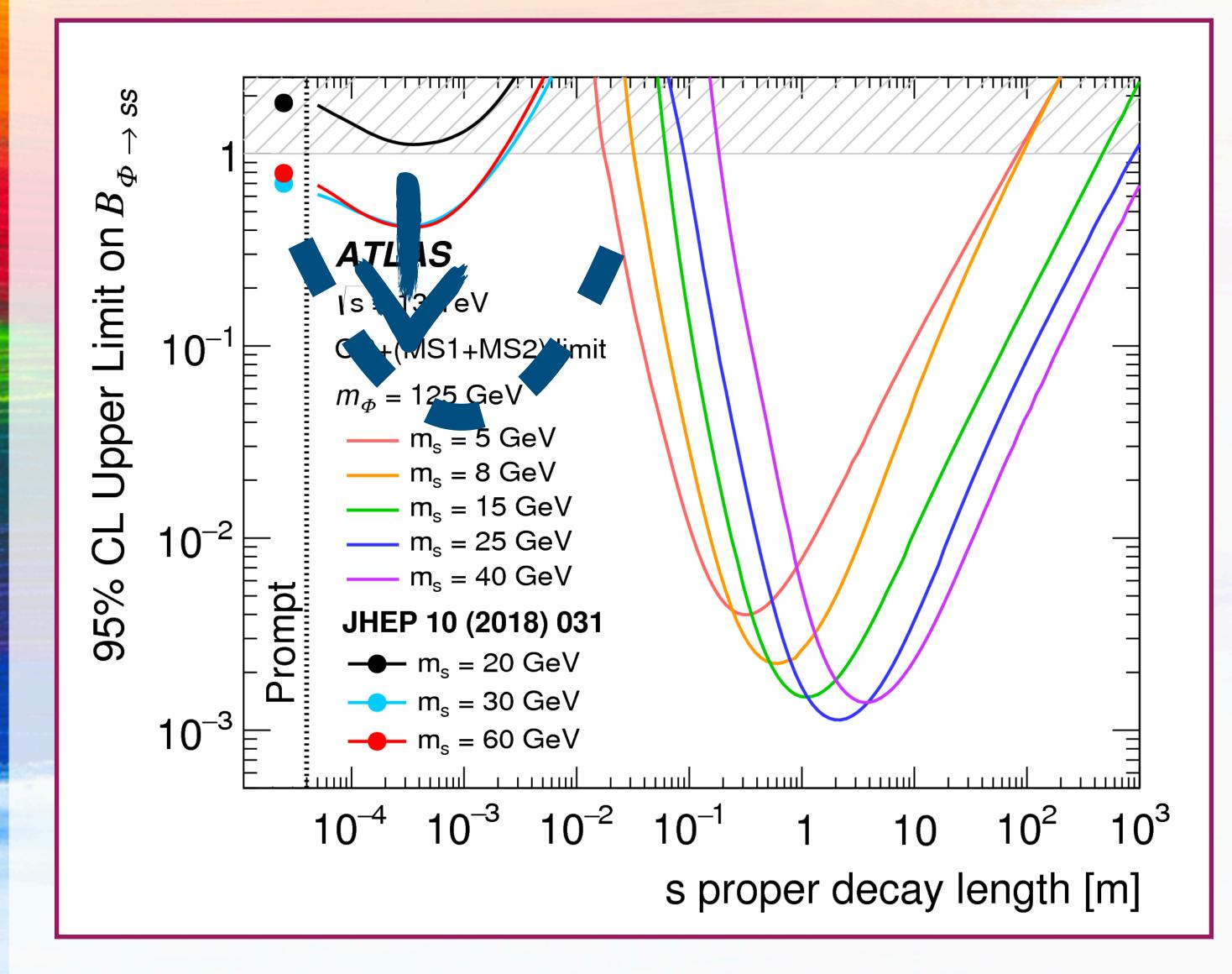
 Previously LRT was only applied to ~10% of the events collected by ATLAS







Make Traditional Searches More Sensitive to LLP



- Standard *b*-tagging is clearly already sensitive to LLP in a given phase space
- With the new LRT, we could make it more sensitive!
- A simultaneous coverage extension!



