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PARTIKELDAGARNA

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DARK MESONS DECAYING TO TOP AND BOTTOM QUARKS

DARK MESONS

 Search for dark mesons decaying into Standard Model top and bottom quarks

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- Dark mesons motivated by Stealth Dark Matter models
 - Analogous to SM QCD
 - Dark rhos and dark pions phenomenologically relevant
- Dark pions pair produced in pp collisions either resonantly through a dark rho, or via Drell-Yan
- Parameters of model: Mass of dark pion, m_{π_D} , ratio of the mass of the dark pion and the mass of the dark rho, $\eta = m_{\pi_D}/m_{\rho_D}$



DARK MESON DECAY

- Gauge phobic model: Decays to SM fermions dominate
- Charged pions decay predominantly to tb, neutral to tt
 - Search for the final states tttb and ttbb
 - in the all-hadronic and 1 lepton channels



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PREVIOUS LIMITS ON DARK MESON PRODUCTION

- All-hadronic channel in the same analysis results public <u>ATLAS-CONF-2023-021</u>
 - Excluded region in low mass, med 0.38 -
 - $SU(2)_L$ model
- Limits from reinterpretation shown in gray
 - By inserting theory expectation into already performed analyses
- Expect to extend limits to higher mass and eta values by 1L results

• Focus of today's talk







OVERVIEW OF THE EXPERIMENT AND ANALYSIS

Data

- Large hadron collider: proton-proton collisions with 13 TeV energy
- Full Run 2 data: 140 fb⁻¹ recorded by the ATLAS detector
- Narrowing down the data to signal phase space: preselection









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Simulation

- Used to calculate expected event yields and observable distributions
- Signal samples (dark mesons)
- Background samples (SM processes, mostly top quarks)





Distribution of lepton transverse momentum in data (black dots), simulated background (solid stacked histograms) and simulated signal (dashed lines) after preselection



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Statistical analysis

- Final signal extraction
- Ongoing in 1 lepton channel



All hadronic channel results

KINEMATIC SELECTION

Selection

- Single lepton triggers
- Preselection: Exactly one lepton (muon or electron), 4 or more jets out of which at least 2 b-tagged (data and simulation)

Refine the selection and define the signal region

- Require 5 or more jets, at least 3 b-tagged
 - Target signature: 8 or 6 jets, including 4 b-jets
- Discriminating kinematic variables defined
 - $\Delta R(l, b_2)$: Delta R between lepton and second closest b-jet
 - $m_{bb_{\Delta R_{min}}}$: The invariant mass of the two b-jets closest to each other
- Require $\Delta R(l, b_2) < 2.7$, $m_{bb_{\Delta R_{min}}} > 100 \text{ GeV}$
- Enriched in signal events



OFFLINE EVENT SELECTION — PRESELECTION







Variables used to define the analysis regions

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OFFLINE EVENT SELECTION — PRESELECTION



Variables used to define the analysis regions



SIGNAL REGION

- Background suppressed by 98.8% (w.r.t. preselection) in signal region
- ► 40%-60% signal retention