Greatly Extend the Parameter Space

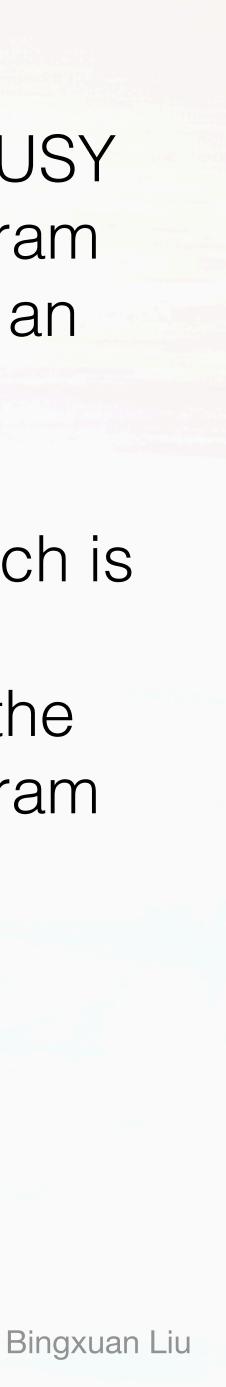
	TLAS SUSY Sea arch 2022 Model		ignatur		` <i>L dt</i> [fb [−]		ss limit					ATLAS Preliminary $\sqrt{s} = 13 \text{ TeV}$ Reference
S	$\tilde{q}\tilde{q},\tilde{q}{ ightarrow}q\tilde{\chi}_1^0$	0 <i>e</i> ,μ mono-jet	2-6 jets 1-3 jets	$E_T^{ m miss}$ $E_T^{ m miss}$	139 139	 <i>q</i> [1×, 8× Degen.] <i>q</i> [8× Degen.] 	1 1	1.0 0.9		1.85	$m(ilde{\chi}^0_1){<}400\mathrm{GeV}\ m(ilde{q}){=}5\mathrm{GeV}$	2010.14293 2102.10874
Inclusive Searches	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q \bar{q} \tilde{\chi}_1^0$	0 <i>e</i> , <i>µ</i>	2-6 jets	E_T^{miss}	139	ğ ğ		Forbidden		2.3 1.15-1.95	$m(\tilde{\chi}_1^0)=0 \text{ GeV}$ $m(\tilde{\chi}_1^0)=1000 \text{ GeV}$	2010.14293 2010.14293
	$ \begin{array}{l} \tilde{g}\tilde{g}, \tilde{g} \rightarrow q\bar{q}W\tilde{\chi}_{1}^{0} \\ \tilde{g}\tilde{g}, \tilde{g} \rightarrow q\bar{q}(\ell\ell)\tilde{\chi}_{1}^{0} \end{array} $	1 e,μ ee,μμ	2-6 jets 2 jets	$E_T^{ m miss}$	139 139	δ δ φ				2.2	${ m m}({ ilde { ilde t}}^1)$ <600 GeV ${ m m}({ ilde { ilde t}}^0)$ <700 GeV	2101.01629 CERN-EP-2022-014
usiv	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow qqWZ\tilde{\chi}_1^0$	0 <i>e</i> ,μ SS <i>e</i> ,μ	7-11 jets 6 jets	E_T^{miss}	139 139	o g g g		1	1.15	1.97	$m(\tilde{x}_{1}^{0}) < 600 \text{ GeV}$ $m(\tilde{x}_{1}^{0}) < 600 \text{ GeV}$ $m(\tilde{x}) = 200 \text{ GeV}$	2008.06032 1909.08457
Inc	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow t t \tilde{\chi}_1^0$	0-1 <i>e</i> ,μ SS <i>e</i> ,μ	3 <i>b</i> 6 jets	$E_T^{\rm miss}$	79.8 139	õğ <u>o</u> ğ			1.25	2.25	$m(ilde{\chi}^0_1){<}200~GeV$ $m(ilde{g}){-}m(ilde{\chi}^0_1){=}300~GeV$	ATLAS-CONF-2018-041 1909.08457
	$ ilde{b}_1 ilde{b}_1$	0 <i>e</i> , <i>µ</i>	2 <i>b</i>	$E_T^{\rm miss}$	139	\tilde{b}_1 \tilde{b}_1		0.68	1.255		$m(\tilde{x}_1^0) < 400 GeV$ 10 $GeV < \Delta m(\tilde{b}_1, \tilde{x}_1^0) < 20 GeV$	2101.12527 2101.12527
rks 'ion	$\tilde{b}_1 \tilde{b}_1, \tilde{b}_1 {\rightarrow} b \tilde{\chi}_2^0 {\rightarrow} b h \tilde{\chi}_1^0$	0 <i>e</i> ,μ 2 τ	6 <i>b</i> 2 <i>b</i>	$E_T^{ m miss} \ E_T^{ m miss}$	139 139	\tilde{b}_1 Forbidden \tilde{b}_1).23-1.35	Δm Δ	$(\tilde{\chi}_{2}^{0}, \tilde{\chi}_{1}^{0}) = 130 \text{ GeV}, \text{m}(\tilde{\chi}_{1}^{0}) = 100 \text{ GeV}$ m $(\tilde{\chi}_{2}^{0}, \tilde{\chi}_{1}^{0}) = 130 \text{ GeV}, \text{m}(\tilde{\chi}_{1}^{0}) = 0 \text{ GeV}$	1908.03122 2103.08189
3 rd gen. squarks direct production	$ \tilde{t}_1 \tilde{t}_1, \tilde{t}_1 \rightarrow t \tilde{\chi}_1^0 \tilde{t}_1 \tilde{t}_1, \tilde{t}_1 \rightarrow W b \tilde{\chi}_1^0 $	0-1 e,μ 1 e,μ	≥ 1 jet 3 jets/1 b	$E_T^{\rm miss}$	139 139	\tilde{t}_1	Forbidden	0.65	1.25		$m({ ilde \chi}^0_1)$ =1 GeV $m({ ilde \chi}^0_1)$ =500 GeV	2004.14060,2012.03799 2012.03799
' gen. 'ect pi	$ \begin{split} \tilde{t}_{1}\tilde{t}_{1}, \tilde{t}_{1} \rightarrow \tilde{\tau}_{1}bv, \tilde{\tau}_{1} \rightarrow \tau \tilde{G} \\ \tilde{t}_{1}\tilde{t}_{1}, \tilde{t}_{1} \rightarrow c\tilde{\chi}_{1}^{0} / \tilde{c}\tilde{c}, \tilde{c} \rightarrow c\tilde{\chi}_{1}^{0} \end{split} $	1-2 τ 0 <i>e</i> ,μ	2 jets/1 <i>b</i> 2 <i>c</i>	$E_T^{\rm miss}$	139 36.1	\tilde{t}_1	roibiddon	Forbidden 0.85	1.4	I.	$m(\tilde{\tau}_1)=800 \text{ GeV}$ $m(\tilde{\tau}_1)=800 \text{ GeV}$ $m(\tilde{\chi}_1)=0 \text{ GeV}$	2108.07665 1805.01649
di. Gi	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow t\tilde{\chi}_2^0, \tilde{\chi}_2^0 \rightarrow Z/h\tilde{\chi}_1^0$	0 e,μ 1-2 e,μ	mono-jet 1-4 <i>b</i>	$E_T^{ m miss}$ $E_T^{ m miss}$ $E_T^{ m miss}$	139 139	\tilde{t}_1	0.55	0.067-	1 18		$m(\tilde{t}_1,\tilde{c})-m(\tilde{\chi}_1^0)=5 \text{ GeV}$ $m(\tilde{\chi}_2^0)=500 \text{ GeV}$	2102.10874 2006.05880
	$\tilde{t}_2\tilde{t}_2, \tilde{t}_2 \rightarrow \tilde{t}_1 + Z$	3 <i>e</i> , <i>µ</i>	1 <i>b</i>	$E_T^{\rm miss}$	139	\tilde{t}_2	Forbidden	0.86		m($ ilde{\chi}$	$m_{(\ell_2)} = 360 \text{ GeV}, m(\tilde{t}_1) - m(\tilde{t}_1^0) = 40 \text{ GeV}$	2006.05880
	${ ilde \chi}_1^\pm { ilde \chi}_2^0$ via WZ	Multiple ℓ /jet $ee, \mu\mu$	s ≥ 1 jet	$E_T^{ m miss} \ E_T^{ m miss}$	139 139	$ \tilde{\chi}_{1}^{\pm}/\tilde{\chi}_{0}^{0} \\ \tilde{\chi}_{1}^{\pm}/\tilde{\chi}_{2}^{0} $ 0.205		0.96			m($ ilde{\chi}_1^0$)=0, wino-bino m($ ilde{\chi}_1^{\pm}$)-m($ ilde{\chi}_1^0$)=5 GeV, wino-bino	2106.01676, 2108.07586 1911.12606
	$ ilde{\chi}_1^{\pm} ilde{\chi}_1^{\mp}$ via WW $ ilde{\chi}_1^{\pm} ilde{\chi}_2^0$ via Wh	2 e, μ Multiple ℓ/jet	S	$E_T^{ m miss} \ E_T^{ m miss}$	139 139	$\tilde{\chi}_1^{\pm}$ $\tilde{\chi}_1^{\pm}/\tilde{\chi}_2^0$ Forbidden	0.42	1.0	6		m($\tilde{\chi}_{1}^{0}$)=0, wino-bino m($\tilde{\chi}_{1}^{0}$)=70 GeV, wino-bino	1908.08215 2004.10894, 2108.07586
EW direct	$\tilde{\chi}_{1}^{\pm}\tilde{\chi}_{1}^{\pm} \text{ via } \tilde{\ell}_{L}/\tilde{\nu}$ $\tilde{\tau}\tilde{\tau}, \tilde{\tau} \rightarrow \tau \tilde{\chi}_{1}^{0}$ $\tilde{\ell}_{L} p \tilde{\ell}_{L} p \tilde{\ell} \rightarrow \ell \tilde{\chi}_{1}^{0}$	2 e,μ 2 τ		E_T^{miss} E_T^{miss}	139 139	$\tilde{\chi}_{1}^{\pm}$ $\tilde{\tau} = [\tilde{\tau}_{L}, \tilde{\tau}_{R,L}]$ 0.16-0.3	0.12-0.39	1.0			$ m(\tilde{\ell}, \tilde{\nu}) = 0.5(m(\tilde{\chi}_1^{\pm}) + m(\tilde{\chi}_1^0)) \\ m(\tilde{\chi}_1^0) = 0 $	1908.08215 1911.06660
	$\tilde{\ell}_{\mathrm{L,R}} \tilde{\ell}_{\mathrm{L,R}}, \tilde{\ell} \rightarrow \ell \tilde{\chi}_1^0$	2 e,μ ee,μμ	0 jets ≥ 1 jet	E_T^{miss} E_T^{miss}	139 139	<i>ℓ̃</i> 0.256		0.7			$m(\tilde{\ell})=0$ $m(\tilde{\ell})-m(\tilde{\chi}_1^0)=10 \text{ GeV}$	1908.08215 1911.12606
	$\tilde{H}\tilde{H},\tilde{H}{ ightarrow}h\tilde{G}/Z\tilde{G}$	0 <i>e</i> , <i>µ</i> 4 <i>e</i> , <i>µ</i>	$\geq 3 b$ 0 jets ≥ 2 large jet	E_T^{miss} E_T^{miss}	36.1 139	<i>Н</i> 0.13-0.23 <i>Н</i>	0.55				$BR(\tilde{\chi}^0_1 \to h\tilde{G}) = 1$ $BR(\tilde{\chi}^0_1 \to Z\tilde{G}) = 1$	1806.04030 2103.11684