Process	Preselection	Jets_N>=5	BJets_70_N>=3	deltaRLep2ndClosestBJet<2.7	bb_m_for_minDeltaR>100	s/sqrt(b)
ttbar-nonallhad	$3756369 \pm 0 \ (100.00\%)$	$1900597 \pm 0 (50.60\%)$	96618 ± 0 (5.08%)	$75248 \pm 0 (77.88\%)$	$31466 \pm 0 (41.82\%)$	
SingleTop	$191809 \pm 0 \ (100.00\%)$	81759 ± 0 (42.62%)	5848 ± 0 (7.15%)	4247 ± 0 (72.63%)	$1919 \pm 0 (45.18\%)$	
4top	$224 \pm 0 (100.00\%)$	222 ± 0 (99.11%)	121 ± 0 (54.64%)	$102 \pm 0 \ (84.07\%)$	$61 \pm 0 (59.86\%)$	
ttbb	$179730 \pm 0 \ (100.00\%)$	127233 ± 0 (70.79%)	52601 ± 0 (41.34%)	41344 ± 0 (78.60%)	17441 ± 0 (42.19%)	
Multiboson	$5351 \pm 0 \ (100.00\%)$	2469 ± 0 (46.15%)	179 ± 0 (7.25%)	$125 \pm 0 (69.59\%)$	$25 \pm 0 (20.26\%)$	
ttbar-allhad	2557 ± 0 (100.00%)	1829 ± 0 (71.54%)	$94 \pm 0 (5.16\%)$	$63 \pm 0 \ (66.35\%)$	27 ± 0 (42.71%)	
ttbarPlusX	$15364 \pm 0 \ (100.00\%)$	12775 ± 0 (83.15%)	3443 ± 0 (26.95%)	2892 ± 0 (84.00%)	$1196 \pm 0 (41.34\%)$	
VJets	$88258 \pm 0 \; (100.00\%)$	$35759 \pm 0 \ (40.52\%)$	$1898 \pm 0 \ (5.31\%)$	$1048 \pm 0 (55.23\%)$	225 ± 0 (21.50%)	
Sum of BG yelds	$4239661 \pm 0 \ (100.00\%)$	$2162642 \pm 0 (51.01\%)$	$160803 \pm 0 (7.44\%)$	125070 ± 0 (77.78%)	52360 ± 0 (41.86%)	
SignalSU2L-25-800	$20 \pm 0 (100.00\%)$	$19 \pm 0 (93.58\%)$	$10 \pm 0 (51.51\%)$	$9 \pm 0 (87.91\%)$	$8 \pm 0 (88.47\%)$	3.356e-02
SignalSU2L-45-400	$15553 \pm 0 \ (100.00\%)$	$14253 \pm 0 \ (91.64\%)$	$8128 \pm 0 \ (57.02\%)$	$7438 \pm 0 \ (91.51\%)$	$3796 \pm 0 (51.04\%)$	1.659e+01
SignalSU2R-35-400	$194 \pm 0 \ (100.00\%)$	172 ± 0 (88.59%)	107 ± 0 (62.49%)	$99 \pm 0 (92.21\%)$	71 ± 0 (71.69%)	3.105e-01
SignalSU2R-45-300	$1419 \pm 0 \; (100.00\%)$	1120 ± 0 (78.92%)	$650 \pm 0 \ (58.05\%)$	$593 \pm 0 (91.23\%)$	216 ± 0 (36.38%)	9.431e-01



CONTROL AND VALIDATION REGIONS REGIONS

- Control region for heavy flavour reweighing (CRHF)
 - Similar and orthogonal to the signal region
 - Used to correct mismodelling of events with a top quark pair produced in association with other heavy flavour quarks (tt+HF)
- Control region enriched in tt events (CR2b)
 - For overall normalisation and extra handle on tt+HF
- Validation region (VR)
 - For validating the background estimate after the fit

Region	N _{jets}	N _{b-jets}	$\Delta R(l, b_2)$	$m_{bb_{\Delta R_{min}}}$
CR2b	>= 4	= 2	-	-
SR	>= 5	≥ 3	<2.7	>100 GeV
CRHF	>= 5	≥ 3	>2.7	<100 GeV
VR	>= 5	≥ 3	>2.7	>100 GeV



STATISTICAL ANALYSIS

Fit setup

Events in signal region, control regions subdivided by how many jets and b-jets they contain

	Jets	5	6	>=7	5	6	>=7
SR/CRHF	b-jets	3	3	3	>=4	>=4	>=4
CR2b	Jets	4	5	6	>=7		

Fit kinematic distribution

 $m_{\text{J}^{had}} + m_{\text{J}^{lep}}$

Sum of the masses of the leading reclustered (anti-kt, R=1.2) jet containing the lepton and not containing the lepton

- Profile log-likelihood fit
 - Using TRexFitter code developed in ATLAS





INTRO | DATA & MC | ANALYSIS STRATEGY | FIT

STATISTICAL ANALYSIS

- Simultaneous fit for signal strength, background correction and uncertainties
- Performed bin-by-bin in each bin of the distribution, in each of the SRs and CRs
- Validated in VRs







Plots blinded: do not show data when signal expectation exceeds 15% of background expectation



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EXPECTED LIMITS

- "Asimov fit" No real data used in SR, this is not a result
- Systematic uncertainties not taken into account (except on luminosity)
 - Expect limits to shrink
 - Limits from all hadronic channel overlaid in blue
 - Limits from theory recasts in solid grey