		0 e,µ	≥ 2 large jet	$S E_T^{\text{mass}}$	139	Ĥ		0.45-0.93	State - Marcado	the interest of the second	$BR(\widetilde{\chi}^0_1 o Z\widetilde{G})=1$	2108.07586
Long-lived particles	Direct $\tilde{\chi}_1^+ \tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^\pm$	Disapp. trk	1 jet	$E_T^{\rm miss}$	139	$ ilde{\chi}_1^{\pm}$ $ ilde{\chi}_1^{\pm}$ 0.21		0.66			Pure Wino Pure higgsino	2201.02472 2201.02472
	Stable \tilde{g} R-hadron	pixel dE/dx		$E_T^{ m miss} \ E_T^{ m miss} \ E_T^{ m miss} \ E_T^{ m miss}$	139	<i>ĝ</i>				2.05	~0	CERN-EP-2022-029
arti	Metastable \tilde{g} R-hadron, $\tilde{g} \rightarrow qq \tilde{\chi}_1^0$ $\tilde{\ell}\tilde{\ell}, \tilde{\ell} \rightarrow \ell \tilde{G}$	pixel dE/dx Displ. lep		E_T^{miss}	139 139	$ ilde{g} [au(ilde{g}) = 10 \text{ ns}] \\ ilde{e}, ilde{\mu}$		0.7		2.2	$m(ilde{\chi}_1^0)$ =100 GeV $ au(ilde{\ell})$ = 0.1 ns	CERN-EP-2022-029 2011.07812
ЪГ		pixel dE/dx		E_T^{miss}	139	$\tilde{ au}$ 0.3 $\tilde{ au}$ 0	34 9.36	0.7			$ au(ilde{\ell}) = 0.1 \text{ ns}$ $ au(ilde{\ell}) = 0.1 \text{ ns}$ $ au(ilde{\ell}) = 10 \text{ ns}$	2011.07812 CERN-EP-2022-029
	$\tilde{\chi}_1^{\pm} \tilde{\chi}_1^{\pm} / \tilde{\chi}_1^0, \tilde{\chi}_1^{\pm} \rightarrow Z \ell \rightarrow \ell \ell \ell$	3 <i>e</i> ,μ			139	$\chi_{1}^{+}/\chi_{1}^{-}$ [BR($Z\tau$)=1, BR(Ze)=1]	0.0	6 25 1.0	5		Pure Wino	2011.10543
	$\tilde{\chi}_1^{\pm} \tilde{\chi}_1^{\mp} / \tilde{\chi}_2^0 \to WW / Z\ell\ell\ell\ell\nu\nu$	$4 e, \mu$		$E_T^{\rm miss}$	139	$\tilde{\chi}_{1}^{\pm}/\tilde{\chi}_{2}^{0} [\lambda_{i33} \neq 0, \lambda_{12k} \neq 0]$		0.95		.55	$m(\tilde{\chi}_1^0)$ =200 GeV	2103.11684
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow qq \tilde{\chi}_1^0, \tilde{\chi}_1^0 \rightarrow qqq$		4-5 large jet	S	36.1	$ ilde{g} = [m(ilde{\mathcal{X}}_1^0) = 200 \; ext{GeV}, \; 1100 \; ext{GeV}]$			1.3	1.9	Large $\lambda_{112}^{\prime\prime}$	1804.03568
RPV	$\widetilde{t}\widetilde{t}, \ \widetilde{t} \to t \widetilde{\chi}_1^0, \ \widetilde{\chi}_1^0 \to t bs$		Multiple		36.1	$\tilde{t} = [\lambda''_{323} = 2e-4, 1e-2]$	0.55		5		$m(\tilde{\chi}_1^0)$ =200 GeV, bino-like	ATLAS-CONF-2018-003
RF	$ \widetilde{t}\widetilde{t}, \ \widetilde{t} \to b\widetilde{\chi}_1^{\pm}, \ \widetilde{\chi}_1^{\pm} \to bbs \\ \widetilde{t}_1\widetilde{t}_1, \ \widetilde{t}_1 \to bs $		$\geq 4b$ 2 jets + 2 b		139 36.7	t $\tilde{t}_1 [qq, bs]$	Forbidden 0.42 0.	0.95 61			$m(\tilde{\chi}_1^{\pm})$ =500 GeV	2010.01015 1710.07171
	$ \tilde{t}_1 \tilde{t}_1, \tilde{t}_1 \rightarrow 0 S $ $ \tilde{t}_1 \tilde{t}_1, \tilde{t}_1 \rightarrow q \ell $	2 <i>e</i> , <i>µ</i>	2 jets + 2 <i>b</i>		36.1	\tilde{t}_1			0.4-1.45	5	$BR(\tilde{t}_1 \rightarrow be/b\mu) > 20\%$	1710.05544
		1μ	DV		136	\tilde{t}_1 [1e-10< λ'_{23k} <1e-8, 3e-10< λ'_{23k}	<3e-9]	1.0		1.6	$BR(\tilde{t}_1 \to q\mu) = 100\%, \cos\theta_t = 1$	2003.11956
	$\tilde{\chi}_1^{\pm}/\tilde{\chi}_2^0/\tilde{\chi}_1^0, \tilde{\chi}_{1,2}^0 \rightarrow tbs, \tilde{\chi}_1^+ \rightarrow bbs$	1-2 <i>e</i> , µ										

*Only a selection of the available mass limits on new states or phénomena is shown. Many of the limits are based on simplified models, c.f. refs. for the assumptions made.

 10^{-1}

Mass scale [TeV]

- Taking the SUSY search program at ATLAS as an example
- Long-lived particle search is only a small category of the search program



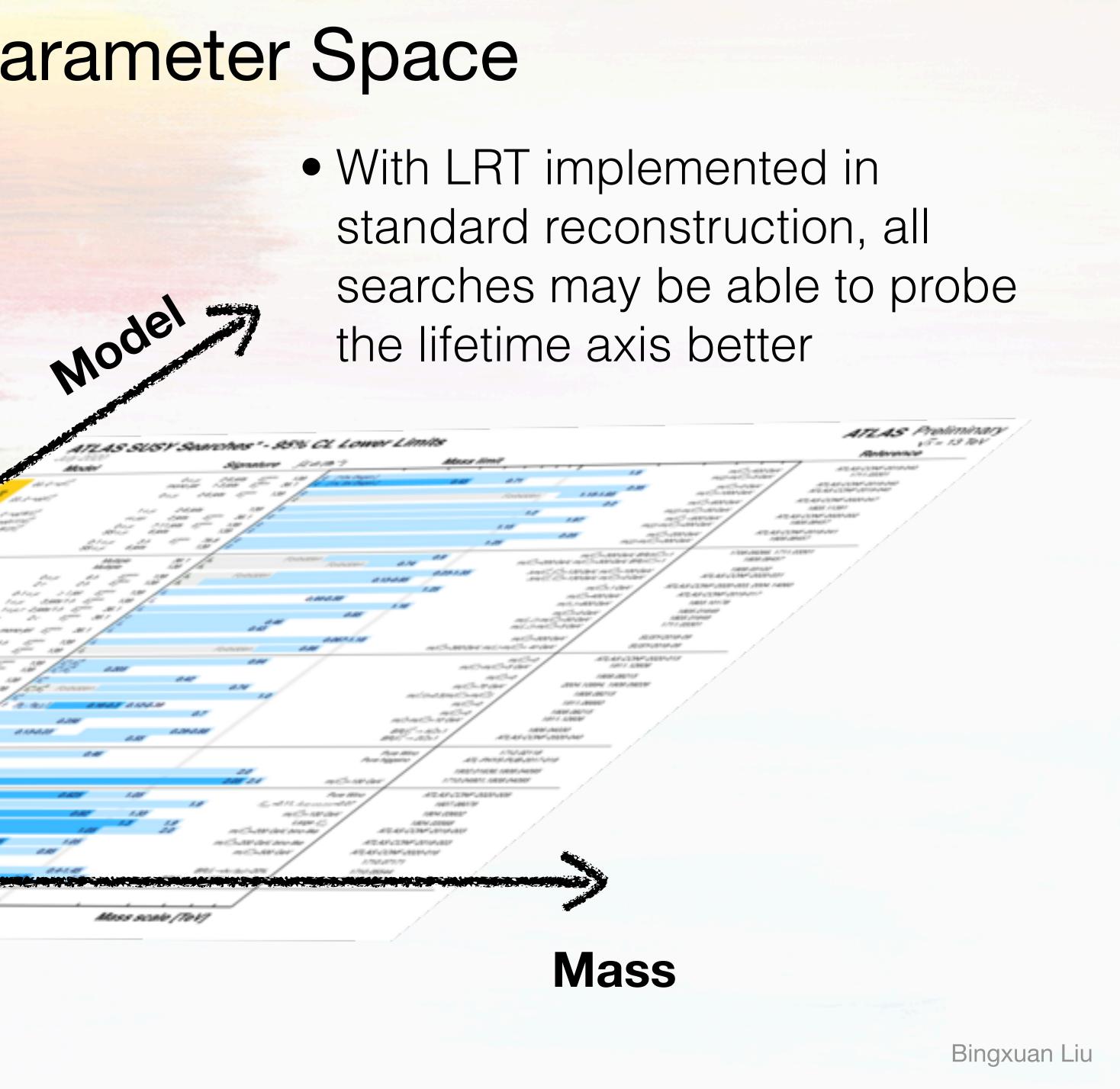
Greatly Extend the Parameter Space



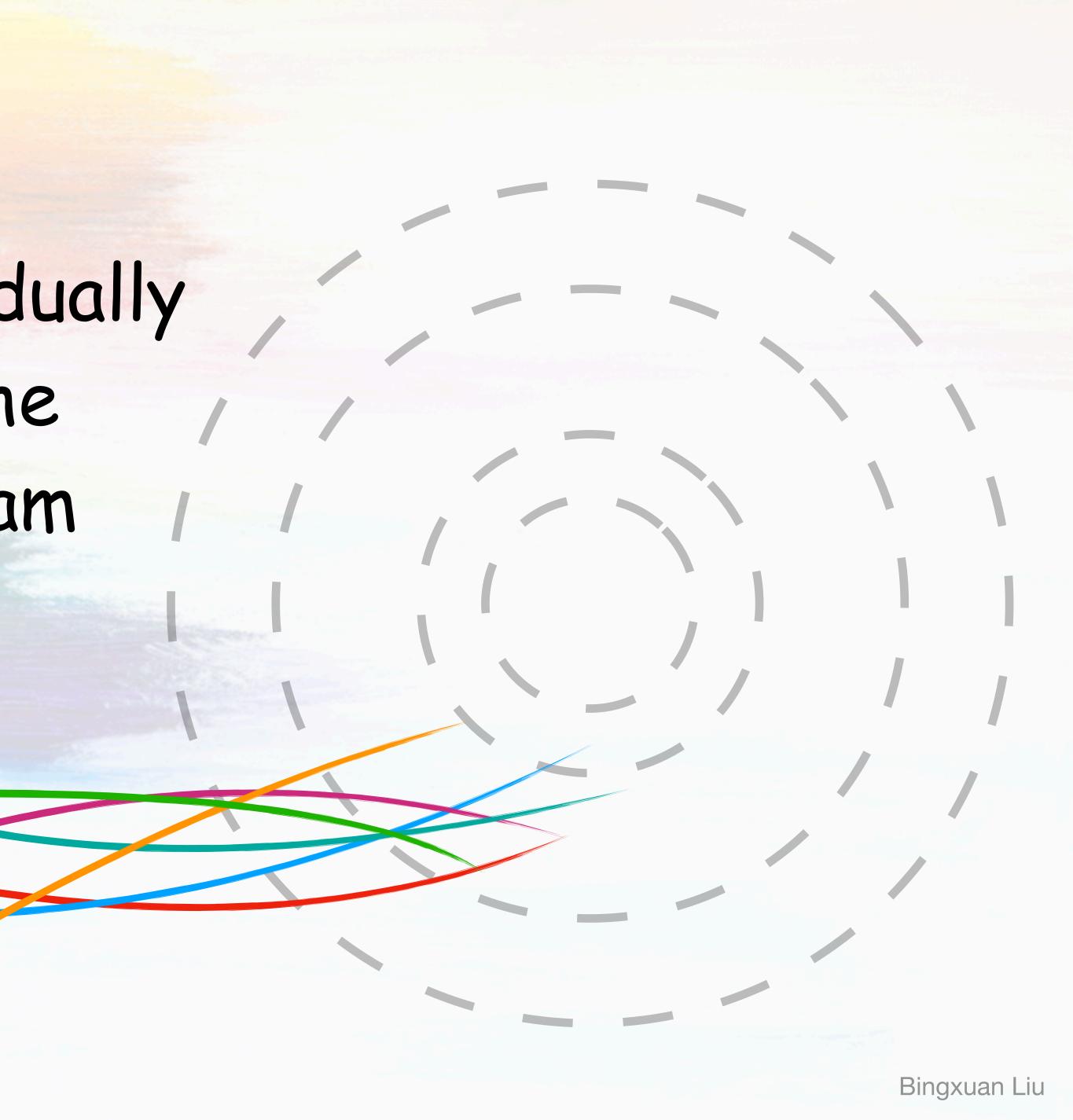
Anderson and a second and a second s second sec

What I am excited about!

standard reconstruction, all the lifetime axis better



LLP searches will gradually become part of the mainstream program

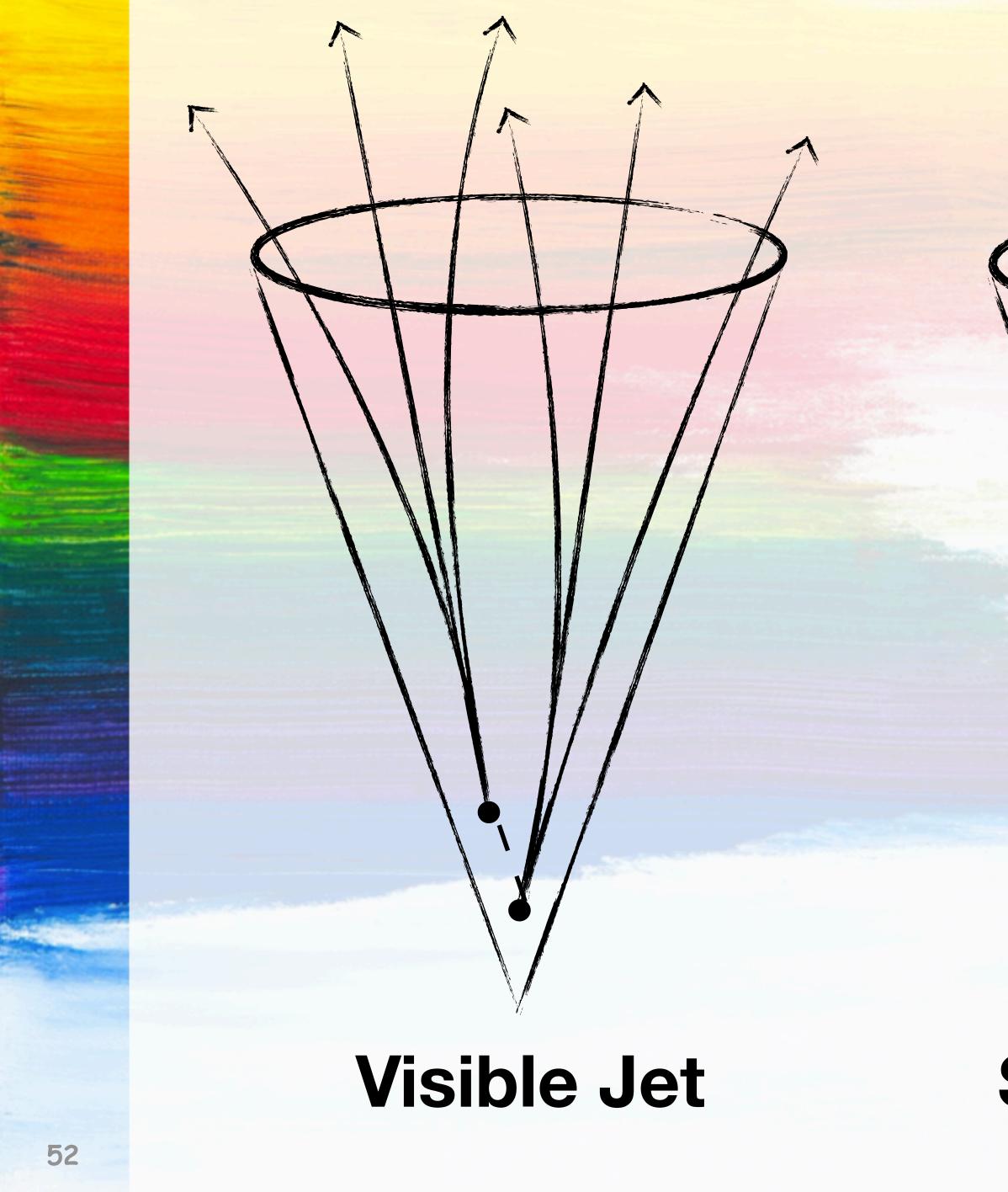


Which means...we can consider

more







<u>JHEP11(2017)196</u>

Invisible decay products

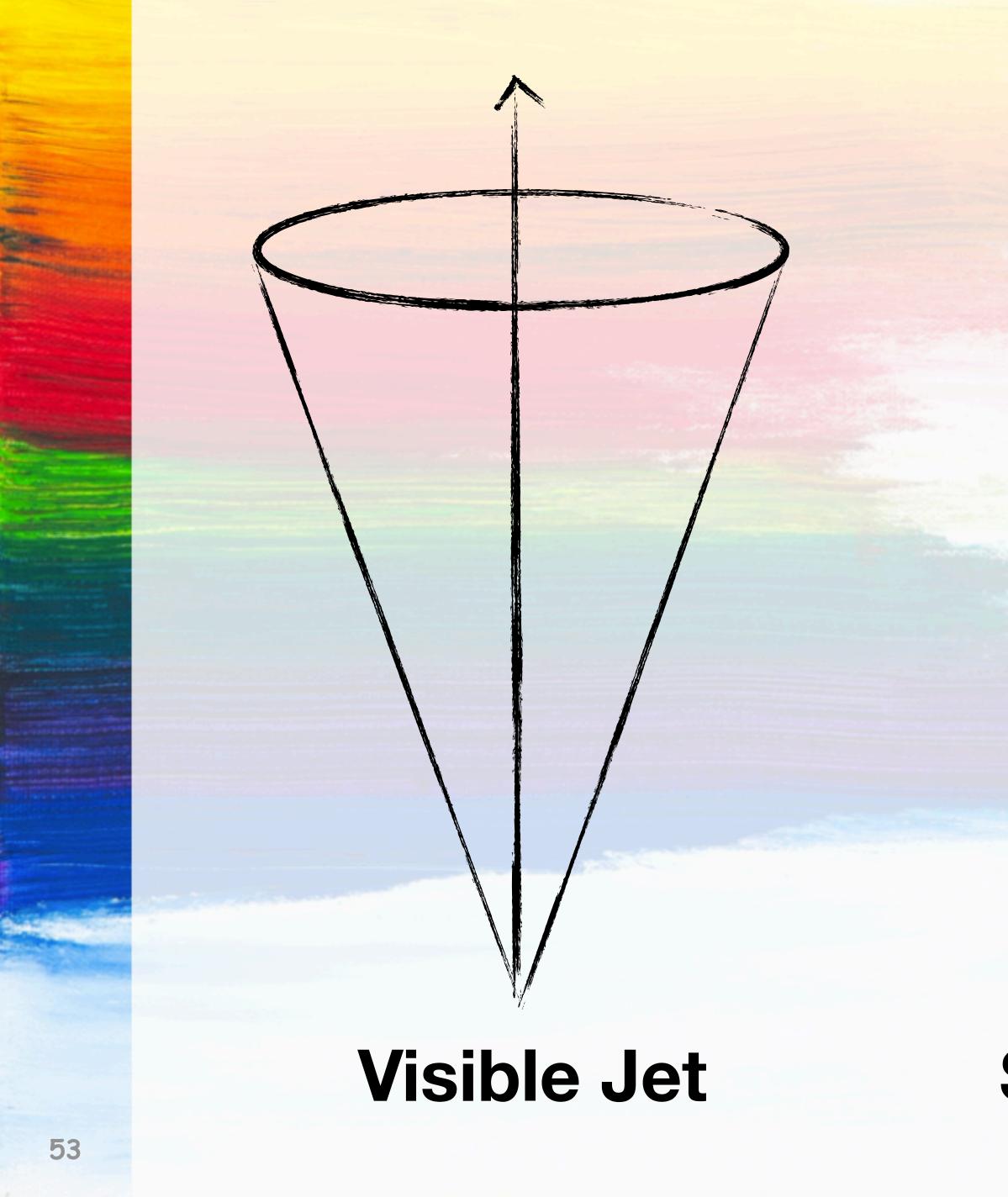
Visible decay products

Semi-visible Jet





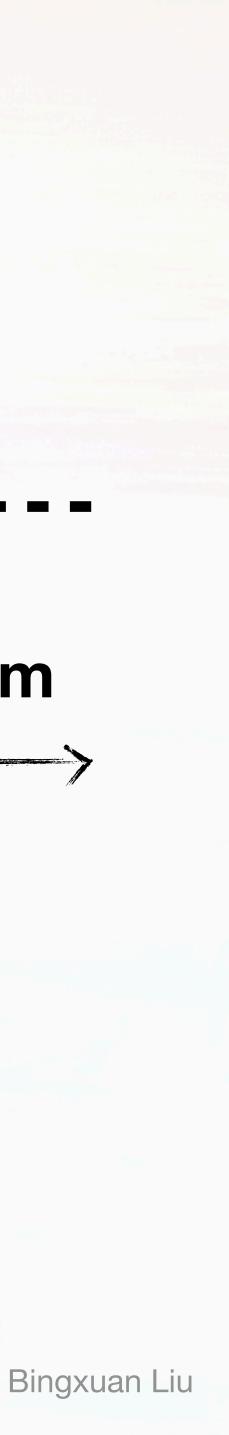
Bingxuan Liu

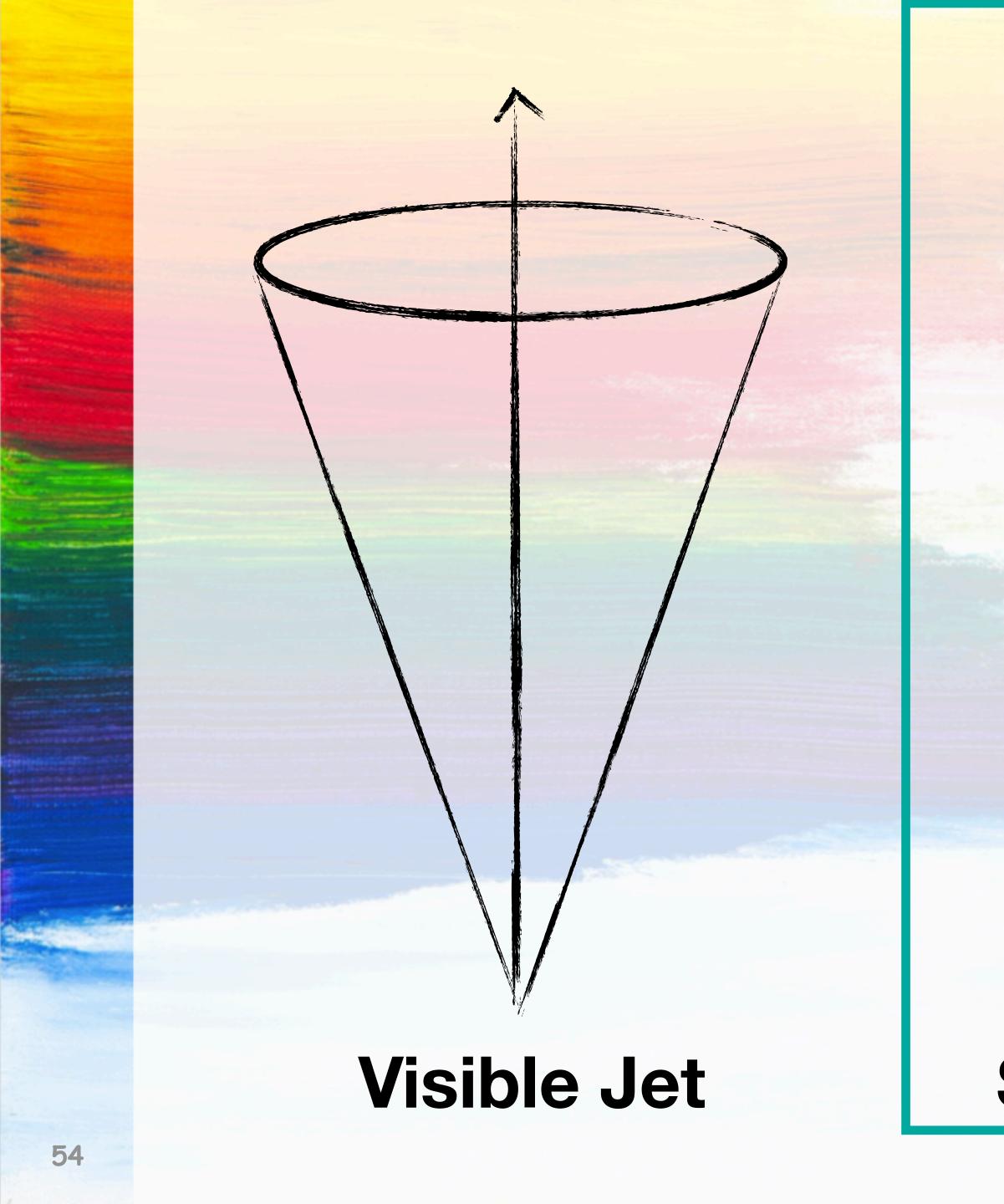


Missing Momentum

Jet

Semi-visible Jet





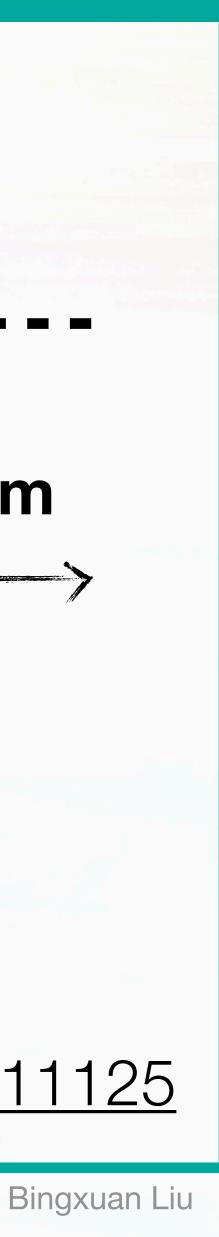


Missing Momentum

Jet

Semi-visible Jet

arxiv:2112.11125



There is definitely room for non-natural signatures!



Searching for them is a natural choice!







and a second second

